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Air Quality

Science and Application

Milano, 14-18 March 2016

Editors

Paola Radice, Sandro Finardi, Aidan Farrow, Charles Chemel, Joana De Medeiros, Vikas Singh and Ranjeet S. Sokhi

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Preface

This 10th International Conference in Air Quality - Science and Application is being held in the elegant and vibrant city of Milan, Italy. Our local hosts are ARIANET and ARPA Lombardia both of whom play a leading role in assessing and managing air pollution in the area. The meeting builds upon the series that began at the University of Hertfordshire, UK in July 1996. Subsequent meetings have been held at the Technical University of Madrid, Spain (1999), Loutraki, Greece (2001), Charles University, Prague, Czech Republic (2003), Valencia, Spain (2005), Cyprus (2007), Istanbul, Turkey (2009) Athens, Greece (2012) and Garmisch-Partenkirchen, Germany (2014).

Over the last two decades controls to limit air pollution have increased but the problem of poor air quality persists in all cities of the world. Consequently, the issue of the quality of air that we breathe remains at the forefront of societal concerns and continues to demand the attention of scientists and policy makers to reduce health impacts and to achieve sustainable development. Although urbanisation is growing in terms of population, transport, energy consumption and utilities, science has shown that impact from air pollution in cities is not restricted to local scales but depends on contributions from regional and global scales including interactions with climate change. Despite improvements in technology, users still demand robust management and assessment tools to formulate effective control policies and strategies for reducing the health impact of air pollution.

The topics of papers presented at the conference reflect the diversity of scales, processes and interactions affecting air pollution and its impact on health and the environment. As usual, the conference is stimulating cross-fertilisation of ideas and cooperation between the different air pollution science and user communities. In particular, there is greater involvement of city, regional and global air pollution, climate change, users and health communities at the meeting.

This international conference brings together scientists, users and policy makers from across the globe to discuss the latest scientific advances in our understanding of air pollution and its impacts on our health and environment. In addition to the scientific advances, the conference will also seek to highlight applications and developments in management strategies and assessment tools for policy and decision makers. This volume presents a collection of abstracts of papers presented at the Conference. The main themes covered in the Conference include:

Air quality and impact on regional to global scales
Development/application/evaluation of air quality and related models
Environmental and health impact resulting from air pollution
Measurement of air pollutants and process studies
Source apportionment and emission models/inventories
Urban meteorology
Special session: Air quality impacts of the increasing use of biomass fuels
Special session: Air quality management for policy support and decisions
Special session: Air pollution meteorology from local to global scales
Special session: Climate change and human health
Special Session: Modelling and measuring non-exhaust emissions from traffic
Special session: Transport related air pollution - PM and its impact on cities and across Europe

Ranjeet S Sokhi, University of Hertfordshire, UK
Sandro Finardi, ARIANET srl, Italy

March 2016

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PART ONE: ORAL SESSIONS

KEY NOTE SPEAKERS

AN ANALOG-BASED METHOD TO GENERATE PROBABILISTIC AQ PREDICTION OVER THE US

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Summary

This study aims to apply the analog ensemble (AnEn) technique to probabilistic predictions of O_3 and $PM_{2.5}$ surface concentrations over the US. The deterministic predictions of O_3 and $PM_{2.5}$ concentrations by Community Multi-scale Air Quality (CMAQ) Chemical Transport Model (CTM) over 564 sites of AIRNow Environmental Protection Agency (EPA) network across the US are used as input to the AnEn. The AnEn model searches for past forecasts similar to the current forecast, and takes the correspondent past observations to build the ensemble predictions. An evaluation of proprieties such as statistical consistency, resolution, and reliability is performed by using a 1-year long data-set of observations. The AnEn algorithm is a cost-effective method to generate reliable and well-calibrated probabilistic air quality forecasts.

Introduction

High concentrations of surface O_3 and $PM_{2.5}$ cause respiratory and cardiovascular problems leading to premature deaths and high costs associated with health care, school absences, missed work, lost income potential from premature deaths, and damages to crops and forests. Accurate air quality (AQ) predictions can provide individuals and communities with timely information to help them limit exposure and reduce health problems caused by poor air quality. The decision-making process effectiveness in the areas of public health and AQ can be improved by developing accurate deterministic predictions and a reliable quantification of their uncertainty provided by the ensemble forecasts.

Methodology and Results

The AnEn technique (Delle Monache et al. 2011, 2013) has been extensively tested for the probabilistic prediction of both meteorological variables and renewable energy (Alessandrini et al., 2015).

The AnEn is built from an historical set of deterministic predictions and observations of the quantity to be predicted. For each forecast lead time and location, the ensemble prediction of a given variable is constituted by a set of measurements of the past (i.e., 1-hour averages of $PM_{2.5}$ and O_3 concentrations). These measurements are those concurrent to past deterministic predictions for the same lead time and location, chosen based on their similarity to the current forecast. The forecasted variables used to identify the past forecast similar to the current one are called analog predictors.

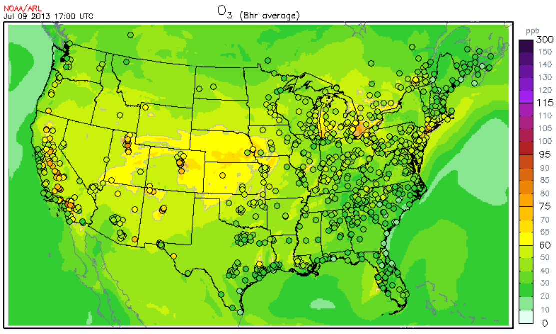

Figure 1 Maximum daily 8-hour average surface O3 on July 9 2013. Shown are the model prediction (shading) from CMAQ, and measurement (filled solid circle) from the AIRNow EPA network.

In this application we use as predictors, among others meteorological variables, the O_3 and $PM_{2.5}$ concentrations forecasts over the continental US generated by the U.S. EPA CMAQ CTM (Byun and Schere, 2006) model. The forecasts are issued at 12 UTC with a 24 hours frequency for lead times between 0-48 hours ahead over the period 01 July 2014-31 July 2015. The first 6 months of this period are used for training purposes while the remaining part for the verification. This includes an in-depth analysis of important attributes of probabilistic predictions generated with the AnEn, carried out using the observations at 564 sites across the US. Attributes such as statistical consistency, reliability, resolution, sharpness, and the spread-skill relationship are verified. The AnEn provides reliable, sharp, and statistical consistent probabilistic AQ predictions, at a fraction of the real-time computational cost of traditional ensemble methods.

Conclusions

This novel application of an analog-based method to AQ predictions demonstrates several advantages:

- A drastic reduction of both systematic and random errors of model-based (CMAQ) deterministic predictions, while considerably increasing the correlation between the predictions and the observations;
- The use of only one deterministic model prediction to generate an ensemble, therefore avoiding the need for model perturbation strategies, and reducing considerably the real-time computational cost of generating an ensemble;
- Intrinsic ability to produce reliable probabilistic forecasts (i.e., no ensemble calibration is required).

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MULTISCALE MODELLING OF HEALTH IMPACTS AND RELATED EXTERNAL COST FROM AIR POLLUTION IN EUROPE AND DENMARK OVER 36 YEARS (1979-2014) USING THE INTEGRATED MODEL SYSTEM EVA

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Summary
A multiscale assessment of health impacts from air pollution and related external cost has been conducted for Europe and Denmark using the integrated EVA model system (Brandt et al., 2013a; 2013b; Geels et al., 2015) over a period of 36 years (1979-2014). The EVA system is based on the impact-pathway methodology, where the site-specific emissions will result, via atmospheric transport and chemistry, in a concentration distribution, which together with detailed population data, is used to estimate the population-level exposure. Using exposure-response functions and economic valuations, the exposure is transformed into impacts on human health and related external costs.

Introduction
According to WHO, air pollution is now the world's largest single environmental health risk (WHO, 2014; http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/). Around 7 million people died prematurely in 2012 as a result of air pollution exposure from both outdoor and indoor emission sources (WHO, 2014). WHO estimates that there were 3.7 million premature deaths in 2012 from urban and rural sources worldwide due to exposure to outdoor air pollution. In Europe, recent results (Brandt et al., 2013a; 2013b) show that outdoor air pollution caused 570.000 premature deaths in 2011 and around 3.500 premature deaths in Denmark alone. Air pollution, in general, is a transboundary and scale dependent challenge with global, regional, national and local sources giving rise to large geographic variability and thereby large differences in the geographical distribution of human exposure to air pollution. Furthermore, air pollution levels has evolved over the latest decades with a decreasing trend due to air pollution legislations at national and international levels. With present state-of-the-art air pollution models, integrated assessment model systems and computer resources it is now possible to perform a long-term assessment of the developments of health impacts across decades.

Methodology and Results
In this study we have used a coupling of two chemistry transport models to calculate the air pollution concentration at different domains and scales; the Danish Eulerian Hemispheric Model (DEHM) setup with four two-way nested domains to calculate the air pollution levels in the Northern Hemisphere with resolutions from 150 x 150 km^2 (Northern Hemisphere) over 50 x 50 km^2 (Europe), 16.7 x 16.7 km^2 (Northern Europe) and down to 5.6 x 5.6 km^2 (Denmark). The Urban Background Model (UBM) is used to further calculate the air pollution concentrations in Denmark at a 1 km x 1 km resolution using results from DEHM as boundary conditions. The emission data as well as the population data have been represented in the model system with the same high resolution. In this study, the integrated model system, EVA, has been used to estimate the health impacts and related external cost for Europe and Denmark at all these scales. New developments of the integrated model system and evaluation of the models against measurements will be presented as well as the development of health impacts and related external costs over a very long time period of 36 years (1979-2014).

Conclusions
A multiscale long term assessment of air pollution concentrations, human health impacts and related external costs has been carried out for Europe for the period 1979-2014. The results can e.g. be used to evaluate and quantify the effect of international agreements driving the significant decrease in anthropogenic emissions of important air pollutants.

Acknowledgement
This work was supported by DCE – National Centre for Environment and Energy with the project: "Health impacts and external costs from air pollution in Denmark over 25 years" and NordForsk under the Nordic Programme on Health and Welfare with the project: "Understanding the link between Air pollution and Distribution of related Health Impacts and Welfare in the Nordic countries (NordicWelfAir)".

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HEALTH IMPACTS THROUGHOUT SOUTHEAST ASIA OF FOREST FIRES IN INDONESIA

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Summary

This study constructs a model framework to evaluate the air quality and health impacts of forest fires in Indonesia, and applies this to 2006, a year with high fire activity. This study finds that these fires are a substantial contributor to air pollution in Southeast Asia, and to the health burden in this region. We then examine the effect that various land protection policies will have on emissions from these forest fires.

Introduction

Globally, outdoor air pollution outdoors is attributed to approximately 3.3 million excess deaths annually (Lelieveld et al. 2015), and is the 8th largest contributor to the global burden of disease (Lim et al. 2012). Landscape fires and biomass burning are major contributors to air pollution in Southeast Asia, and climate change may exacerbate the risk of fires through drought and by making conditions more favorable for forest pathogens and pests. Here, we estimate the health impact of forest fires in Southeast Asia and discuss how alternatives for land management will affect fire conditions.

Methodology and Results

We developed a modeling framework that combines satellite-based land use change and fire data and a fire emissions inventory to estimate $PM_{2.5}$ emissions for the 2006 fire season in Indonesia, which was a year when both the El Niño Southern Oscillation and Indian Ocean Dipole were in their warm phase. We then feed the $PM_{2.5}$ emissions into an atmospheric chemistry, fate, and transport model to simulate changes in air quality across Southeast Asia. We then develop an air pollution health impact assessment model to estimate mortality impacts across Southeast Asia of the 2006 fire season, using high-resolution population data and up-to-date epidemiology adapted to scenarios with high levels of $PM_{2.5}$. The modeling shows that the fires substantially increase $PM_{2.5}$ across SE Asia – around 11 μg/m^3 averaged across Indonesia, 8 μg/m^3 in Singapore, and 4.5 μg/m^3 in Malaysia. This increase in $PM_{2.5}$ can be attributed to around 64,000 excess deaths in Indonesia, 1,500 excess deaths in Singapore, and 7,700 in Malaysia. Additionally, we simulate the effect of different land management policies and economic scenarios, and find that policy choices can dramatically affect fire emissions – a policy with intensive protection of forest land which prioritizes protection of peatland may result in a ~50% reduction in fire emissions.

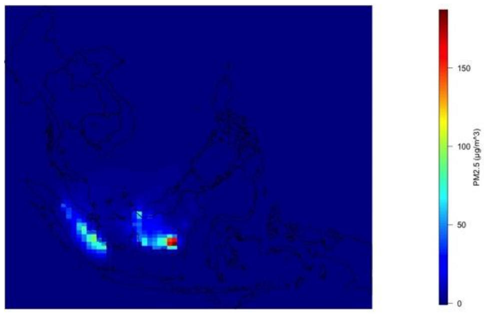

Fig.1: Annual average $PM_{2.5}$ attributable to fires in Indonesia in 2006.

Country	Deaths from fires	$PM_{2.5}$ from fires (μg/m^3)
Indonesia	64,000	11.19
Malaysia	7,700	4.57
Singapore	1,500	8.82

Table 1: Excess mortality attributable to 2006 fires in Indonesia, and countrywide average $PM_{2.5}$ attributable to fires in Indonesia in 2006.

Conclusions

The emissions from forest fires in Indonesia are a substantial burden to both air quality and health, in all of Southeast Asia, and climate change could make conditions in the region more conducive to fires. However, policies to protect forest from fires, especially those in peatland, could substantially reduce these emissions.

Acknowledgement

This work was supported by a grant from the Rockefeller Foundation.

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HISTORY AND PERSPECTIVE OF AIR QUALITY IN MILAN AND THE PO VALLEY: SCIENTIFIC AND MANAGEMENT CHALLENGES

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Summary
The evolution of pollutants concentration levels in the city of Milan during the last 4 decades clearly shows the impact of the local economic and social changes together with the effects of combustion/transport technologies improvement and environmental measures. Despite its improvement, present air quality condition qualifies Milan and the Po Valley as air pollution hot spots of Europe, this condition is also related to their peculiar orographic characteristics and to the meteorological conditions unfavourable to pollutants dispersion, that often affect the area. The historical recording of concentrations and the overall knowledge provided by a number of studies focused on the Po Valley are the starting point to identify deficiencies of our present knowledge about emissions, dispersion and chemical reactions of pollutants. The effectiveness of past measures and the difficulties to individuate and realize policies capable to achieve the compliance with European air quality standards are analysed to propose research priorities and suggest possible emission sectors to be targeted to reach a better air quality and reduce the health impact of air pollution in Milan and similar critical regions.

Introduction
Milan urban area is located in the central-northern part of the Po Valley and accounts for about 3.5 million inhabitants. The Po Valley has a global population of about 20 million people, it is home a large fraction of the Italian industry, agricultural production and livestock. The pollutant emissions generated by economic activities, together with residential heating and traffic, give rise to one of the areas of major concern for air pollution in Europe, where the European Commission air quality standards are presently not attained for NO_2, PM10 and O_3. The atmospheric circulation of the Po valley is characterised by the strong modification of synoptic flow due to the high mountains (Alps and Apennines chains) that surround the valley on three sides. Local atmospheric circulation, dominated by calms and weak winds, favours the development of critical dispersion conditions, gives rise to air pollution episodes and makes local measures hardly effective.

Methodology and Results
Available air quality observations (starting from late '70s) set in evidence the dramatic reduction of pollutant concentrations determined by the deindustrialization process, the change of fuels for residential heating, technological improvement and renewal of vehicles, and implementation of European and local measures. The concentrations reduction rates decreased from the beginning of the new century, preventing the achievement of air quality limits compliance. State-of-the-art measurements and modelling tools have been used to evaluate the impact of planned measures. Scenarios analysis identified source sectors to be targeted but showed difficulties to reach the compliance objective. A further effort to improve our knowledge and refine our analysis tools is needed to increase the studies reliability. Literature modelling studies show more difficulties in reproducing PM concentrations in the Po Valley than elsewhere in Europe. Non exhaust traffic emissions (in particular from brakes and tyres) and resuspension contribution are not yet reliably estimated. Large uncertainties affect biomass burning emissions especially for ultrafine PM, condensable VOCs and PAHs.

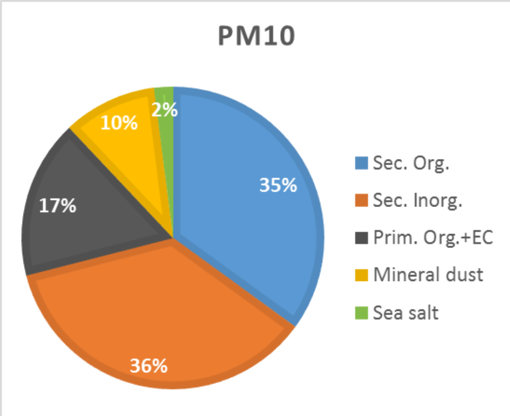

Fig.1 PM10 composition measured in Milan urban background station (from AIRUSE LIFE+ project)

The improvement of meteorological modelling of during weak wind is desirable due to the common overestimation of wind intensity and dispersion conditions. PM in Milan has a dominant contribution from inorganic and organic secondary aerosols (Fig. 1; AIRUSE, 2015) highlighting the need of multiscale analysis and measures planning. Many model applications and inter-comparison studies pointed out that the production of secondary aerosols is often underestimated and improvements of gas phase/aerosol models effectiveness is desirable.

Conclusions
Milan and Po Valley climatology highlights the need of a further improvement of scientific knowledge about air quality in critical conditions to support and improve the capability to evaluate measures effectiveness. Present knowledge identifies biomass burning for residential heating and agricultural activities as the emission sectors that can be targeted by effective emission reduction policies, without forgetting traffic contribution. A better prediction capability can support measures adoption: considering territory specificity, relevant economic investments and planning of innovative and visionary measures are needed to achieve air quality standards compliance.

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MODELLING THE FUTURE HEALTH IMPACTS RELATED TO OZONE, SECONDARY INORGANIC AEROSOLS AND PRIMARY PM IN EUROPE — RESPONSE TO PROJECTED CHANGES IN CLIMATE, EMISSIONS, DEMOGRAPHY AND BUILDING STOCK

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Summary
An integrated assessment system has been setup for projections of the future developments in air pollution related premature mortality across Europe. The main objective has been to study the impact of changes in climate, emissions, building stocks and demography on the regional scale impacts of exposure to surface ozone (O_3), Secondary Inorganic Aerosols (SIA) and primary particulate matter (PPM).

Introduction
It is well known that air pollution components like ozone (O_3) and particulate matter smaller than 2.5 µm ($PM_{2.5}$) are associated with negative health effects for humans. The World Health Organization now rates air pollution as the largest single environmental health risk at the global scale. Integrated assessment systems can be used to increase our knowledge on how the negative impacts of air pollution will change in the future due to changes in main drivers like climate and both natural and anthropogenic emissions. The health effects are age-dependent so the general trend in Europe towards an aging society can also modify the impact of air pollution. Likewise will the trend towards a more energy efficient building stock in Europe be important for the infiltration rate of outdoor pollution into the houses and hence for the general exposure of the population. In this study we use an assessment system to investigate the relative importance of these parameters.

Methodology and Results
The assessment system is based on a model chain including both global and regional climate models and two Chemistry-Transport Models (CTMs), DEHM and MATCH (Geels et al. 2015). The model chain applies climate data and anthropogenic emissions representing current day conditions as well as projections for the future. Here also the possible impact of a warming climate on anthropogenic ammonia emissions is included. In the current setup the Danish Economic Valuation of Air Pollution (EVA) (Brandt et al. 2013a,b) system combines the air quality simulations from the two CTMs with gridded demography data to get the population exposure. Population-level health impacts are then assessed by linking the exposure to a number of exposure-response functions. We have extended the system to describe changes in infiltration rates and the possible impacts on the exposure in the Nordic countries. Even if energy saving are highly prioritised in EU, the resulting impacts on the building stock and hence infiltration rates have not previously been included in long term projections of air pollution related premature mortality. The sensitivity of the health outcome to the projected changes in drivers is tested stepwise and we focus on two future decades (the 2050's and 2080's) relative to a present day decade (the 2000's).

Conclusions
If the anticipated reductions of 30-85% in emissions of main air pollutants in Europe are obtained towards the 2080s, a reduction of up to almost 80% in PM-related chronic mortality could be reached. Climate change alone can lead to a small increase (ca. 15 % for Europe in total) in the number of premature deaths related to ozone-exposure in the two future periods. For the Nordic region it has been evaluated how the transition towards more energy efficient housing impact the subsequent infiltration rate of outside air pollution into the houses and hence the exposure. For the first time it has been quantified how this will add positively to the decline in PM2.5 related health impacts. The change in demography and increase in ammonia emissions has on the other hand the potential to increase the number of death related to air pollution.

Acknowledgement
This has mainly supported by the Nordic Council of Ministers through the FAN project (KOL-1204). The development of an ammonia scenario has been funded through the EU project ECLAIRE (project No.: 282910).

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THE IMPACT OF WEATHER CHANGES ON AIR QUALITY AND HEALTH IN THE UNITED STATES IN 1994-2012

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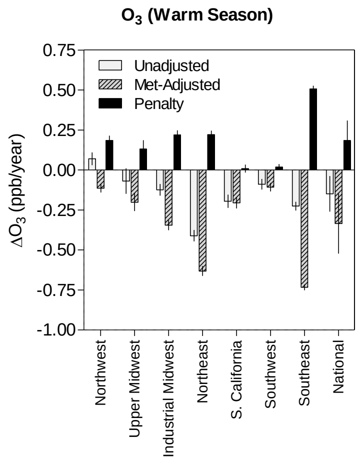
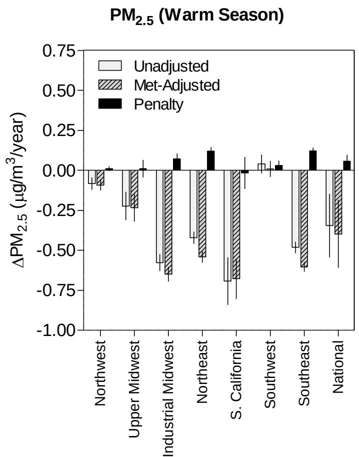
Summary
In this study, we aimed to estimate historical weather-related changes in air pollution and the associated health impacts in the US. Using statistical models, we quantified the retrospective weather "penalty" on ozone (O_3) and fine particulate matter ($PM_{2.5}$). We found significant weather-related air pollution increases, which were associated with over 20,000 premature deaths during our study period of 19 years. We found that temperatures have risen and wind speeds have declined in the past two decades—both changes promote accumulation of air pollution. Past changes in weather conditions have already had significant adverse impacts on air quality and health, and the weather penalty on air pollution and its associated health impacts will likely persist in the future climate.

Introduction
Air quality is heavily influenced by weather conditions. There is a growing body of evidence that climate change will adversely impact air quality. As O_3 and $PM_{2.5}$ exposures are associated with premature mortality (Krewski *et al* 2009, Jerrett *et al* 2009), it is important to understand the impact of a changing climate. Many climate modeling studies have projected future O_3 and $PM_{2.5}$ concentrations; however, less is known about the historical impacts of long-term weather changes.

Methodology and Results
We analyzed 19 years of air pollution and weather data (1994-2012) from 468 O_3 monitoring sites, 62 $PM_{2.5}$ monitoring sites, and over 200 ground-level weather stations across the US. Using statistical regression models, we quantified past weather-related increases, or "weather penalty", in O_3 and $PM_{2.5}$, and thereafter estimated the associated excess deaths. We derived the weather penalty as the additional increases in air pollution relative to trends assuming constant weather conditions (i.e., trends adjusted for temperature, wind speed, relative humidity, and precipitation frequency). During our study period, temperature increased and wind speed decreased in most US regions. Nationally, weather-related 8-h max O_3 increases were 0.18 ppb per year (95% CI: 0.06, 0.31) in the warm season (May-Oct) and 0.07 ppb per year (95% CI: 0.02, 0.13) in the cold season (Nov-Apr) (*Fig 1*). The weather penalties on O_3 were relatively larger than $PM_{2.5}$ weather penalties, which were 0.056 $\mu g/m^3$ per year (95% CI: 0.016, 0.096) in warm months and 0.027 $\mu g/m^3$ per year (95% CI: 0.010, 0.043) in cold months. Weather penalties on O_3 and $PM_{2.5}$ were associated with 290 (95% CI: 80, 510) and 770 (95% CI: 190, 1,350) excess annual deaths, respectively. Over a 19-year period, this amounts to 20,300 excess deaths (5,600 from O_3, 14,700 from $PM_{2.5}$) attributable to the weather penalty on air quality.





Unadjusted trends, weather-adjusted trends, and weather penalties of 8-h max O_3 and $PM_{2.5}$ by region in May-Oct. 95% confidence intervals shown.

Conclusions
Historical changes in weather conditions have had significant impacts on air quality and health. Temperature has increased and wind speed has decreased in most US regions. As climate models predict temperature increases, higher frequency of heat waves, and more stagnation episodes, weather-related increases in O_3 and $PM_{2.5}$-related mortalities will likely persist in the future.

Acknowledgement
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THE EFFECTS OF INTERCONTINENTAL EMISSION SOURCES ON EUROPEAN AIR POLLUTION LEVELS

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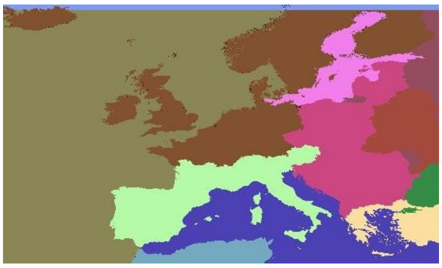
Summary

This study aims to quantify the contributions from European and non European sources to air pollution levels in Europe. The main focus is on ozone as this species has a sufficiently long residence time in the troposphere to be advected between continents, but results for other species as PM is also discussed. The study demonstrates that although the largest contribution to air pollutions in Europe are from European sources, there are also large contributions from other continents, in particular for ozone as this species has a relatively long residence time in the free troposphere.

Introduction

In HTAP 1 final report (HTAP, 2010) it was shown that a significant portion of the boundary layer ozone could be attributed to intercontinental sources, but in HTAP 1 several scientific questions were left open, or in need of being constrained. As a result an extended model experiment has been set up under HTAP2 (Task Force on Hemispheric Transport of Air Pollution, www.htap.org). The model calculations from a set of global models, all using the same set of anthropogenic emissions, will help to characterize and constrain the uncertainty in these estimates. In this presentation we show some of the first results from this modelling exercise, focusing on the effects on the European continent. The results from HTAP2 will in the future serve as input to assessments of the impacts of control strategies on the contribution of regional and extra-regional emissions sources to the exceedance of air quality standards and to impacts on human health, ecosystems, and climate.

Figure.1 *Source receptor regions in Europe. Brown:NW Europe w of Baltic Sea (R41), Rlight green SW Europe(R42), Dark red E. Europe(R43), yellow Greece and Turkey(R44) pe*



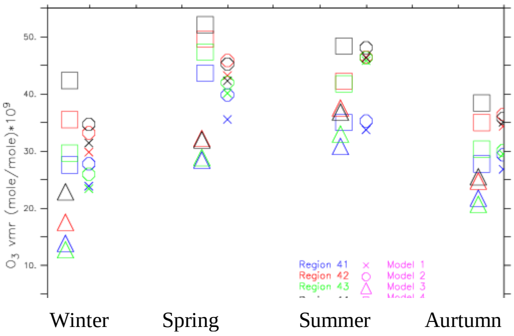
Methodology and Results

Models participating in the HTAP2 experiment are requested to perform a number of calculations, reducing the anthropogenic emissions of air pollutants in several regions of the world, combined and separately for NOx, SOx, particulate matter, CO and VOC (Volatile Organic Matter). In the source/receptor calculations the anthropogenic emissions are reduced by 20% in different source regions throughout the globe. Here we focus on the effects on European air pollution levels. For HTAP2 a set of receptor regions have been defined, shown in Figure 1.

Conclusions

The HTAP2 calculations are still ongoing, and a limited set of model calculations are yet available. More results will be available in the coming months. In the HTAP (2010) report it was estimated that the response to a 20% reduction of ozone precursor emissions outside Europe amounted to 43% of the response to 20% reduction in European sources. Roughly half that response would be from North American sources. But depending on the regions shown in Figure 1, there is a spread in the contribution from both European and non European sources. For ozone the largest contributions from other continents are calculated for the spring months when ozone production over the polluted continents starts to increase, while at the same time the lifetime of ozone in the free troposphere is relatively long. The ozone production over the continents peaks in summer, but at the same time the lifetime of ozone in the free troposphere is decreasing. As an example Figure 2 shows the seasonal contributions to ozone levels in the European regions shown in Figure 1 from a 20% reduction in North American anthropogenic emissions. The calculated contributions from North America are of similar magnitude for the four regions, with the largest contributions calculated for region 44 (Greece and Turkey). More results will be added here as more model calculations become available.

Figure 2*. Seasonal contributions to boundary layer ozone in the 4 European regions calculated by 4 different global models*



Acknowledgement

This work has been funded by EMEP under the LRTAP UNECE Convention.

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CHARACTERIZING THE INFLUENCE OF HEMISPHERIC TRANSPORT ON REGIONAL AIR POLLUTION

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Summary
Observational and modeling studies have demonstrated that pollutants near the Earth's surface can be convectively lofted to higher altitudes where strong winds can efficiently transport them from one continent to another, thereby impacting air quality on intercontinental to global scales. Since transport is efficient in the free-troposphere and since simulations over Continental scales and annual cycles provide sufficient opportunity for "atmospheric turn-over", i.e., exchange between the free-troposphere and the boundary-layer, a conceptual framework is needed wherein interactions between processes occurring at various spatial and temporal scales can be consistently examined. The WRF-CMAQ model is expanded to hemispheric scales and multi-decadal model simulations performed for the period spanning 1990-2010 are analyzed to examine changes in hemispheric air pollution resulting from changes in emissions over this period. Source region sensitivities estimated using the direct decoupled method in CMAQ are then combined with the estimated long-term trends to characterize the changing contributions of different source regions to background O_3 levels in the U.S.

Introduction
Strategies for reduction of pollution levels of surface air over a region are complicated not only by the interplay of local emissions sources and several complex physical, chemical, dynamical processes in the atmosphere, but also hemispheric background levels of pollutants. To assist with the design of emission control strategies that yield compliance with more stringent air quality standards, models must possess the fidelity to accurately simulate ambient pollutant levels across the entire spectrum ranging from background to extreme concentrations. Consistent modeling frameworks that can represent the interactions between various physical and chemical atmospheric processes at the disparate space and time scales are thus needed to characterize the relative contributions of different source regions to background pollution levels at receptor regions.

Methodology and Results
Expansion of the coupled WRF-CMAQ modeling system to hemispheric scales is pursued to enable the development of a robust modeling framework in which the interactions between atmospheric processes occurring at various spatial and temporal scales can be examined in a consistent manner. The WRF-CMAQ modeling system was applied over a domain encompassing the northern hemisphere. The horizontal domain, set on a polar stereographic projection, was discretized using grid cells with a 108 km resolution, while the vertical extent ranging from the surface to 50 mb was discretized with 44 layers of variable thickness with a 20 m deep lowest layer. Emissions of NO_x, SO_2, CO, volatile organic compounds, and particulate matter from anthropogenic, biomass burning, and biogenic sources were derived from existing global inventories. Model simulations for the 1990-2010 period and numerous associated sensitivity simulations (examining impacts of vertical layer structure, stratospheric O_3 influences, representation of NO_x recycling through organic nitrates, halogen chemistry in marine environments) have been conducted to establish the capability to exercise CMAQ over the Northern hemisphere. CMAQ configured with the direct decoupled method is used to estimate source region contributions to O_3 levels in the receptor region. These are then combined with the multi-decadal simulations to delineate the trends in the relative contributions of different source regions across the northern hemisphere to background O_3 levels in the U.S.

Significance and Implications
The U.S. National Ambient Air Quality Standard (NAAQS) for O_3 was recently proposed to be lowered to 70ppb, raising the importance of accurate characterization of background pollution levels. Changes in emission patterns over different regions of the world are likely to exacerbate the impacts of long-range pollutant transport on background pollutant levels in the U.S., which may then impact the attainment of local air quality standards. The successful expansion of coupled WRF-CMAQ to the hemispheric scales now provides a robust framework to examine interactions between atmospheric processes occurring at various spatial and temporal scales in a consistent manner and to characterize changes in regional background pollutant levels as well as the spatial heterogeneity in aerosol loading and associated radiative impacts over the Northern hemisphere.

INTELLIGENT TRANSPORT SYSTEMS (ITS) AS A TOOL TO REDUCE CARBON FOOTPRINT AND POLLUTANT EMISSIONS IN CITIES

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Introduction

Daily increasing levels of congestion underscore the importance of intelligent transportation systems. The idea of ITS is to ensure the efficient utilization of the available road capacity by controlling traffic operations and influencing drivers´ behaviour by providing information. The aim of this paper was to present a study that developed a new evaluation methodology regarding the impact of ITS-related initiatives, measures and innovations on urban mobility and on individual vehicle and vehicle fleets energy consumption and CO2 emissions.

Methodology and Results

The project implemented existing commercial models and tuned them to simulate the impacts of ICT measures. These activities were accompanied by real-world experiments using floating cars in the cities of Turin, Madrid and Rome. The experiments were on the one hand used to calibrate the enhanced models and on the other to validate the performance and accuracy of the methodology. The project (ICT-Emissions) has produced results addressing a wealth of cooperative ITS systems. To enable a reliable prognosis of future developments in a scenario approach the project covered a large number of current and near future vehicle technologies such as hybrid, plug-in hybrids and electric vehicles. The main achievements include the overall consistency of the modelling approach across the micro and the macro level both for traffic and emissions, a new Gipps' function for eco-driving simulation, a micro-level driver simulator for Adaptive Cruise Control (ACC), extension of ADAS simulator to micro traffic simulators, data collection with floating cars with and without ICT measures in place, validation and development of eco-driving cycles and creation of a web-based database application. As regards vehicle related ITS (i.e., ecodriving, green navigation, ACC), the analysis of the results showed that a. On a per vehicle basis, effects on CO2 emissions can be substantial – Reductions can exceed 15%, b. The CO2 benefit is constrained by the traffic conditions and penetration rates themselves, as the on-road ITS equipped vehicle fraction increases, c. The maximum is reached at up to 50% penetration and under non-congested conditions and d. Benefits differ with driving environment. For traffic targeted ITS (Variable Speed Limits, Urban Traffic Control), the analysis of the results showed that: a. Under non congested conditions the maximum reduction due to Urban Traffic Control can reach up to 8%, b. Traffic conditions constrain the effect on total CO2 emissions, e.g. congestion reduces the benefit, c. Similarly Variable Speed Limits can have a local effect in the order of 2% CO2 reduction and d. Most importantly, the global effect needs to be considered, on top of the local effect.

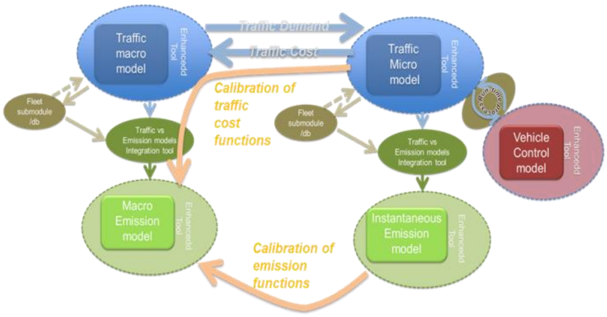

Fig.1. Architecture of the integrated methodology

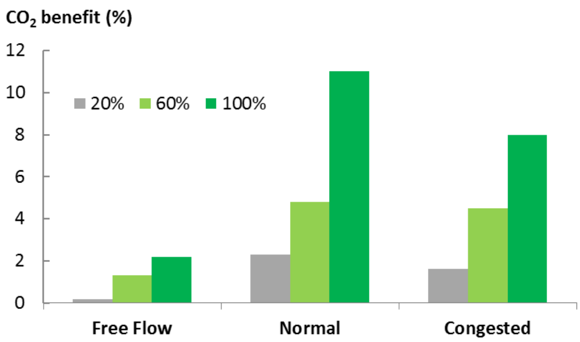

Fig.2. CO2 benefit (%) at urban roads for 3 different traffic levels and 3 ACC penetration rates: 20-60-100% (right)

Conclusions

Overall, ITS was found to be able to measurably contribute to CO_2 emissions reduction, although the effects are found to depend on local conditions (traffic, infrastructure, fleet, etc.). This potential will best be deployed in the future in combination with more advanced vehicles and systems e.g. predicting navigation systems in combination with hybrid vehicles

Acknowledgement

This work was funded by the 7th European Framework project ICT-Emissions - Assessing the impact of ICT on road transport emissions (Project Reference: 288466).

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NORTH AFRICAN DUST SOURCES AND DUST EXPORT TOWARDS EUROPE AND THE CARIBBEAN

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Summary

We discuss the atmospheric dust life-cycle over North Africa including its dust transport pathways towards Europe and across the Atlantic toward the Caribbean. This study includes satellite data providing information on active dust sources, and model simulations providing information on atmospheric circulation and near-surface wind speed distribution. Using both satellite and numerical model data in concert, a multi-dimensional picture of the atmospheric dust life-cycle can be drawn. Outcomes from this study illustrate (1) the spatio-temporal distribution of dust sources over North Africa, (2) identified atmospheric circulation patterns fostering dust emission and transport along the major pathways toward Europe and across the Atlantic, and (3) the variability of the dust concentration as part of the local aerosol burden.

Introduction

Mineral dust emitted from arid and semi-arid region is a major contributor to the atmosphere aerosol burden and a global player in the Earth system. The knowledge on the contribution of mineral dust to the atmospheric aerosol composition is crucial for understanding the multi-faceted aerosol-atmosphere interactions: Mineral dust aerosol influences directly the Earth radiation budget by absorbing and scattering solar radiation, and indirectly by affecting atmospheric dynamics and cloud formation processes. As mineral dust provides nutrients to the ecosystems, it ultimately impacts on the CO_2-cycle. Mineral dust not only impacts on the environment, it further affects our modern way of living and human well-being as it contributes to local and regional reduction in air quality.

Methodology and Results

Studies analysing satellite observations illustrate the spatial and temporal distribution of emitting dust sources (Schepanski et al., 2012). Results show that high surface wind speeds, a prerequisite for dust entrainment into the atmosphere, are frequently related to the morning break-down of the nocturnal low-level jet (LLJ). For North African dust emission, the LLJ is the dominant and frequent driving mechanism for dust uplift, in average 65% of DSA events inferred from MSG SEVIRI IR dust index images are related to LLJs (Schepanski et al., 2009). Here, we present a study investigating atmospheric circulation patterns over North Africa favouring (a) dust entrainment into the boundary layer, and (b) dust export towards Europe and the Caribbean Sea - the two major transport pathways of North African dust. Satellite-based information on the spatio-temporal distribution of dust source activation (DSA) events are inferred from 15-minute MSG SEVIRI dust observations are linked to atmospheric circulation regimes over North Africa determining the surface wind speed distribution and ultimately dust emission and transport. Multi-annual simulations of the atmospheric dust life-cycle using the meso-scale atmosphere-aerosol model system COSMO-MUSCAT (Tegen et al., 2013) are analysed with regard to the spatio-temporal distribution of DSA, dust transport pathways and the atmospheric circulation. Major meteorological features and determining dominant atmospheric circulation patterns are: (1) the Harmattan flow, (2) the Monsoon flow, (3) the Saharan heat low, (4) cold surges and cold-air intrusions from the Mediterranean into the North African continent, and (5) cyclones. All elements show a significant variability in their spatial extent respectively centre location and strength, which affects the spatio-temporal distribution of DSA events and dust transport pathways ultimately determining atmospheric dust concentrations over populated areas in Europe and overseas.

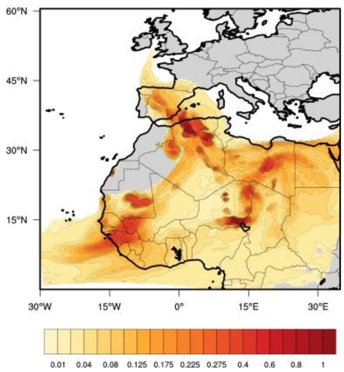

Figure 2: Dust optical depth simulated by COSMO-MUSCAT illustrating dust transport from North Africa towards Europe on 29 March 2014, 15 UTC.

Conclusions

Altogether, the results from this study aim at illustrating the relevance of knowing the dust source locations in concert with the atmospheric circulation. Ultimately, this study addresses the question of what is finally transported toward Europe and across the Atlantic from which source regions - and fostered by which atmospheric circulation pattern. Outcomes from this study contribute to the understanding of varying atmospheric mineral dust contributions to the aerosol burden affecting populated areas around Europe and across the Atlantic.

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AIR QUALITY AND IMPACT ON REGIONAL TO GLOBAL SCALE

25-YEAR REANALYSIS OF REGIONAL BACKGROUND SURFACE OZONE FOR SWEDEN

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Objectives

The objectives of this work are to map the surface ozone in Sweden during 1990-2014 using a combination of model and measurements, and to determine trends and 25-year extreme values.

Introduction

Surface ozone is monitored annually through measurements and modelling. Changes in global, European and Swedish emissions over the last 25 years may have caused changes to the Swedish background surface ozone. To monitor whether the situation is improving or not we conduct a reanalysis which can be used to investigate trends and to which we can compare the annual monitoring. We take into account changes in measurements, and changes in global, European and Swedish emissions and climate variability.

Methodology

Figure 1. Measurement sites used in the 2dvar analysis.

We use data assimilation in two dimensions (2dvar) to combine hourly measurements of surface ozone with modelled ozone fields (the first guess). Measurements are generally considered as having smaller errors than the dispersion model, whereas the latter has full temporal and spatial coverage. By combining the two we achieve a time-consistent dataset that is an improvement as compared to measurements and model. The dispersion model MATCH is used for modelling surface ozone and for the data assimilation. It is driven by the meteorological reanalysis EURO4M and emissions from EMEP (Europe) and SMED (Swedish high-resolution) and its domain covers Europe whereas the 2dvar was conducted covering Sweden and Norway.

Two reanalysis datasets were produced

Including all available measurements

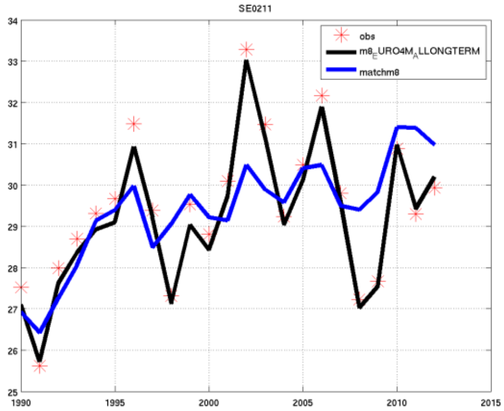
Including only long-term measurement datasets

The first dataset is the best possible mapping for each single year. The second data set can be used for trend and extreme value analyses.

Results

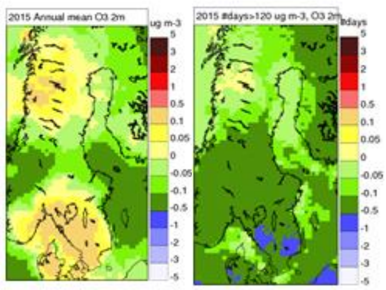
The 2dvar analysis technique was evaluated using cross validation for one year (2013). This resulted in improved bias and correlation coefficient compared to the first guess. The 2dvar results are dependent on the observations (the bias is approx. zero and the correlation coefficient approx. 1 at the observation sites). Measured and modelled (MATCH, 2dvar) annual statistics were also compared for all years (see Fig. 2).

Figure 2. Annual mean surface ozone modelled with MATCH (blue line), observed (red star) and from the 2dvar analysis (black line) at one observation site in Sweden.



Trends and extreme values were calculated based on the second data set for a number of metrics, such as SOMO35, AOT40 and exceedances above threshold levels (see examples in Fig. 3). The annual mean has decreased in northern and southern Sweden, whereas it has decreased in the middle. AOT40 and SOMO35 are decreasing almost everywhere. This is due to a decrease in the highest concentrations in the whole country, whereas the lowest percentiles have increased.

Figure 3. Trend in annual mean (left) surface ozone and number of exceedance days above the threshold 120 $\mu g\ m^{-3}$. Unit: μg m-3 per year (left) and #days per year (right).



Conclusions

Two data sets describing a combination of measured and modelled surface ozone in Sweden have been produced. This can be used for monitoring whether the situation is improving or deteriorating, and for trend analyses and effect studies. The highest percentiles of surface ozone have decreased in Sweden whereas the lowest have increased.

Acknowledgement

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CHANGES IN PERSIAN GULF AIR QUALITY OBSERVED BY THE OZONE MONITORING INSTRUMENT

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Summary
A decade's worth of trace gas and aerosol observations from the Ozone Monitoring Instrument (OMI), on-board NASA's Aura satellite, is used to study changes in local air-quality at over 500 locations across the Persian Gulf and Middle East. A time series analysis that examines the trends in nitrogen dioxide (NO_2), formaldehyde (HCHO), sulphur dioxide (SO_2), and retrieved aerosol parameters, reveals that air quality is significantly deteriorating for the majority urban areas.

Introduction
Air-quality in Iranian cities is often much worse than, for example, more publicised air-pollution events in China, yet it has been seldom investigated; only a handful of studies exist for the Persian region. Furthermore, emissions of pollutants gases, such as nitrogen oxides ($NO_x = NO_2 + NO$), within this region are only expected to increase in the future owing to the presence of large industrialised areas, high population densities, inefficient transport networks, and lack of regulatory air-quality controls. The main goal of this work is to use space-borne measurements of atmospheric composition to improve our understanding of air pollution over the Persian Gulf and surrounding area, and to determine long-term changes in the region's air-quality.

Methodology and Results
A detailed time series analysis is performed to examine the temporal variations in nitrogen dioxide (NO_2), formaldehyde (HCHO), sulphur dioxide (SO_2), and retrieved aerosol parameters, as observed by the OMI instrument over 2005-2014. The variations in these trace gases within about 10 km of over 500 locations in the Persian Gulf regions are quantified. Statistical tools based on those used for greenhouse gas analysis, are used to determine the overall trend and growth rate variability, and seasonal variations in these air-quality metrics. The variability of ancillary retrieval parameters such as air mass factors, cloud cover and aerosol loading are also examined to determine if observed changes in these trace gases are in fact real.

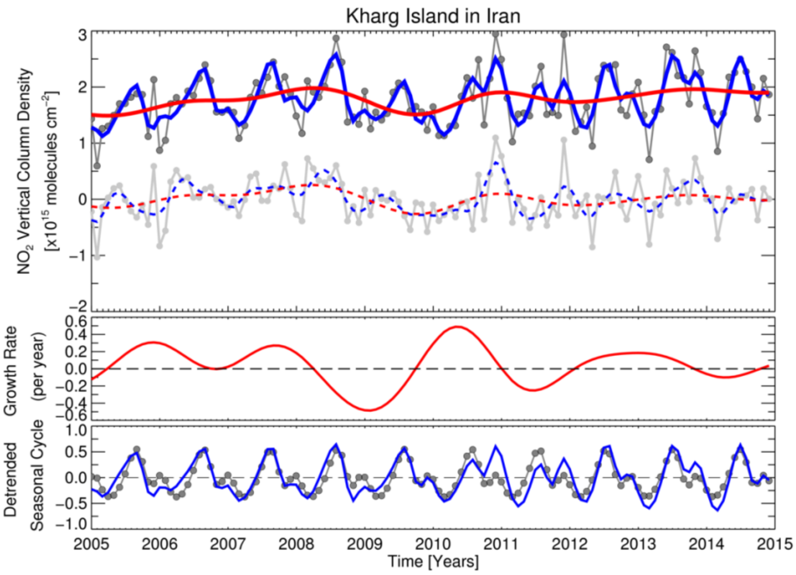

Fig.1 Example time series analysis of OMI NO_2 vertical columns over Kharg Island (Iran). The top panel shows the observed vertical columns (in dark grey) and the spectral decomposition fit to the data (in blue). The middle and bottom panels show the temporal variation in the growth rate and seasonal cycle respectively.

Conclusions
The analysis shows that air-quality at over 70% of locations with the Persian Gulf is significantly getting worse (particularly for NO_2) and that regulatory control over surface pollutant emissions is drastically need to mitigate the subsequent impact on air-health.

MULTI MODEL PROCESS STUDY ON INTERCONTINENTAL TRANSPORT OF MERCURY

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Summary

In this study we used an ensemble of chemistry transport models (CTMs) to identify and quantify the global transport patterns of mercury. Models were evaluated and improved using a newly available global dataset of mercury observations. Anthropogenic emissions were found to be the major source of mercury deposition with east Asia (coal combustion) and Africa (gold mining) being the major sources regions (sectors). Due to the legally binding Minamata Convention on mercury which will come into force in 2017, countries are obliged to drastically reduce Hg emissions (UNEP, 2013). Based on future emission scenarios, we investigated the impact of different policies on the global mercury cycle in the near future.

Introduction

This study is part of the EU FP7 project GMOS (Global Mercury Observation System). Based on the observations of the GMOS network we use an ensemble of CTMs to identify the major source regions and source sectors and to quantify their impact on the global mercury cycle from emission to deposition. Mercury is a substance producing significant adverse neurological and other health effects, with particular concerns expressed about its harmful effects on unborn children and infants (UNEP, 2013). Recent studies estimate, that the mercury burden has increased by a factor of 7 in the atmosphere and a factor of 5 in the Ocean since pre-industrial times (Amos et al., 2013). The main sources of mercury are the combustion of fossil fuels and small scale artisanal gold mining (Pirrone et al., 2010). In the atmosphere, gaseous elemental mercury is dispersed globally before it is oxidized and deposited. In the Ocean mercury is then methylated and accumulates along the food chain.

Methodology and Results

In the course of the GMOS project a mercury modelling task force (MMTF) was initiated in order to include research groups from outside the EU. At first, a common set of sensitivity analysis runs was performed to investigate the influence of emission speciation and atmospheric chemistry on global and regional transport patterns. In total 4 global and 3 regional CTMs participated in the MMTF (Table 1). In a second step, we used source apportionment techniques to track mercury emissions from major source regions and source sectors (Fig. 1b). Moreover, the source apportionment was done for three future emission scenarios. It was found, that about 50% of today's global Hg deposition is due to legacy emissions. These are mainly re-emissions of previously deposited Hg from the Ocean. Because of the constant cycling of Hg between Ocean and Atmosphere this source of deposition can be neglected when calculating a net flux into the Ocean. Looking only at the anthropogenic sources of deposition to different oceanic regions, it was found that Hg emissions from east Asia (orange) are responsible for more than 50% of the total (Fig. 1a). The second largest source region is Africa (pink) contributing 12% on a global scale. Emissions from Europe (green) are only important for the Mediterranean and other regional Seas. Future emission scenarios indicate, that emissions from south Asia will become more important on a global scale, potentially becoming the strongest source region in 2035. Meanwhile emissions from east Asia are expected to stagnate or decrease, depending on the scenario.

Model	Institution
GLEMOS	EMEP / MSC-E
ECHMERIT	CNR-IIA (Italy)
GEM-MACH-Hg	Environment Canada
GEOS-Chem	MIT (USA)
CMAQ-Hg	HZG (Germany)
WRF-CHEM	CNR-IIA (Italy)
p-TOMCAT	Cambridge (UK)

Table 1: CTMs and Institutions participating in the Mercury Modelling Task Force (MMTF)

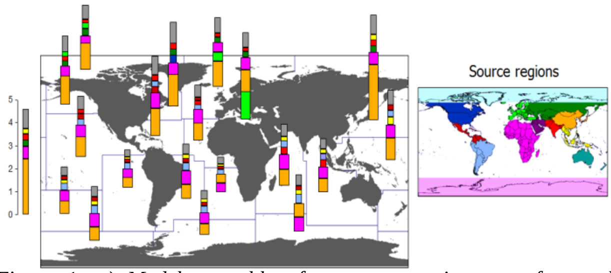

Figure 1: a) Model ensemble of source apportionment of annual mercury deposition into FAO aquatic regions (left). The bar to the left depicts the source apportionment for the total deposition into the Ocean. b) Colours indicate source regions tracked by the CTMs (right)

Conclusions

A model inter-comparison study showed that CTMs are capable to reproduce the global concentration and deposition patterns as observed by the GMOS network. In general the model ensemble leads to a better agreement with observations. Based on these refined models we identified east Asia and Africa as the current major sources of mercury deposition into the Ocean. Emission scenarios for 2035 indicate that depending on the implementation of the Minamata Convention Hg input into the Ocean can be reduced drastically and that emissions from south Asia might become more important on a global scale.

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ANALYSIS OF NO2 POLLUTION IN MEGACITIES BY EARTH OBSERVATION

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Summary
In this study we investigate the variability and trends of NO2 pollution in 30 megacities by analyzing different Earth Observation data sets. Multi-annual records of tropospheric NO2 from SCIAMACHY (2002-2012) and GOME-2 (2007-2015) are combined with the global urban footprint of each megacity as a proxy for urban growth. The consistent and homogenous data sets enable a global comparison of the findings for the megacities and a classification with respect to their socio-economic development. The possibilities of current and upcoming Earth Observation missions are discussed.

Introduction
Concerning air pollution and its effects on human health and climate, megacities and mega-regions have become the focus in recent years (WMO, 2012) However, from a global perspective, megacities are quiet heteorogeneous in terms of urban growth rates and the resulting spatial pattern. Moreover, their predominant functionalities, ie whether industrially dominated or already taking part in the emerging information society, impact on pollution characteristics as well.

Method and results
A globally systematic multi-sensor approach is applied to analyse NO2 pollution variability in megacities linked to urban growth rates and population development. To quantify the global tropospheric NO2 variability satellite-based observations of GOME-2 (2007-2015) and SCIAMACHY (2002-2010) are examined The linear trend is determined by an approach building upon Weatherhead et al. (1998). The classification of the dynamics of urban development and the spatial pattern for 2002 and 2012 is based on optical Landsat and TanDEM-X radar data (Taubenböck et al., 2014).
Considering the per-capita NO2 pollution, the megacities can clearly be classified into three groups with differentiated pollution characteristics (of increasing magnitude): the cities of the Global South, the cities of Europa and USA, and the cities in China and Korea. With respect to the linear trends, each of these groups shows a typical development. While the NO2 levels in Europe and USA are decreasing, a strong increase can be found throughout the megacities of the Global South. Heterogeneous trends are observed for Chinese and Korean megacities. Here the trends vary spatially and urban growth pattern need to be taken into account to draw the conclusions in line with in-situ measurements. This is demonstrated by the NO2 analysis of the mega-region Guangzhou-Shenzhen-Hong Kong, a dynamic industrial and economic region with globally unprecedented growth rates so far.

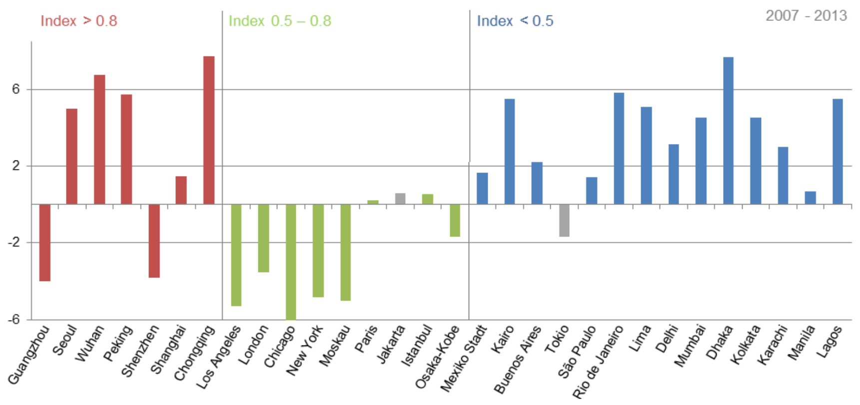

Fig 1: Megacities sorted by per-capita NO2 pollution (decreasing from left to right) and the corresponding relative trends (%/year)

Conclusion
Satellite-based time series of tropospheric NO2 observations and urban settlement pattern have been combined for the first time. The systematic analysis enables to classify megacities with respect to growth, pollution characteristics and significant trends as well as to delineate heterogeneous trends within megaregions.

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INDOOR CONCENTRATION OF PM_1, $PM_{2.5}$ AND PM_{10} IN A MAIN SHOPPING MALL IN AL AIN CITY, UAE

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Summary
The study was carried out with the main objective of assessing concentrations of fine particulate matter (PM_1, $PM_{2.5}$ and PM_{10}) and Total Suspended Particles (TSP) in the indoor air of one of the main malls in Al Ain, UAE, during the months of June and July 2015. Measurements were carried out using a DustTrak instrument in five locations. High concentrations of fine particulate matter, exceeding the WHO standards for both $PM_{2.5}$ and PM_{10} by large margins, were observed posing serious health implications to the public. Re-suspension of particles due to cleaning and especially movement inside the mall as well as diffusing of outdoor fine particles may be a major contributor to the high levels of particulate matter recorded in the mall.

Introduction
Indoor air quality is an important public health issue as people spend most of their time indoors. This is especially so for regions with extreme climate condition such as the United Arab Emirate (UAE) where in summer air temperature can soar to over 45°C. Indeed urban air pollution is one of the leading risk factors for the global burden of disease. Of particular concern are airborne fine particles that cause greater health impact than any other air pollutants (Ashmore and Dimitroulopoulou, 2009). This study was conducted in one of the main malls in Al Ain city, UAE, an environmental issues of significant concern given that there is always an inflow of large populations into the malls for shopping, entertainment and dining especially during the summer months when outdoor temperature is too high for any outdoor activities. The study was carried out with the main objective of assessing concentrations of fine particulate matter (PM_1, $PM_{2.5}$ and PM_{10}) and Total Suspended Particles (TSP) in the indoor air of one of the main malls in Al Ain during the months of June and July 2015.

Methodology and Results
Measurements were carried out using a DustTrak™ dust monitor (Model 8534) in five locations as follows: within a shop located on the ground floor close to an entrance from one of the main parking lots (S1), inside a supermarket on the first floor (S2), inside a furniture shop on the first floor (S3) and on a corridor facing the main entrance, also on the first floor (S4). Another sampling point was in one of the main parking lots (S5). Scanning electron microscopy was used for particle morphology analysis.
The 24-h mean concentrations of PM_1 varied from 21.89 μg/m^3 to 40.46 μg/m^3. $PM_{2.5}$ values ranged between 23.15 μg/m^3 and 44.57 μg/m^3 whereas PM_{10} values were between 25.58 μg/m^3 to 58.66 μg/m^3 and TSP range was from 27.78 μg/m^3 to 76.71 μg/m^3. Indoors, the highest concentrations of particulate matter were observed in the shop on the ground floor closer to the entrance to the parking lot probably due to penetration of particulate matter from the parking lot and resuspension due to cleaning and movements within the shop. Much higher concentrations were recorded at the parking lot where 24-h mean PM_1 values were 88.85 μg/m^3 (25.16-190.64), $PM_{2.5}$ was 101.19 μg/m^3 (31.65-203.73 μg/m^3), PM_{10} was 132.07 μg/m^3 (37.38-292.67 μg/m^3) and TSP was 139.67 μg/m^3 (37.28-324 μg/m^3), exceeding the WHO (2006) standards for both $PM_{2.5}$ and PM_{10} by a large margin posing serious health implications to the public. Peak PM values were recorded from late afternoon until around 10:30 pm (Fig. 1) when the mall closes indicating that indoor movements causing resuspension of particles was mainly responsible for high values observed. Outdoor influence is also possible as much higher concentrations were observed on the ground floor in the shop adjacent to the main entrance (S1) from the parking lot as well as on the first floor closer to the main entrance (S2). The evaluation of SEM micrographs of the samples showed that most of the particles are smaller than 10 μm.

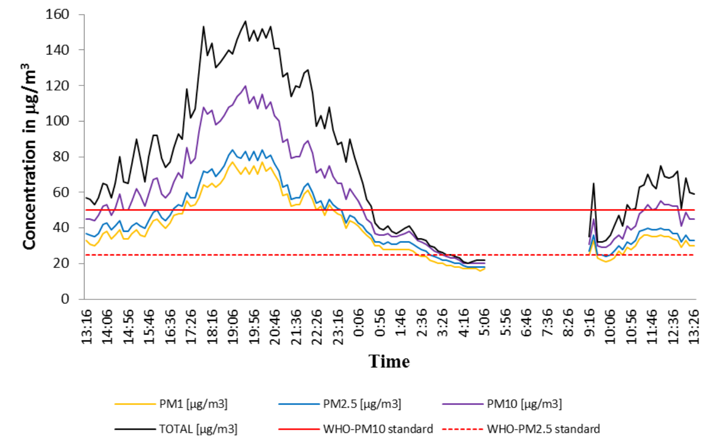

Fig. 1 showing the diurnal profile of fine particles recorded in a shop close to the entrance from one of the parking lots in the Mall

Conclusion
This is a pioneering work on indoor particulate matter assessment in the malls in the UAE. Considering the high values of fine particulate matter observed in the study and especially given that malls are major recreation centres in the UAE, more elaborate and long-term studies are needed to understand their influences on human health and to identify the respective emission sources of these pollutants.

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A SUB-GRID MODEL FOR IMPROVING THE SPATIAL RESOLUTION OF AIR QUALITY MODELLING AT A EUROPEAN SCALE

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Summary
A sub-grid model has been developed to simulate the spatial distributions of mean annual NO_2 and NH_3 concentrations within the grid cell of a chemical transport model. The inclusion of the sub-grid model substantially improves the predictions of the chemical transport model reducing both mean model error and increasing the spatial correlation with measured concentrations.

Introduction
Currently, chemical transport models used to assess impacts of air quality applied at a European scale, such as the EMEP MSC-W model (Simpson et al., 2012), lack the spatial resolution necessary to simulate the fine-scale spatial variability. This spatial variability is especially important for assessing the impacts to human health or ecosystems of short-lived pollutants, such as nitrogen dioxide (NO_2) or ammonia (NH_3). In order to simulate this spatial variability, a sub-grid model has been developed to estimate the spatial distributions (at a spatial resolution of 1 × 1 km^2) of atmospheric concentrations within the grid squares of a chemical transport model (in this case the 50 × 50 km^2 grid squares of the EMEP model). The sub-grid model combines high resolution emission data with simple parameterisations of atmospheric dispersion to simulate the spatial distribution of mean annual concentrations within each grid square of the chemical transport model.

Methodology and Results
Simple parameterisations of atmospheric dispersion from a 1 × 1 km^2 area source were produced using three atmospheric dispersion models (ADMS v4, AERMOD v12345 and LADD) and an arbitrary European meteorological dataset. For the dispersion of NH_3, the source was assumed to be at ground level (to represent agricultural sources), whereas for NO_2, simulations were carried out for two emission heights (ground level to represent traffic sources and a height of 400 m to represent the effective emission height of large stack sources). The mean dispersion fields (average of the three models) were then multiplied by high resolution (1 × 1 km^2) emission maps of NO_2 and NH_3 for two study areas (Scotland and the Netherlands) using a moving window approach. The resulting maps of "sub-grid distributions" were then combined with the low-resolution 50 × 50 km^2 concentration predictions of the EMEP model (in order to conserve the large-scale processes whilst adding the fine detail) to give high resolution (1 × 1 km^2) concentration maps (Fig. 1). A statistical comparison of the performance of the two models shows that the sub-grid model represents a substantial improvement on the predictions of the EMEP model reducing both mean model error (from 37% to 32% for NO_2 and from 42% to 30% for NH_3 and increasing the spatial correlation (r) with the measured concentrations (from 0.52 to 0.79 for NO_2 and from 0.74 to 0.86 for NH_3).

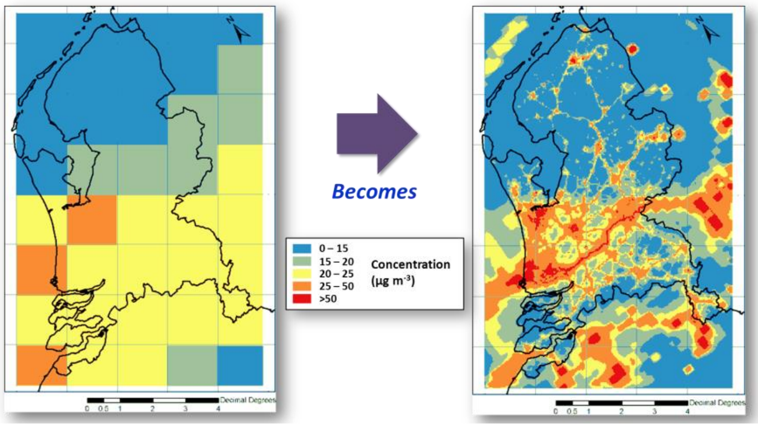

Fig.1 EMEP model predictions of mean annual NO_2 concentrations in the Netherlands (left) and with the inclusion of the sub-grid model (right).

Conclusions
The inclusion of a sub-grid model that combines high resolution emission data with simple parameterisations of atmospheric dispersion can improve the annual mean concentration predictions of chemical transport models applied at a European scale.

Acknowledgement
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CHARACTERIZATION OF THE OZONE PLUME OVER THE IBERIAN PENINSULA DUE TO MADRID AND BARCELONA CITIES

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Summary
On-road transport is the main anthropogenic contributor to O_3 precursor's emissions in Madrid and Barcelona metropolitan areas: 65%/59% of NOx, 40%/33% of NMVOC, and 67%/85% of CO emissions, respectively; but this contribution to O_3 is not well understood. The present work aims at increasing the understanding on the role of on-road transport emissions from main Spanish urban areas in O_3 dynamics over Spain under typical meteorological circulation types.

Introduction
Despite the ~30% emission decrease of the main tropospheric ozone (O_3) precursors in Spain in the 2001-2012 period, the O_3 concentration in summer still exceeds the target value for the protection of the human health of the Air Quality Directive (2008/50/EC).

Methodology and Results
The ISAM-CMAQ within the CALIOPE air quality system (WRF/HERMES/CMAQ/BSC-DREAM8b) has been applied to understand the effect of on-road transport emissions of Madrid and Barcelona metropolitan areas to O_3 concentration and its dynamics. The results indicate that the daily maximum O_3 concentration attributed to the on-road transport emissions from Madrid and Barcelona metropolitan areas contribute up to 24% and 8% to total O_3 concentration, respectively, within an area of influence of 200 km. The contribution is particularly significant (up to 80-100 µg m-3 in an hour) to the O_3 concentration peak during the central hours of the day in the O3 season (April-September). The maximum O3T-MAD concentration is calculated within the metropolitan area of Madrid but the plume, channelled by the Tajo and the Henares valleys, affects large areas of the Iberian Peninsula. The O3T-BCN plume is more driven by sea-land and mountain-valley breezes than by the synoptic advection and its maximum concentration is usually registered over the Mediterranean Sea. The O_3 concentration transported long-range to the Iberian Peninsula is significant in the area of influence of Madrid and Barcelona, being maxima under cold (70-96%) and minima in warm circulation types (35-70%).

Conclusions
The daily maximum contribution of the on-road transport emissions from the Madrid and Barcelona metropolitan areas to the total O_3 concentration modelled under the most typical meteorological circulation types (CTs) affecting the Iberian Peninsula is 23.5% for Madrid and 7.7% for Barcelona. For both Madrid and Barcelona areas of influence (~ 200 km) there is a background O_3 concentration of ~60 µg m-3 on average for all the CTs. The O_3 attributed to on-road transport emissions is relevant to explain O_3 peak concentration and exceedances of the regulatory target values.

Acknowledgement
This work is partially funded by the Iberdrola Foundation by the pre-doctoral grant held by V. Valverde and the post-doctoral grant held by M. T. Pay in the Beatriu de Pinós program (2011 BP-A2 00015), and partly funded by the CGL2013-46736-R and 2014 SGR 522 projects.

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ASSESSING EFFICACY OF NEW PLANT-WALL SYSTEM TO REDUCE INDOOR AIR POLLUTION

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Summary

The aim of this research has been to provide a detailed investigation of alternative methods for improving indoor air quality, including an assessment of whether a novel modular, optionally fan-assisted or passive plant-wall system, can be utilized to reduce the energy load on mechanical building ventilation systems. Module biosafety was first examined by measuring possible bioparticle emanations. The biosafety of the modules was examined first, by measuring possible bioparticle emanations. No significant increase in fungal particles over background levels was found. Furthermore, no Legionella spp. was detected. The tested indoor air pollutions were CO_2, TVOCs and PM10/2.5 and the plant-wall module's removal capacity was determined. Data indicated both the optionally fan-assisted or passive plant-wall system can reduce concentrations of CO_2, VOCs and PM10/2.5. Using an unoccupied, single-person office space, the research also determined a set of metrics relating to optimum lighting type, intensity and airflow rates, for two commonly used indoor plant species, Epipremnum aureum and Chlorophytum comosum, to achieve the most effective reduction of the tested indoor air pollutants. The information resulting from the findings will be useful to building managers, particularly in maximising air quality improvement performance by the installation of fan-assisted, living-plant-based wall modules and encourage future implementation of plants within buildings to reduce indoor air pollutant concentration.

Introduction

Evidence from several studies suggest indoor plants can reduce concentrations of indoor air pollutants, including TVOC's and CO_2 (Tarran et al., 2007). In addition, they have also been implicated in improving individual psychological well-being and hence, overall workplace productivity. Urban air pollution is a major global health problem. The US EPA (2015) reports that indoor air can be up to 2 to 5 times – and sometimes 100 times, higher than a city's outdoor air. The use of indoor plant-walls is an increasingly popular element of city building design, since they can be further developed and utilised to improve indoor air quality by reducing the concentration of CO_2, TVOCs and PM10/2.5 and improve a building's sustainability rating by reducing the use of mechanical building ventilation systems.

Methodology and Results

The modules (50x50 cm, containing 16 plants per module) were tested first in air-tight bench-top chambers, and then in an unoccupied, single-person office space. For the biosafety trials, air samples were taken with a Reuter Centrifugal air sampler onto Sabouaud's dextrose agar strips, and incubated at 23°C for 7 days. Fungal colonies were identified to genus level by gross microscopic morphology. The fungal propagule density as colony-forming units per cubic metre (cfu/m^3) in the tested office was found not to exceed that of typical ambient office fungal propagule density loads, nor was any hazardous genera identified (such as Aspergillius fumigatus). Each of the plant-wall modules were tested for presence/absence of Legionella spp., using both water, soil and air samples. These were conducted as per the Centers for Disease Control and Prevention recommended environmental sampling procedures and Legionella spp. identification. In bench-top chamber testing, increasing levels of CO_2 draw down were found over a 40 minute period, with light intensities at 10, 50 and 100 µmol m^{-2} s^{-1} respectively. With two common internationally used indoor plant species, Chlorophytum comosum and Epipremnum aureum, it was found that CO_2 draw down was greatest at 100 µmol m^{-2} s^{-1}, with an average loss of 10% from an initial starting concentration of 1000 ppm. PM10/2.5 draw down rates with the two plant species were also measured over a 40 minute period, with varying fan-assisted intensities, after an initial injection of 1000 µg/m^3 of particulate matter. With fan-assistance on, the PM10/2.5 levels were reduced to normal ambient indoor levels after an average of 5 minutes. With no fan-assistance an average of 17 minutes was required for PM10/2.5 concentrations to reach ambient office levels, and with no modules a period of about 26 minutes was recorded.

Conclusions

This research, which investigated fan-assisted plant-wall removal capacity of indoor air contaminants, indicated that the modules tested can improve indoor air quality by reducing indoor concentrations of CO_2, VOCs and PM10/2.5. Compared to modules without substrate ventilation or when no modules were present, it was also found, in bench-chambers or in offices, that when fan-assisted, the modules were more effective at reducing levels of the pollutants. In addition, the modules, with or without fan-assistance, were found not to be a source of Legionella spp., nor did they increase airborne fungal propagule density above normal background levels. The goal of this research is to contribute to the long term effectiveness of such modular green-wall systems to improve indoor air quality, reduce energy loads of the heating, ventilation and air-conditioning (HVAC) systems within city buildings, thereby improving a building's sustainability rating.

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DEVELOPMENT APPLICATION EVALUATION OF AIR QUALITY AND RELATED MODELS

TEN YEARS OF CITY-WIDE HIGH-RESOLUTION SIMULATIONS OF NO_X CONCENTRATIONS

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Summary
Ten years of hourly NO_x concentrations in two Swiss cities are simulated using the GRAMM/GRAL modelling system at the building resolving scale. We compare the hourly simulations to in situ measurements of meteorological parameters and NO_x concentrations. The prevailing wind patterns in the surroundings of the two cities are well reproduced by the mesoscale model GRAMM. These winds constrain the microscale model GRAL which simulates the air flow and air pollutant dispersion within the cities at 5 m resolution. Observed magnitudes and temporal variability of NO_x concentrations are mostly well reproduced suggesting a generally high quality of the simulations suitable for average population exposure assessment. While short temporal scales (up to one day) are not well simulated, probably due to a poor representation of the cycle of emissions, concentration variations at synoptic to seasonal scales are precisely reproduced.

Introduction
The impact of air pollution on human health is well established through numerous long- and short-term epidemiological studies. However, a precise assessment of the exposure of individual persons has been lacking in most epidemiological cohort studies conducted so far due to the difficulties in properly representing the large spatial and temporal variations of pollutant levels in cities. Approaches to tackle this issue require either dense observation networks or expensive high-resolution models. Here, we present and evaluate a modelling system providing detailed air pollution maps at hourly resolution for long periods of time (10 years in our case) with affordable computation resources and using standard air quality observations existing in most cities.

Methodology and Results
The mesoscale meteorological model GRAMM (Almbauer et al., 2000) accounts for the influences of topography and of land use types at 100 m resolution in the region around each city (~40 km). The microscale model GRAL (Oettl, 2015) is nested into GRAMM and simulates the flow and air pollutant dispersion within the city at building resolving resolution (example for the city of Lausanne in Figure 1). Dispersion simulations are computed for a large set of different emission categories (e.g., light and heavy traffic, heating, industry). The modelling system relies on a catalogue of steady-state reference simulations. In situ observations of wind direction and speed are used to choose the optimal matching situation in the catalogue for every hour of the simulated period.

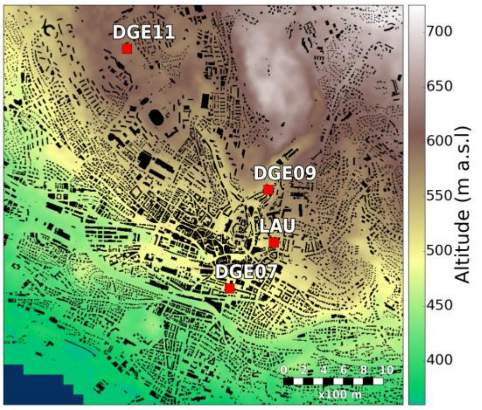

Fig.1 Validation sites in GRAL domain.

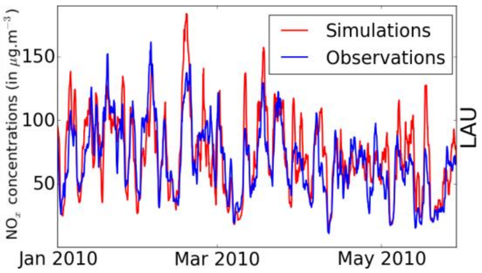

Fig.2 Daily time series at a validation site

At the mesoscale, land-use- and topography-driven wind patterns are very well reproduced by the GRAMM model, despite a general underestimation of wind speeds. At the building scale, the winds within the street canyons are well simulated by the GRAL model (at the 4 validation sites in Figure 1), though narrow streets are not well represented at the chosen 5 m resolution (e.g., at DGE07), leading to unrealistically high concentrations. The average magnitude of simulated concentrations deviates by less than 10% at 3 of the 4 validation sites in the city, where the winds in the local street canyon are well simulated. The diurnal variability of NO_x concentrations is reproduced with a correlation coefficient of 0.4 – 0.6 depending on the site, only 10% better than what could be obtained by a direct extrapolation of traffic density. Day-to-day variability, conversely, is very well simulated, with correlations of 0.8 – 0.9. Thus, the alternation between periods of pollutant accumulation under stable high-pressure conditions and cleaner, windy periods is very precisely simulated by our modelling system.

Conclusions
We developed a comprehensive tool for long-term city-wide high-resolution simulations of air pollution. This tool is very accurate in reproducing the 3D average magnitude and variability of concentrations at the city scale. A better horizontal resolution and improvements in accounting for emission variability at different time-scales are still required for accurately dealing with pollution peaks shorter than the daily timescale.

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COUPLING METEOROLOGICAL AND CHEMICAL ENSEMBLES IN AIR QUALITY DATA ASSIMILATION

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Summary
In this study we investigate the impact of including meteorological uncertainties into an ensemble of air quality model runs. This is analyzed with respect to the possibilities of using the ensemble to drive an Ensemble Kalman Filter based data assimilation approach.

Introduction
Ensemble modelling is an attractive method of accounting for uncertainties inherent to air quality modelling. Besides this, ensembles also enable access to powerful assimilation methods such as the Ensemble Kalman Filter (EnKF). Their success however relies on adequate descriptions of the model uncertainty. These uncertainties are caused by a variety of factors: Emissions, model parametrizations as well as the input meteorology. While research has been done on multi-model ensembles to assess uncertainties in the model formulation as well as on ensembles with input parameters changed, less attention has been paid to meteorological uncertainty.

Method and results
Generating an ensemble of meteorological data is straightforward. We use the WRF model (Skamarock et al., 2008) driven by global ensemble data from the GEFS v2 reforecast dataset. Furthermore we use different physical parametrizations of WRF to obtain a meteorological ensemble with 30 members. As a cheaper alternative, we employ a meteorological ensemble of three members consisting of forecasts with different lead time. This approach may appear attractive as these data are often available as results from operational forecast chains.
These results are then fed into the POLYPHEMUS/DLR ensemble modelling system that is based on the Polyphemus air quality platform (Mallet et al. 2007). This system adds uncertainty of emissions and other parameters to produce an air quality ensemble consisting of 80 members. The model domain as illustrated in the figure covers Europe at a horizontal resolution of 0.5°.
In order to assess the impact on the quality of the simulated background error covariances, we analyze the background error correlations. The figure shows the results the correlation of ozone at 200m height in Munich with other pixels at that height for a single point in time (during August 2011) for the small (top) and large ensembles. It can clearly be seen that the larger meteorological ensemble reduces spurious correlations at larger distances from the point of reference.
This is crucial for ensemble data assimilation as the spurious correlations for the small ensemble are so large that even rigorous localization was not able to get a working EnKF assimilation.

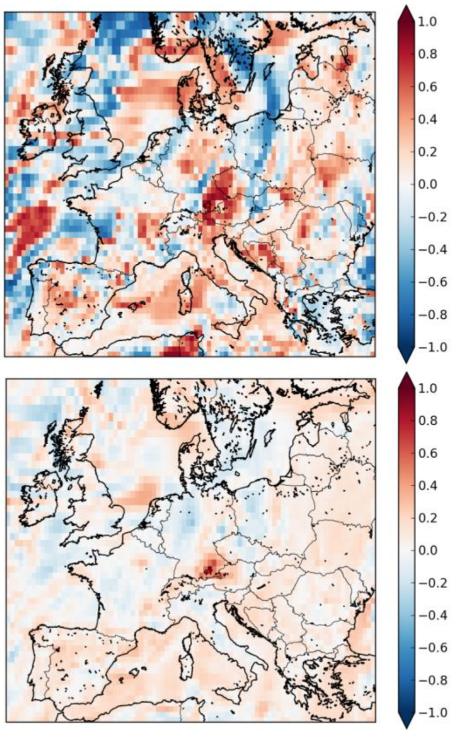

Figure: Ensemble correlations of ozone with a point near Munich at 200m height for the small (top) and large (bottom) ensemble. See the text for details.

Conclusion
Including meteorological uncertainty into air quality ensembles is desirable. However, for the purpose of data assimilation, there appears to be no way around operating a full-blown meteorology ensemble. A likely reason is that the small meteorological ensemble introduces too large discontinuities within the ensemble causing the correlation artifacts.

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HOW GOOD ARE AEROSOL-CLOUD INTERACTIONS IN ONLINE COUPLED MODELS?

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Summary

A model evaluation of aerosol-cloud interactions through the Air Quality Model Evaluation International Initiative phase 2 (AQMEII-2) (Alapaty et al., 2012) has been performed using satellite data.

Introduction

Atmospheric aerosols affect air quality and influence the Earth's radiation budget. The study of aerosol radiative effects and feedbacks with the climate system is nowadays one of the most important topics in climate science. In order to build confidence in air quality-climate interaction studies, a thorough evaluation of integrated meteorology-atmospheric chemistry models is needed, at both global and regional scale. Aerosol-cloud interactions (ACIs), in particular, continue to constitute one of the most important uncertainties in anthropogenic climate perturbations. The main objective of this contribution is to assess whether the inclusion of ACIs in regional-scale, integrated models improves the simulation of the climate-chemistry-cloud-radiation system over Europe. For this purpose, simulations for the year 2010 conducted with several different models under the umbrella of AQMEII-2 and the European COST Action EuMetChem are used.

Methodology and Results

An overview of the one-year model simulations contributing to this study is presented in Table 1. It includes six simulations with and one simulation without accounting for ACIs. In order to analyze the effect of different model settings on the representation of ACIs, the simulation of a number of different cloud variables is compared and evaluated against observations. The evaluation uses satellite data from the ESA Climate Change Initiative (http://www.esa-cloud-cci.org/) and from the MODIS instrument. The following variables affected by ACIs have been studied: cloud condensation nuclei, cloud droplet number, cloud ice path, cloud optical depth, cloud water liquid path, effective radius and convective/large scale precipitation. In addition, the relationship between aerosol optical depth (AOT) and several cloud variables has been studied. Finally, the effect of ACIs on air quality was analyzed based on two similar simulations with and without considering ACIs. Results indicate that the on-line representation of ACIs increases the number of cloud condensation nuclei as well as cloud droplet number over areas with high aerosol levels, for example during the Russian and Portuguese forest fire in summer 2010. Overall, the models tend to underestimate the cloud fraction over the entire domain. Precipitation over the Atlantic Ocean is enhanced when prognostic aerosol concentrations are accounted for in the process of cloud droplet formation. Furthermore, a positive relationship between some cloud variables and AOT is observed, simulated by the majority of the models. Changes in ozone and particulate matter due to ACIs have also been found.

<table>
<tr><th>Simulation</th><th>Model</th><th>Microphysics</th><th>Gas Phase</th><th>SW radiation</th><th>LW radiation</th><th>Aerosol</th><th>Aerosol feedbacks</th></tr>
<tr><td>1</td><td rowspan="5">WRF Chem</td><td>Lin</td><td rowspan="2">RADM2</td><td rowspan="3">RRTM</td><td rowspan="3">Goddard</td><td rowspan="3">MADE SORGAM</td><td rowspan="4">Yes</td></tr>
<tr><td>2</td><td rowspan="4">Morrison</td></tr>
<tr><td>3</td><td>RADM2 integ1</td></tr>
<tr><td>4</td><td>RACM</td><td rowspan="2">RRTMG</td><td rowspan="2">RRTMG</td><td>MADE VBS</td></tr>
<tr><td>5*</td><td>RADM2</td><td>MADE SORGAM</td><td>No</td></tr>
<tr><td>6</td><td>RACMO LOTOS-EUROS</td><td>Tiedtke, Tompkins Neggers</td><td>CB-IV</td><td>RRTM</td><td>RRTM</td><td>ISORROPIA II 2 bins</td><td rowspan="2">Yes</td></tr>
<tr><td>7</td><td>METUM UKCA</td><td>Wilson & Ballard</td><td>RAQ</td><td colspan="2">Edwards-Slingo</td><td>Classic</td></tr>
</table>

Conclusions

The on-line representation of ACIs reduces the bias and improves correlations between observed and model simulated cloud variables for some regions and periods. Further comprehensive studies will be needed for a better understanding of these interactions and to help us to improve the knowledge of the climate and air quality interactions.

Acknowledgement

We acknowledge AQMEII2, EuMetChem COST Action ES1004, the Joint Research Center Ispra and the Institute for Environment and Sustainability for its ENSEMBLE system, and CGL2013-48491-R/CGL2014-59677-R (through European Regional Development Fund –FEDER).

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MONITORING AIR QUALITY OVER CHINA: RESULTS OF THE PANDA MODELING SYSTEM

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Summary

By combining space and in-situ observations and surface emissions of chemical pollutants with complex mathematical models of atmospheric composition, detailed analyses and reliable predictions of regional air quality in East Asia are produced within the EU-funded project PANDA and disseminated to the public. Through collaboration between scientists from Europe and China, this project aims to improve our understanding of the processes responsible for the formation, dispersion and destruction of air pollutants. Detailed modeling studies of recent haze events in East Asia are conducted and comprehensive prototype systems for the prediction of air quality are developed with the aim of improving methods for monitoring air quality in support of European and Chinese policies.

Introduction

In this study, we combine space and in-situ observations and WRF-Chem regional model simulations to analyse regional air quality in East Asia during haze events that occurred recently in 2010 and 2013. The detailed modeling studies aim to evaluate (e.g. Figure 1) and improve the performance of the WRF-Chem model which is also used for our air quality prediction system developed within PANDA. An ensemble modeling approach based on several global and regional state-of-the art models is constructed and an inter-comparison exercise is organised in order to improve our understanding of the differences among current models for simulating and predicting haze events in East Asia.

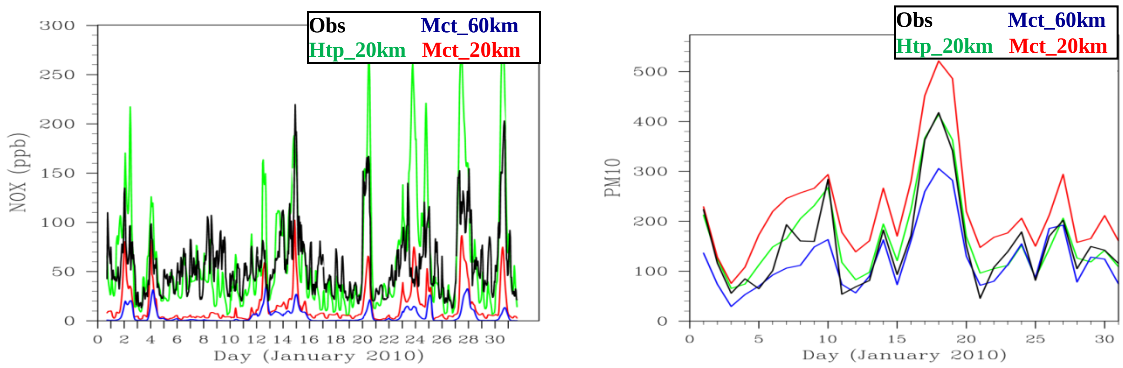

Fig.1 Comparison of WRF-Chem model results at 60km and 20km resolution with MACCity (Mct_) and HTAPv2(Htp_) emissions against surface observations (Obs) of NOx and PM10 respectively in Shanghai and Beijing in January 2010.

Methodology

Our modeling system follows a downscaling approach: global model systems provide initial and boundary conditions to regional model simulations over East Asia with WRF-Chem. Model simulations at higher resolution (e.g. 20km) are then performed over a nested domain which covers the most polluted regions in East Asia. In this study, we show a comprehensive evaluation (e.g. Figure 1) of our modeling system with satellite and in-situ observations of pollutants (O_3, CO, NOx and particles) at several surface stations during the pollution events that occurred in winter 2010 and 2013 and summer 2010. Sensitivity of the model results to emissions emissions is investigated using different emission inventories (MACCity, REASv2 and HTAPv2). The impact of initial and boundary forcing is assessed using data from MOZART (NCAR) and MACC (ECMWF) global simulations. The performance of our modeling and forecasting system is also evaluated against other models in an inter-comparison modeling exercise.

Conclusion

In this study we demonstrate the importance of using a downscaling approach to better reproduce and predict air pollution events that occur in East Asia. The performance of our WRF-Chem modeling system is influenced not only by the grid resolution but also the emission inventories used, their resolution and diurnal variation as well as the choice of boundary and atmospheric forcing. Interesting differences are found among the models involved in our study indicating the need to assess the relation between the performance of the models and the complexity of their chemistry and aerosol schemes.

Acknowledgement

The authors acknowledge supported from the EU-funded project PANDA. We acknowledge the ECCAD and MEIC teams for providing emission inventories and the Jülich Supercomputing Centre (JSC) for the granted computing time.

A MULTI-MODEL CASE STUDY ON AEROSOL-METEORLOGY INTERACTIONS WITH REGIONAL ONLINE COUPLED CHEMISTRY-METEOROLOGY MODELS

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Summary

Simulation results from three different online coupled meteorology-atmospheric chemistry models are compared and analysed with respect to the effect of the aerosol radiative impact on meteorological fields, effect of aerosol cloud interactions, and feedbacks on pollutant concentrations.

Introduction

The importance of different processes and feedbacks in online coupled chemistry-meteorology models for air quality simulations and weather prediction is investigated in COST Action ES1004 EuMetChem (http://eumetchem.info/). In order to analyse the aerosol direct and indirect effects and the response of different models to aerosol-meteorology interactions case studies for two episodes were performed with different online coupled models (Baklanov et al., 2014) as a coordinated exercise of Working Groups 2 and 4 of EuMetChem.

Methodology and Results

Simulations with different online coupled meteorology-atmospheric chemistry models were carried out for Europe with and without including aerosol-meteorology interactions. The two considered episodes are the Russian heat wave and wildfires episode in July/August 2010 and a period in October 2010 with enhanced cloud cover and rain and including an event with Saharan dust transport to Europe. These episodes had been identified during the previous AQMEII phase2 exercise (Galmarini et al., 2015) and were selected on behalf of their strong potential for direct and indirect aerosol effects on meteorology. The participating models were COSMO-ART, COSMO-Muscat, and WRF-Chem with different chemistry and physics options (for references of the models see Baklanov et al, 2014). Common emissions and boundary conditions for all participating models and a unified output strategy allow analyzing the model output with respect to similarities and differences in the model response to the aerosol direct effect and aerosol cloud interactions.

The high aerosol emissions during the summer 2010 Russian wildfire episode led to pronounced feedback effects. For example, the direct aerosol effect lowered the episode mean solar radiation by up to 100 W m^{-3} and episode mean temperature by up to 1 degree in the area with maximum aerosol from fire emissions. A quite magnitude of the response to the direct aerosol effect was found for WRF-Chem and COSMO-MUSCAT. The high aerosol concentrations emitted from the wildfires over Russia were found to decrease the small amount of precipitation over Russia during this episode by another 10% to 30% when aerosol cloud interactions were taken into account for the WRF-Chem simulations.

Conclusions and Outlook

For the applied horizontal resolution, the impact of aerosol feedbacks on pollutant distributions was frequently smaller than differences among the single models. As a next step, a more systematic analysis of aerosol cloud interactions for different WRF-Chem options will be performed.

Acknowledgement

We gratefully acknowledge the contribution of various groups to the second air Quality Model Evaluation international Initiative (AQMEII) activity: TNO (anthropogenic emissions database); ECMWF/MACC project & Météo-France/CNRM-GAME (chemical boundary conditions), FMI (fire emissions), the support by Cost action ES1004 EuMetChem and the contributions of all members of the Cost action ES1004 EuMetChem.

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MODELLING OF AIR QUALITY ALONG STATE ROADS IN DENMARK

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Summary
This study mapped air quality along the state road network in Denmark including all major motorways and main roads. For the first time a national data set of modelled air quality data along the entire state road network has been established in Denmark. The OML-Highway model, which is a GIS-based tool for calculating air quality along roads in open terrain, was used to map air quality. The model approach, input data and evaluation of model results will be presented together with the model results.

Introduction
The Danish Road Directorate has supported the development of the OML-Highway model, its application in a number of Environmental Impact Assessments (EIA), a guidance report on air quality assessment along motorways and a user manual for the OML-Highway model - all carried out by the Department of Environmental Science, Aarhus University (AU). With the present project the Danish Road Directorate aims to map air quality along all state roads to be able to provide this information to the general public on their website using webGIS. The new information will also be used as environmental indicators in the annual reporting of environmental impacts of the state roads. Furthermore, the data set is envisioned to be a screening tool in relation to future EIAs of state road projects.

Methodology and Results
The OML-Highway model requires information about the road network with traffic data, background concentrations, meteorological data and calculation points. The road network is based on vejman.dk which includes traffic data for all state roads in Denmark. Travel speed data is based on GPS readings from many vehicles. Background concentrations are calculated with the regional air quality model Danish Eulerian Hemispheric Model (DEHM) and a local-scale model Urban Background Model (UBM) with associated emission and meteorological data. Emissions for Denmark are based on the emission model SPREAD which has emissions for Denmark for all sources broken down on a 1x1 km^2 grid. The calculations are carried out in the following way. The starting point is calculated background concentrations for the centre point of a 1x1 km^2 grid from DEHM/UBM. This constitutes the background concentration for a given road segment of the road network. Emissions from the state roads have not been included in these background calculations to avoid double-counting of emissions from roads. Next, the OML-Highway model is used to calculate the contribution from the road to the calculation points along the road within 1000 m from the centre line. The nearest located background concentrations are added to concentrations of the calculation points. In this approach a simplified chemistry model was used to predict NO_2. The geographical variations of NO_2, $PM_{2.5}$ and PM_{10} in 2012 are shown in the below figure.

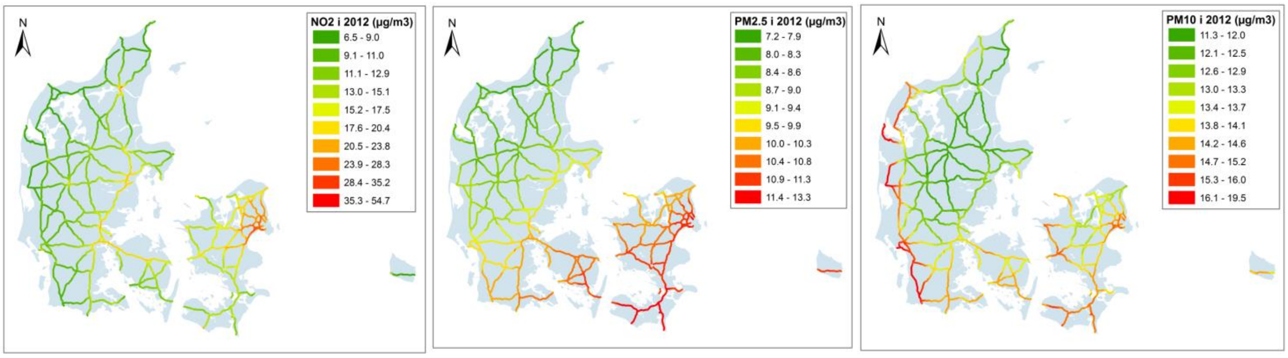

Fig.1. Geographical variation of calculated annual means of NO_2, $PM_{2.5}$ og PM_{10} in 2012.

Conclusions
Air quality as annual means of NO_2, $PM_{2.5}$ and PM_{10} along the Danish state road network within 1000 m from the centre line has been modelled for the first time to describe the geographic variation, and as a source of information to the general public. Indicative exceedances of the NO_2 annual mean were identified along parts of the most busy motorway sections at short distance from the road. Annual means of $PM_{2.5}$ and PM_{10} were well below limit values.

Acknowledgement
The Danish Road Directorate financed the project.

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THE LARGE EDDY SIMULATION APPROACH IN AIR QUALITY RESEARCH - APPLICATION EXAMPLES USING THE ADREA-HF CODE

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Summary
The Large Eddy Simulation (LES) is a Computational Fluid Dynamics methodology with proliferous applications in a wide range of scientific fields. In air quality research, the LES offers unique advantages like the accurate representation of flow unsteadiness and of the transient mixing processes. Part of the LES potential is presented in the present study through application examples that include turbulent flow and dispersion studies in different geometries (street canyons, room, city).

Introduction
The cumulative number of all publications that use LES increases so fast, that doubles every 4,3 years. LES is a natively time-dependent methodology that partly resolves turbulence and leads to deeper understanding of the turbulent flow, which is very crucial for the pollutant dispersion studies. LES can handle flows with inherent intermittency and calculate the dispersion from sources that change with time and space. LES reveals flow phenomena like bursts and unsteady vortices and provides concentration extremes. The consequences from the dispersion of odorous, toxic, or flammable gases can be predicted. Turbulent structures and coherent vortices can be examined. LES provides the time series of the variables solved, offering a tremendous volume of information that can be obtained through statistical processing. The advantages of LES can be seen in practice through the applications presented, most of which include comparison with experimental results.

Methodology and Results
In all cases examined, the Smagorinsky model was used along with a van-Driest dumping function near the wall. Numerics involved central differences in space and Crank-Nicolson in time. The number of cells varied from 162000 of case 1 (street canyon) to 3,3 million of case 4 (city). In **case 1**, dispersion from a street-level line source in a street canyon was examined. LES results compared very well with experimental data. Visualization of instantaneous concentration isosurfaces revealed characteristic tongue-like structures that redistribute the pollutant inside the canyon and transfer it intermittently towards the free stream. Examination of concentration time series showed among others the high variance of the values near the source and the high-frequency turbulence near the top of the canyon. In **case 2**, the flow and dispersion in two asymmetric canyons was theoretically examined. The study of the turbulent structures made clear the high correlation of negative velocity fluctuations with high concentration areas (Fig.1a). It was found that pollutant removal in the step-down canyon was mainly due to turbulent transport (96%), while the removal in the step-up was much higher and was due in about 84% to advection (Fig.1b). The examination of a puff evolution showed in practice the about 10 times lower ability of the step-down canyon to disperse the pollutant. In **case 3**, the dispersion of a light flammable gas in a hallway was examined. Comparison with experimental data showed superior performance of ADREA-HF LES compared to results from RANS and another LES code. Concentration values presented bursts at the sensor close to the source. This fact made clear that the use of LES is indispensable if the danger of explosion has to be estimated. In **case 4** the flow in the semi-idealized city "Michel-Stadt" was simulated. Comparison of the results with wind tunnel data showed good agreement in the average flow, while the stresses were underestimated from LES. The study of the evolution of the velocity vectors with time revealed areas of interesting physical phenomena like bursts, sudden flow direction changes and unsteady vortices, which are expected to have a significant role in the pollutant dispersion. LES was able to provide skewed and bimodal probability density functions of flow variables in areas of high unsteadiness. The study of coherent structures, through concurrent visualization of vorticity and velocity-fluctuation isosurfaces, made clear the dominance of vorticity sheets and hairpin vortices above the city roof-level. It was found that the hairpin vortices (which have strong correlation with pollutant removal events) are created mainly through upward piercing of the vorticity sheets from low-velocity areas.

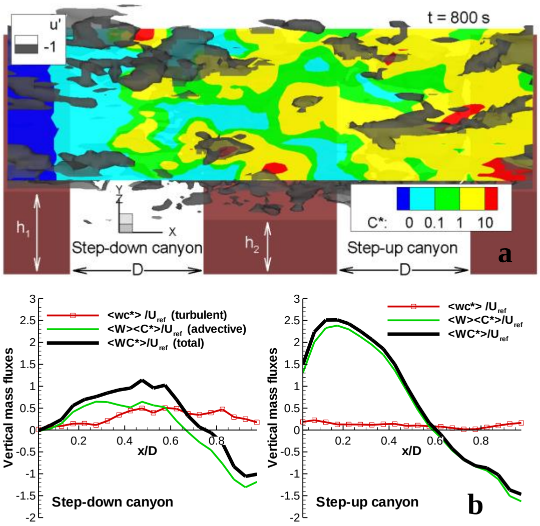

Fig.1 ***a****. Low velocity isosurfaces and concentration contours above the canyons.* ***b****. Streamwise distributions of turbulent, advective and total pollutant mass fluxes at* $z=h_2$

Conclusions
The LES methodology inherently resolves turbulence and is very suitable for cases of transient flows with high unsteadiness. The LES opens new horizons in the volume of information that can be extracted from a simulation, especially through statistical processing of the resulting time-series. The examination of turbulent structures and pollutant removal mechanisms and the deeper understanding of dispersion processes are examples of the numerous prospects the LES offers. Hence, there is need to encourage the use of LES in air quality research.

EVALUATION OF A GLOBAL TROPOSPHERIC OZONE SMILULATION WITH STATION DATA INCLUDING METEOROLOGICAL VARIABLES

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Summary

The goals of this study are first to define an objective method for appropriate vertical model level selection for model-data comparison and second to perform time filtering to decrease the impact of the potential bias on the chemistry model evaluation, which arises from the model's failure to simulate mesoscale weather events. Hourly measurements of temperature (T), relative humidity (RH), and ozone (O_3) at ten stations are analysed with 3-hourly model output from the Monitoring Atmospheric Composition and Climate (MACC) reanalysis for the time period 2007-2012. Using the minimum mean square error of the T or RH anomalies, we find that the optimum vertical level for the evaluation of the model at mountain stations (altitude >1000m) is between the surface and the level which corresponds to the actual altitude of the station. At low-elevation sites, this criterion correctly identifies the surface layer as the optimal layer. Time filtering does indeed affect the ozone bias; it may be reduced by up to 35%.

Introduction

Since the coarse grid box resolution (~100 km) of global chemistry climate models (CCM) prevents an adequate representation of mesoscale meteorology such as mountain wave activities, upslope wind, land-sea breeze etc., a variety of spatio-temporal sampling have been used in order to improve model-data comparison. Schutgens et. al. (2015) emphasised temporal sampling has a large impact on model evaluation and suggested 3 or 6 hourly data may be more appropriate to many model evaluation than daily or monthly model data as it is currently common practice. Another significant impact of the coarse model resolution is poor representation of the true surface elevation. As a result, it is not-trivial to choose the best vertical model for comparison to data from mountain stations. Consequently, some authors have simply disregarded mountain sites from their analysis. Others have selected the vertical model level based on the minimum difference between actual altitude and average grid-cell elevation (e.g. E. Katragkou et al., 2015). This may lead to poor model-data agreement in some cases, because the model atmosphere might be classified as free tropospheric air, while there can be local boundary layer influences affecting the measurements at the real station. In this study, T and RH data in hourly resolution is used to identify the optimum model level for the comparison of chemical composition data.

Methodology and Results

Comparison between the anomalies of measured and simulated meteorological variables such as T and RH is used to select the appropriate vertical model level. It turns out that the optimum model level for mountain stations will lie between the surface level and the level which corresponds to the altitude of the station. During the night time, the optimum model level is located several levels beneath that of during the day. For surface stations (altitude < 500 m) the optimum level sits at the surface (See Table 1). In a second step, the meteorological data are used to identify the time periods when the model captures the meteorological situation well, and is therefore unlikely influenced by local perturbations and representative for a larger region on the scale of the model resolution. When this filter is applied, the MSE of simulated ozone mixing ratios is often reduced regardless of whether T or RH is used as reference (Table 1). Note that this is not a necessary consequence, because it is also possible that "bad matches" of meteorological conditions hide true model errors which then become more apparent if the data are filtered.

[MSE(O3 | good match) - MSE(O3 | bad match)] * 100. / MSE(O3 | bad match)

Station_ id	Alt (m)	day			night			24-hours		
		Lev	T	RH	Lev	T	RH	Lev	T	RH
PYR	5076	47	-9.6	-22.8	50	-14.4	-10.0	48	4.3	-6.19
JFJ	3580	47	-11.8	-18.3	48	-9.6	-15	47	-14.8	-17.3
kvv	1720	51	-0.2	-2.5	51	4.6	-13.2	51	-5.5	-14
RIG	1031	55	-27	-19.8	56	-22.8	-13.3	56	-32.7	-27.8
PAY	490	60	-37	-27	60	-29.6	-35.4	60	-2.9	-5.4
NGL	62	60	-9.6	2	60	-9.3	-0.04	60	-2.7	-1.3
YON	30	60	-2.8	19.5	60	5.17	3.52	60	16.3	21.8
MNM	8	60	-1	-14.5	60	-15.8	-14.5	60	4.5	-22.1
ZGT	1	60	-32.3	-14	60	-13.1	5.2	60	-15	-7.9

Table1. Relative difference of MSE for ozone after vertical model level selection and time filtering.

Conclusions

The appropriate choices of the vertical model level and the time episodes for model-data comparisons have a considerable impact on the evaluation of chemistry climate models. Here, we explored the use of highly resolved meteorological observations to identify the optimum model level and filter the time series data. The results suggest that this meteorological information is indeed helpful to improve the model evaluation.

Acknowledgement

We acknowledge GAW World Data Center for Greenhouse Gases (WDGCC) at the Japan Meteorological Agency in Tokyo for their help for providing observation data.

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Schutgens N. A. J., Partridge D. G., Stier P., 2015. The Importance of Temporal Collocation for the Evaluation of Aerosol Models with Observation. Atmos. Chem. Phys. Discuss, 15, 26191-26230

DETAILED INVESTIGATION OF TRAFFIC POLLUTION DISPERSION NEAR DENMARKS NO_2 HOT-SPOT

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Summary
This study aims to investigate in details the pollution situation near one of Denmark's NO_2 hot-spots, the monitoring station at H.C. Andersens Boulevard (HCAB) in Copenhagen. The investigations cover various elements as detailed traffic counts in each of the 7 traffic lanes; wind speed measurements both at a nearby roof station and inside the street canyon and measurements at different locations in the street additional to the main monitoring station. Moreover the study contributes to a further development of the Operational Street Pollution Model (OSPM) that allows handling the inhomogeneous distribution of the emissions over the various lanes and the positioning of the receptor location further away from the buildings. The presentation will give an overview of the study and show the main results and conclusions derived from this comprehensive project.

Introduction
HCAB is a street station in the Danish National Monitoring Programme and presently the only monitoring station where the EU limit value for NO_2 is exceeded. This exceedance triggered a lot of interest and research connected with this station. Previously the Danish EPA funded a measuring campaign over several month with a parallel station moved about 3 m further away from the traffic compared to the permanent station (Ellermann et al. 2014). These parallel measurements indicated a relatively large difference of 10 µg/m^3 (18%) between both locations.

In order to investigate these small scale air pollution gradients in more details and develop methods to describe these gradients better with OSPM, a new project has been initiated.

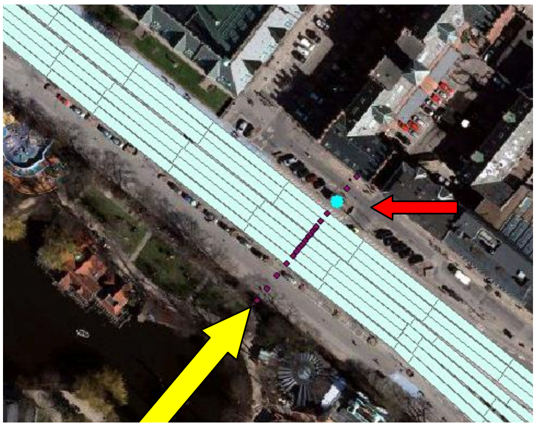

*Fig.1 Map of the location of the measuring station H.C. Andersens Boulevard (read arrow) and the 7 traffic lanes close to it. The cross section for traffic counts is marked.Table.1. Some of the AQMEII2 models features of the simulations studied (* simulation without considering ACIs).*

Methodology and Results
The location of the permanent monitoring station at HCAB close to the 7 traffic lanes is shown in Fig. 1. The here-described investigation includes the following experimental elements:

Concentration measurements using passive samplers and small mobile sensors arranged in horizontal profiles along and perpendicular to street orientation to investigate the gradients in NO_2 concentrations
Detailed traffic counts and emission modelling in all 7 driving lanes
Meteorological measurements using sonic anemometers both in the street canon and at the roof top.

Based on these experimental inputs as well as previous work conducted by Ottosen at al. (2015), this project also includes a further development of OSPM as: the operational implementation of the inhomogeneous distribution of the emissions in-between different driving lanes and enable a variable horizontal positioning of the modelled receptor point between building wall and driving lanes in case of very wide sidewalks or bike lanes as shown in Fig.1.
The project results help gain a deeper understanding of the complex dispersion situation near HCAB and key findings of the various project elements will be presented. The newly implemented features in OSPM give a much better possibility to describe the measured pollution levels and gradients.

Acknowledgement
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MODELLING AND COMPARING THE IMPACT OF THREE SEA SALT EMISSIONS PARAMETERIZATIONS ON ATMOSPHERIC NITRATE CONCENTRATIONS IN THE NORTH-WESTERN EUROPEAN REGION

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Summary
This study aims to evaluate how strong different sea salt emission parameterizations impact atmospheric nitrate (NO_3^-) concentrations in order to access how relevant sea salt emission improvements are for secondary particle formation. For this purpose three sea salt emission parameterizations were compared in chemistry transport model (CTM) simulations and compared against EMEP measurements. It was found that none of the considered parameterizations generally improved predicted NO_3^- compared to measurements. Commonly, the presence of sea salt should decrease NO_3^- concentrations. Unexpectedly, one parameterization led to an increase in NO_3^- compared to the situation without sea salt.

Introduction
Sea salt particles contribute considerably to total particle mass in coastal regions offering surface for condensation of air pollutants, such as nitric acid (HNO_3). Therefore, sea salt needs to be considered in air quality model studies in coastal regions. In some regions, HNO_3 condensation primarily depends on the availability of sea salt (Im, 2013). The target of this study is to evaluate the impact of different sea salt emission parameterizations on nitrate (NO_3^-) in North-western Europe.

Materials and Methods
The Community Multiscale Air Quality (CMAQ) Modeling System v5.0.1 was employed for the study. Sea salt emissions are parameterized by Gong (2003) and are enhanced in the surf zone. In this study, sea salt emissions were updated by a salinity dependence. The model was run for each two month in winter and summer 2008. Below, GO03 and ZERO denote runs with standard and no emissions, respectively. Two additional sea salt emission parameterizations SP13 (MA03/MO86/SM93 of Spada et al. (2013)) and OV14 (Ovadnevaite et al., 2014) have been implemented. Modelled NO_3^-+HNO_3 (SNO3) data were evaluated against daily EMEP measurements. The sum is compared because three-filter packs were employed at some EMEP stations. Mean normalized bias (MNB), Spearman's correlation coefficient (R), and the relative difference to the ZERO case were calculated ($\Delta_{zero} = (\mu_{case} - \mu_{zero})/\mu_{zero}$). The two presented stations (two of 18 considered ones) are located on an island (DK05) and inland (DE07).

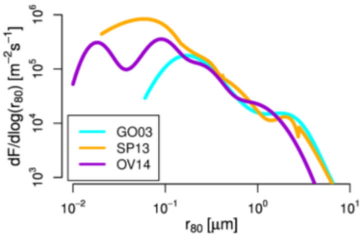

Fig.1 Sea salt emission parameterizations

Results and Discussion
SNO3 correlates better at DK05 than at DE07. The impact of the emission case on R is low. OV14 case commonly produces the highest MNB. SNO3 is underestimated at DK05 and slightly overestimated at DE07. The underestimation at DK05 is probably caused by lack in NO_X emissions.
We expected less SNO3 in the presence of sea salt because coarse particle mass is dominated by sea salt and coarse particle depose faster than fine ones. However, SNO3 concentrations of OV14 exceeded those of ZERO ($\Delta_{zero} > 0$). We assume that the dry deposition velocity of OV14 coarse particles is lower than expected due to relatively small coarse particle fraction (Fig. 1).

Tab.1 Stat. SNO3 data (summer 2008). MNB is given in µg/m³. Δ_{zero} denotes $(\mu_{case} - \mu_{zero})/\mu_{zero}$.

	Case	MNB	R	Δ_{zero}
DE07	GO03	0.04	0.39	-10.5%
	SP13	0.09	0.40	-6.4%
	OV14	0.23	0.44	6.3%
	ZERO	0.16	0.41	0.0%
DK05	GO03	-0.30	0.57	-11.9%
	SP13	-0.27	0.57	-8.5%
	OV14	-0.18	0.59	3.7%
	ZERO	-0.20	0.58	0.0%

Conclusions
None of the three compared sea salt emission parameterizations led to generally better predicted SNO_3 concentrations. In the OV14 case, SNO3 concentrations are commonly higher than in the GO03 and SP13 cases because of a lower dry deposition velocity. The OV14 concentrations are even higher than ZERO concentrations which was unexpected. From this result we conclude that sea salt does not generally reduce atmospheric nitrate concentrations but that the impact depends on the size distribution. Therefore, size resolved sea salt particle emissions need to be further assessed in further studies.

Acknowledgement
We acknowledge discussion with Matthias Karl, Anna Backes, Jan Arndt (all HZG), Uma Shankar, James Kelly, and Brett Gantt (all U.S. EPA). EMEP data was extracted from the NILU's EBAS database. Data evaluation was performed with R.

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HOW TO ENSURE HIGH QUALITY PREDICTIONS OF DISPERSION MODELS IN HIGH COMPLEX TERRAIN? – A GUIDELINE FOR RANKING MODEL'S PERFORMANCE

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Summary
Our investigation aims to establish quality criteria for high-resolution models to ensure a realistic dispersion calculation in high complex terrain. Evaluation data sets were identified, which mainly fulfill the demands on data quality and spatial density. Various models with different complexity used for scientific as well as consultant purposes were evaluated with respect to the near surface atmospheric fields. Simple error measures reveal a clear separation between high complex models and less complex low order models, which are not able to properly simulate the atmospheric processes in the planetary boundary layer. The application of a kind of bootstrap analysis helped to derive evaluation criteria for the different evaluation data sets. This study shows that a careful model error analysis is required for calm wind conditions.

Introduction and Objectives
A prerequisite for air quality assessments are reliable measurements and high quality tools for dispersion calculations. However, considering model applications used to prepare certificates for future planned industrial sites or factories, there are no well-defined quality criteria or evaluation strategies out there in the German-speaking region. In particular in regions with complex and steep terrain high quality simulations with high resolutions are needed to guarantee a dispersion modeling of industrial pollutants as realistic as possible. Therefore, we aim to examine and derive evaluation criteria and strategies for consultant-applied models which are going to be part of industrial standards and guidelines.

Methodology and results
The main challenges in establishing quality criteria for models running on a resolution of about 100 meter are first, the identification of proper evaluation data providing a high-density observational network and reliable measurements in particular with respect to wind direction, wind speed and temperature. Second, synoptic situations favoring the high load of pollutants within the planetary boundary layer have to be investigated with respect to model forcing, considering also an easy to use handling for consultant companies. Four different data sets remained as candidates for an evaluation suite: a postfrontal flow around an isolated hill (Sophienhöhe, Germany), the establishment of a counter-flow in the Graz basin (Austria) in winter time (Öttl, 2000), drainage flows in the Stuttgart basin (Germany) in spring time (Figure 1) and the flow in the Sochi region at the Southern Caucasus. Qualitative and quantitative criteria were developed for each test case. Due to small sample sizes the quantitative evaluation has to be restricted to simple measures AME and RMSE. Moreover, for calm wind conditions meandering effects has to be considered for the error calculation. Evaluation of various models with different complexity reveals that the error characteristics for the near winds is different for the most sophisticated mesoscale models compared to less sophisticated low order models. Due to the application of a kind of bootstrap analysis a threshold is derived for each test case, which allows for a separation between 'good' models and 'bad' models. The 'acceptable' model error turns out to be test case specific, but, for instance, the AME is often below 1 m/s in wind speed and below 20° in wind direction.

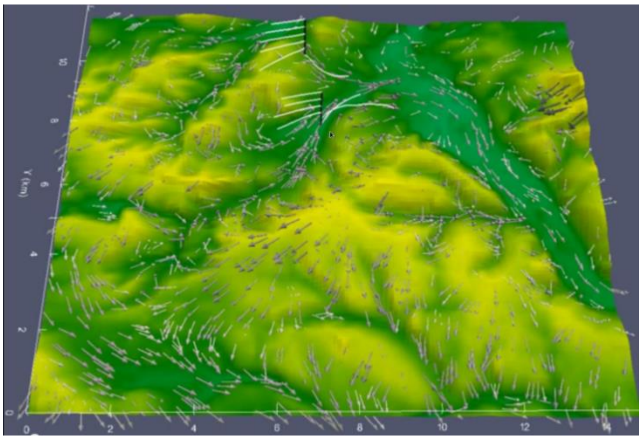

Figure 3: Temperature and flow field simulation for the test case Stuttgart (Germany)

Conclusions
High-quality and high-density measurement networks are rare but essential for the evaluation of models in high complex terrain. The small amount of measurements sites often allows only for the usage of simple evaluation measures. However, general methods may be used to find evaluation criteria (thresholds) appropriate for each individual measurement data set, but more reference data sets are needed to further examine such a generalized method proposed here.

Acknowledgements
This work was supported by the German Association of Engineers and funded by the Federal Environmental Agency of Germany. We acknowledge the experts providing a thorough insight into the measurement campaigns.

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POLLUTED EVENTS OVER ASIAN CITIES: VALIDATION, SOURCE RECEPTOR TEST AND FIRST RESULTS.

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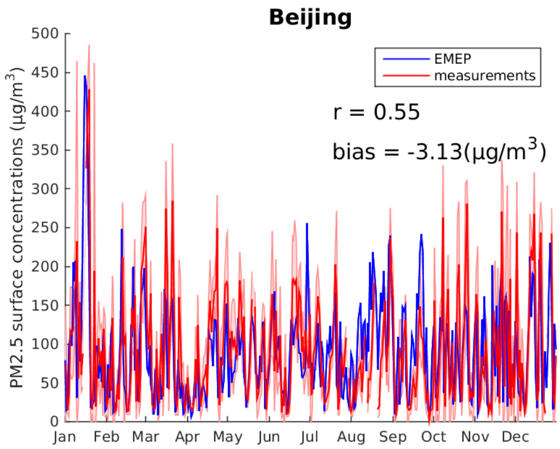
Summary
This study aims to evaluate the EMEP MSC-W chemical transport model (CTM) in simulating high pollution events over cities in Asia. This work is the first attempt to use the EMEP CTM with a fine horizontal resolution (0.1°×0.1°) over Asia and to simulate the pollution over urban regions. The first part of the work has been to focus on the evaluation of the EMEP CTM with measurements from different platforms (satellite, ground-based, in situ) and to identify the biases or the errors in the simulation. This evaluation is important in order to establish the capabilities of the model to identify air pollution sources. Sensitivity of the simulations to emissions over the test cities (Delhi, Beijing, Shanghai and Guangzhou/Honk Kong/Macau) is also presented.

Introduction
The EMEP MSC-W chemistry transport model (Simpson et al., 2012) has been used for decades to calculate source-receptor relationships between European countries (including Russia). Since 2010 MET Norway has been involved in regional source-receptor calculations in forecast mode for the European FP7 and H2020 projects MACC-II and MACC-III. Currently, this type of calculations is done operationally for 6 European cities on a weekly basis (see http://macc.copernicus-atmosphere.eu/services/aqac/policy_interface/regional_sr/ for more information and results). For the European FP7 project PANDA, the method has been applied to Chinese agglomerations. The model resolution is 0.1°×0.1°, using ECMWF IFS meteorological data and HTAPv2 (0.1°×0.1°) emissions.



Methodology and Results
The first objective of our work is to evaluate our simulations with measurements and to analyze how sensitive our simulations are to emissions sources. For this work we collected different datasets for different years.
For example, the US administration provides surface PM2.5 measurements over their embassy and their consulates. In total, there are measurements over 4 stations: Beijing, Chengdu, Guangzhou and Shanghai. Fig. 1 presents the time series for 2012 over Beijing. The figure shows that the model is able to capture the levels and the temporal variation of surface concentrations during this selected year, although some deviation is recognized (probably related to the relatively coarse resolution of the model with respect to point measurements and the lack of NRT emission data).

Fig. 1 Daily PM2.5 surface concentrations over Beijing from Jan 2012 to Dec 2012. The blue curve represents the EMEP simulations and the measurements are plotted in red. The correlation coefficient and the mean bias are also provided. The shade error bar corresponds to the standard deviation.

A test of source-receptor calculations for 4 different cities (Delhi, Beijing, Shanghai and Guangzhou) was also performed. In this study we were interested by 2 months: January and July. For this evaluation, all emissions over each city were reduced by 15%. A similar reduction was also done in another simulation for all emissions except over the cities. Both simulations (reduction over the city and reduction everywhere except over the city) were compared separately to the base run that included all emissions. These tests highlighted the large impact of local sources and surrounding environment on pollution levels over the Asian cities. For example Guangzhou is twice more influenced by the reduction of the emissions inside the city for PM10 than Beijing in July. Each Chinese city presents a small increase of their surface O_3 concentrations after reduction of all the emissions inside the cities.

Conclusions
The EMEP CTM allows reliable simulations of air pollution events, and in the future we could use the model to forecast this surface pollution.

Acknowledgement
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MODELLING NO_2 CONCENTRATION USING CFD-RANS MODEL WITH HIGH RESOLUTION TRAFFIC EMISSIONS

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Summary

The aim of this work is to obtain high resolution maps of average pollutant concentration for a large period (several weeks) in real urban areas. To achieve this purpose, several meteorological scenarios are simulated by using CFD-RANS model taking into account high resolution emissions, the aerodynamical effects of vegetation and urban morphology. This study is focused on an urban area of Madrid (Fernández Ladreda square) where high NO_2 concentration values are registered. An intensive experimental campaign was carried out with a large number of passive samplers distributed around the square. These measurements are used to validate the modelling results.

Introduction

High resolution maps of average concentration over a large period of time are necessary for air quality management and the assessment of abatement measures. The Computational Fluid Dynamics (CFD) models are able to simulate airflow and pollutant dispersion with very high resolution (~1m). However, due to computational loads, it is not possible (within a reasonable CPU time) to run an unsteady CFD simulation of several weeks or months. The solution proposed (Santiago et al., 2013) is to run only a set of scenarios (corresponding to 16 wind directions) using steady CFD-RANS simulations. In this study, this methodology is applied to a complex urban area using emissions from a very detailed microscale traffic and emission model. This is an important issue because according to previous source contribution analysis, NO_2 ambient concentration levels in the innermost area of Madrid are strongly dominated by road traffic (Borge et al., 2014).

Methodology and Results

The size of the study area (Fig 1.) is 1km x 1km. The modelling domain comprises one tunnel, several kinds of vegetation and several streets with high traffic intensity. Emissions used to feed the CFD-RANS model cover a 300m x 300m around the square with a resolution of 5 m. Twelve emission scenarios corresponding to different traffic patterns for different periods of the day and days of the week are considered in this study. The final map of average concentration is made by means of a combination of the simulated scenarios considering concurrent wind patterns within the period analysed. Pollutant concentration is computed assuming i) non-reactive pollutants and ii) thermal effects negligible in comparison with dynamical effects. As a consequence tracer concentration at a certain hour depends only on emissions, background pollution and wind speed at that hour (no memory between one hour and the following one). In addition, the dynamic effects of vegetation are included in CFD simulations assuming the trees as a porous medium (Santiago et al., 2013). It should be noted that the period simulated in this study correspond to winter conditions (February 2015), where the pollutant concentrations are less affected by atmospheric chemistry and thermal effects are negligible. The methodology is assessed using experimental data from 200 passive samplers distributed around the square.

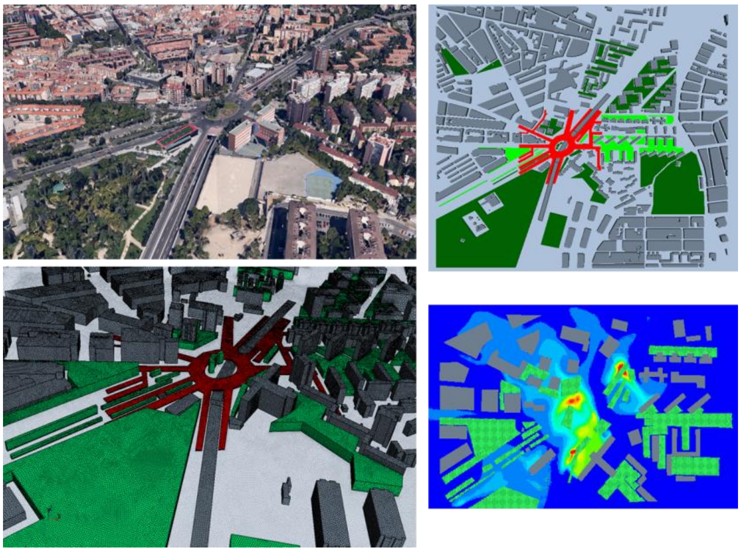

Fig1. *Real geometry, computational domain and pollutant distribution for SE wind direction*

Conclusions

A high resolution emission model has been satisfactorily implemented in the CFD-RANS model. The results obtained with this methodology are in agreement with experimental measurements of the campaign.

Acknowledgement

This study has been supported by the project TECNAIRE (S2013/MAE-2972) funded by The Regional Government of Madrid.

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ENVIRONMENTAL AND HEALTH IMPACT RESULTING FROM AIR POLLUTION

ENDOTOXIN IN AIR VERSUS DUST: COMPARISON BETWEEN AMBIENT FARMING ENVIRONMENT AND INDOOR HOME ENVIRONMENT

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Summary

This study aims to investigate the relationship between airborne endotoxin and farm soil-dust or indoor house-dust borne endotoxin present in total inhalable particles and particles of different size ranges. Good correlation was observed between dustborne endotoxin and airborne endotoxin in indoor home environment, however, significant correlation was lacking in ambient farming environment. Although levels of aerosolizable endotoxin in farm soil dust were relatively stable, airborne concentration of endotoxin differ a lot probably due to different farming activities including spraying of pesticides and spraying of water in farms.

Introduction

Endotoxin is a cell wall component of Gram-negative bacteria and is composed of lipopolysaccharides as a main ingredient. Inhaled endotoxin contributes significantly to the induction of airway inflammation and dysfunction. Many studies in occupational environments including farming environments have shown positive associations between endotoxin exposure and different types of respiratory disorders, including asthma-like symptoms, chronic airway obstruction, bronchitis, byssinosis, and elevated airway responsiveness. Endotoxin exposure in various work environments has also been recognized as a causative factor in the etiology of occupational lung diseases, such as non-allergic asthma and organic dust toxic syndromes. Low level exposures to endotoxins stimulate the immune system and are believed to play a role in its appropriate development. However, high concentration of endotoxin, usually anticipated in moisture damaged homes, can act as irritant and very high inhalation exposure can cause a flu-like illness that includes fever and difficulty in breathing. Airborne particulate matter in both indoor and outdoor environment carry a significant amount of endotoxin. Both airborne and dust borne endotoxin levels should be characterized to understand the exposure routes for inhalable endotoxin and adequate information is unavailable on this research topic, particularly in ambient farming environment.

Methodology and Results

Endotoxin in aerosolizable soil dust of agricultural farms and floor dust of houses were analysed. Aerosolizable soil dust from farms were collected by using a microbial source tester or FSSST. The FSSST is an inexpensive and portable device which was found suitable for aggressive sampling of releasing potentially aersolizable fungal spores, endotoxin, and (1→3)-β-D-glucan from various contaminated sources. The FSSST sampling unit is a closed aerosolization chamber, equipped with two pumps that are tightly placed on the farm ground during aerosolization tests. A push vacuum pump produce an airflow that pass through a HEPA filter. The incoming air flow directed through the 112-orifice stage at the bottom of the device, create air jets toward the contaminated surface. The dust aerosolized by the air jets were collected into a filter in a cassette connected at the sampling line operated by a pull vacuum pump. The process inside the FSSST cap simulated the release of aerosolizable endotoxin from the farm ground surface in worst case scenario, with their subsequent immediate collection. Dust samples from homes were collected with a vacuum cleaner at a flow rate of 800 l/min. A custom-made cone-shape HEPA filter trap with a collection efficiency exceeding 95% for particles larger than 0.3 μm was attached to the nozzle of the vacuum cleaner to collect the dust sample. For carpeted floor, dust samples were collected from an area of 2 m^2 at a vacuuming rate of 2 min/m^2. For non-carpeted floor, the entire floor of the selected room was vacuumed at the rate of 1 min/m^2. Large dust particles were removed by sieving and the resulting dust was stored at −20 °C before analyses. Air samples were collected with a combination of Button Inhalable Sampler (for total inhalable particles) and the NIOSH two-stage cyclone sampler for estimating inhalable and size-selective exposure levels for endotoxin. This approach significantly improved the current air sampling protocols for endotoxin. Endotoxin in all sample extracts obtained from two types of dust samples, the Button Sampler, and NIOSH two stage cyclone sampler were analysed using the endotoxin-specific kinetic chromogenic LAL-assay (Pyrochrome, Associates of Cape Cod, East Falmouth, MA). Dust samples were extracted in pyrogen-free sterile water by sonication and intermittent shaking followed by centrifugation. Supernatants were collected and analysed. Similarly, filter extracts and tube extracts from air samplers were analysed for endotoxin. In brief, pyrogen free water plus 0.05% Tween 20 were added to extracts, vortexed for 1 h, and aliquots of 25 μL were transferred to 96 microwell plates. After adding specific Pyrochrome reagent the absorbance and kinetics of color reactions were studied by a Microplate Reader at 405 nm. Endotoxin concentration levels were calculated as endotoxin units (EU/m^3 and EU/mg). Correlations between endotoxin in dust versus air in home environments were significant with respect to concentration (EU/m^3; $r = 0.325$; $p = 0.036$) and loading on floor surfaces (EU/m^2; $r = 0.311$; $p = 0.045$), however, similar significant correlations were lacking in farming environment between the endotoxin levels in aerosolizable soil dust versus airborne concentrations ($p > 0.05$), although both measurements were conducted in parallel.

Conclusions

Determinants for airborne and dusts borne endotoxin exposure levels in indoor home environments are similar, however for an ambient farming environment these determinants are too diverse and probably soil dust is not a major source for airborne endotoxin in farming environments.

Acknowledgement

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EXPOSURE TO PARTICULATE MATTER AND CHRONIC OBSTRUCTIVE PULMONARY DISEASE IN THE CITY OF NOVI SAD, REPUBLIC OF SERBIA

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Summary
The objective was to examine the relationship between the concentration of particulate matter with 10 or less microns in diameter (PM_{10}) and hospital admissions (HA) for Chronic Obstructive Pulmonary Disease (COPD) in the City of Novi Sad, Republic of Serbia (NS). Epidemiological time series approach was applied throughout 3 year's period (2011 - 2013). Poisson regression model adjusted with temperature (T), relative humidity (RH), years (Y), seasons (S) and weekends (W) was used for statistical analysis. The results showed significantly positive association between mean daily PM_{10} concentration and daily number of COPD HA, in a way that 10μg/m^3 increment of PM_{10} increases COPD HA by 6%.

Introduction
There is a large body of evidence of the effects of short-term exposure to PM_{10} on human health (1). According to World Health Organization (WHO) 3.7 million deaths were attributable to ambient air pollution in 2012 (2). The objective of the study was to examine the association between PM_{10} and HA for COPD.

Methodology and Results
The epidemiological time series approach for the period 1st January 2011 - 31st December 2013 was used. The mean PM_{10} concentration at each day was regressed to number of HA for COPD (ICD10: J44) at the same day, with confounding factors: values of T and RH, Y, S and W. The data of the daily PM_{10}, T and RH values were provided by RHIS, while the data of daily COPD HA were provided by IPHV. Poisson regression processed by SPSS software (Version 21) was used. Statistically significant coefficient for the PM_{10} at a 5% level was accepted as evidence of association. The results were expressed as a RR with the 95% Confidence Interval (95%CI) for quantifying the increase/decrease of the risk for HA, based on a corresponding daily 10 μg/m^3 increment of PM_{10} over the entire study period.
Throughout observed period 875 HA caused by COPD were registered with average daily number 0.79±0.99 (Table 1). The mean PM_{10} was 35.71μg/m^3±22.91 μg/m^3, average value of T and RH was 12.11^{0}C±9.11^{0}C and 69.51%±16.29%, respectively. Poisson regression (Table 2) showed that mean daily PM_{10} were positively associated with COPD HA (p=0.003). Average daily number of COPD HA increase by 6% for each 10μg/m^3 increment of PM_{10} (RR=1.006; 95%CI: 1.002 - 1.009).

Table1. Descriptive statistics of COPD HA, PM_{10} and the meteorological data in the NS, throughout study period (2011-2013)

	Average	Std. Deviation	Minimum	Maximum
COPD (n=875)	0.79	0.99	0.00	5.00
PM_{10} (μg/m3)	35.71	22.91	0.85	148.36
Temperature (^{0}C)	12.11	9.11	-18.00	30.00
Relative humidity (%)	69.51	16.29	23.00	98.00

Table 2. Adjusted RR* estimates and 95% CI for COPD admissions associated with PM_{10} concentrations in NS

				95% Confidence Interval for β	
Pollutant	**β coefficients**	**p Value**	**RR**	**Lower Bound**	**Upper Bound**
PM_{10}	0.003	0.156	1.006	1.002	1.009
Temperature	-0.001	0.036	0.999	0.998	1.000
Relative humidity	-0.007	0.010	0.993	0.987	0.998

*Poisson regression model adjusted with years, seasons and weekends

Conclusion
Association of mean daily PM_{10} concentrations, even they were well below WHO guideline values, and daily COPD HA among person aged 18+ in the NS in the period 2011-2013 represents public health problem and suggests further multidisciplinary preventive action.

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2. Burden of disease attributable to outdoor air pollution for 2012. Geneva (Switzerland): World Health Organization, 2014

REDUCTION IN MORTALITY PARALLELS DECREASE IN PM_{10} EXPOSURE, LOMBARDY (ITALY)

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Summary
Concentration of particulate matter with aerodynamic diameter ≤ 10µg/m^3 (PM_{10}) has been decreasing over the last years in Lombardy. Annual deaths attributable (AD) to PM_{10} exceeding the WHO 20µg/m^3 threshold for PM_{10} annual average were 302.4 in 2003-2006 and dropped to 162 in 2014. The reduction in PM_{10} concentrations over time halved the number of ADs.

Introduction
In the last ten years, the concentration of PM_{10} in the Lombardy region has been gradually decreasing (http://www2.arpalombardia.it/sites/QAria/_layouts/15/QAria/Inquinanti.aspx). Such a reduction is most likely due to combined effects of climatic variations, implementation of policies for air quality control and the economic crisis affecting volumes of road traffic and industrial production. Taking the cue from the health impact assessment performed by Baccini et al. (2011) on the main cities of Lombardy in the period 2003-2006, we evaluated how the mortality burden due to PM_{10} varied when considering its concentrations in 2014.

Methods and Results
Since we considered a short calendar period, we assumed our study population and its mortality rates to be constant over time. We also assumed that the effect of PM_{10} on mortality did not change and we used the same *a posteriori* city-specific concentration-response functions (CRF) of Baccini et al. 2011. PM_{10} annual average concentrations for 2014 were acquired from the air quality monitoring network of the Lombardy Regional Environmental Protection Agency. We considered air pollution and natural mortality data for 13 areas: 11 cities with more than 50,000 inhabitants, 1 smaller alpine town (Sondrio), and the agricultural administrative district of Lodi. The impact of air pollution on mortality was quantified in terms of the number of deaths attributable (AD) to exposure levels exceeding the threshold of 20µg/m^3 for PM_{10} annual average (WHO Air Quality Guidelines, 2005). ADs per year were calculated for the periods of interest (p_1= 2003-2006, p_2 = 2014). We then focused on the difference between AD_{p_1} and AD_{p_2} to quantify the variation of the mortality burden between the two periods (Δ_{AD}). The attributable community rate (ACR, Steenland and Armstrong, 2006) per 100,000 inhabitants was also calculated for each area and period as well as its difference between the two periods (Δ_{ACR}). Results are reported in the table.

Study Area	Population (2007)	PM_{10} in $\boldsymbol{p_1}$ (µg/m^3)	PM_{10} in $\boldsymbol{p_2}$ (µg/m^3)	CRF	$\mathbf{AD_{p_1}(ACR_{p_1})}$	$\mathbf{AD_{p_2}(ACR_{p_2})}$	$\boldsymbol{\Delta_{AD}}$ ($\boldsymbol{\Delta_{ACR}}$)	$\boldsymbol{\Delta_{AD}}$ 80% Credibility Int.
Bergamo	115,781	46.1	26.0	0.33	10.2 (8.8)	2.3 (2.0)	7.9 (6.8)	-3.4 ; 19.1
Brescia	189,742	49.4	31.3	0.13	4.7 (2.5)	1.8 (0.9)	2.9 (1.5)	-9.8 ; 15.9
Busto Arsizio	80,633	44.7	26.0	0.27	4.6 (5.7)	1.1 (1.4)	3.5 (4.3)	-3.3 ; 10.2
Como	83,175	43.6	25.0	0.30	5.7 (6.8)	1.2 (1.4)	4.5 (5.4)	-3.3 ; 12.2
Cremona	71,998	53.5	32.0	0.25	6.4 (8.9)	2.3 (3.2)	4.1 (5.7)	-5.1 ; 13.6
Lecco	47,325	38.4	19.0	0.18	1.6 (3.4)	0.0 (0)	1.6 (3.4)	-3.9 ; 7.3
Lodi district	219,670	52.6	33.0	0.32	19.9 (9.1)	8.1 (3.7)	11.8 (5.4)	-4.1 ; 28.9
Mantova	47,649	50.6	33.0	0.34	5.6 (11.7)	2.4 (5.1)	3.2 (6.7)	-1.8 ; 8.5
Milan	1,299,633	52.5	36.0	0.63	231.3 (17.8)	115.3 (8.9)	116.0 (8.9)	65 ; 176
Pavia	70,207	44.4	33.0	0.29	5.2 (7.4)	2.8 (4.0)	2.4 (3.4)	-2.2 ; 7.3
Sondrio	22,214	42.8	20.0	0.28	1.2 (5.4)	0.0 (0)	1.2 (5.4)	-1.4 ; 3.9
Varese	82,037	29.6	25.0	0.40	3.0 (3.7)	1.6 (2.0)	1.4 (1.7)	-0.6 ; 3.6
Vigevano	60,738	42.2	31.0	0.24	3.0 (4.9)	1.5 (2.5)	1.5 (2.5)	-1.9 ; 5.1
Total	2,390,802	-	-	0.30	302.4 (12.6)	140.4 (5.9)	162.0 (6.8)	24.2 ; 311.6

Conclusions
The observed reduction in air pollution concentrations over time halved the number of attributable deaths. The WHO threshold for PM_{10} annual average is still far from being met in most of the cites, and appropriate policies for emission reduction could still have a large beneficial effect on population health.

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SECTORIAL CONTRIBUTIONS TO AMBIENT PM CONCENTRATIONS IN STOCKHOLM AND ESTIMATED PREMATURE MORTALITY DUE TO BLACK CARBON EXPOSURES

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Summary
We have modelled annual mean PM_{10}, $PM_{2.5}$, PM-exhaust and Black Carbon (BC) concentrations and exposures 1990-2011 from different sources at between 35 and 500 meter resolution to be used in epidemiological studies and health impact assessments. For the city of Stockholm the population weighted BC was 0.75 µg m^{-3} due mainly to road traffic and residential biomass combustion. Applying a relative risk of premature mortality of 6% per µg m^{-3} we estimate that local emissions of BC in 2011 causes about 400 premature deaths per year in Stockholm.

Introduction
Of ambient air pollutants, PM exposure is considered to be most important for adverse health effects, but evidence is not conclusive on which particulate characteristics or sources that are responsible for the effects. Recent epidemiological studies indicate that associations between adverse health effects is stronger for BC than PM2.5 (Janssen et al., 2011). In this study we have performed dispersion calculations of annual mean concentration of PM due to local emission from several sectors in Stockholm County. We compare estimated premature mortalities associated with PM exposures using published relative risk factors.

Methodology and Results
We have developed local emission inventories of PM_{10}, $PM_{2.5}$, PM-exhaust and black carbon (BC) for road traffic, sea traffic, residential heating (including leisure firing) and energy production in Stockholm County for the years 1990, 1995, 2000, 2005 and 2011. For road traffic the emissions consists of both vehicle exhaust and non-exhaust particles generated during wear of brakes, tyres and road surface. Using a Gaussian dispersion model urban background concentrations at roof-top level in built-up areas and a street canyon model annual mean concentrations of PM_{10}, $PM_{2.5}$, PM-exhaust and BC were calculated at a spatial resolution of between 35 – 500 meters. Generally, road traffic non-exhaust particles is the dominating source of PM_{10} and $PM_{2.5}$ in Stockholm County, but e.g. in rural areas combustion particles from residential heating and leisure firing can constitute the largest local source. For BC, emissions from road traffic is somewhat more important than emissions from residential heating when it comes to population exposure. The emissions from sea traffic contribute little to the overall PM exposure due to the location of the emissions in relation to the residents.

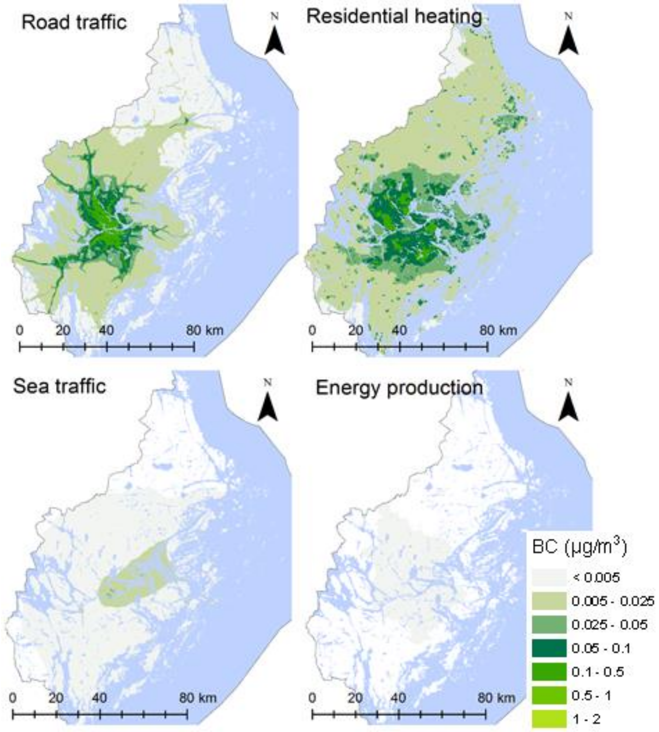

Figure 1. Annual mean BC concentrations due to local emissions in Stockholm County in 2011.

We have also calculated the excess number of premature deaths associated with exposure to locally emitted PM based on population weighted concentrations for the city of Stockholm in 2011. Assuming a relative risk of 6% per 1 µg BC m^{-3} and using our population weighted mean concentration due to local sources of 0.75 µg m^{-3} we obtain approximately 400 premature deaths per year due to BC emissions. This is compared to the mortality associated with PM10 and PM2.5.

Conclusions
Exposure calculations of PM_{10}, $PM_{2.5}$, PM-exhaust and BC for different source sectors in Stockholm County show that road traffic and residential heating are the dominating sources. Population exposure of BC due to local emissions is estimated to cause 400 premature deaths per year.

Acknowledgement
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CHILDREN EXPOSURE TO AIR POLLUTANTS IN INDOOR OF PRIMARY SCHOOLS RETROSPECTIVE AIR QUALITY SIMULATION TO SUPPORT EPIDEMIOLOGICAL STUDIES

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Summary
Past air quality conditions in Lombardia Region have been to be reconstructed to support epidemiological investigations concerning lung cancer. A correct evaluation of long term exposure to air pollution is important to estimate its effects on pathologies characterised by long latency. During the latest decades Milan area experienced a relevant decrease of pollutants concentration that does not allow to consider present air quality representative for past air pollution conditions. Air pollution levels have therefore been reconstructed using air quality modelling, with an approach suitable to produce results comparable with present air quality assessments. Hourly and long term average concentrations have been compared with the available measurements for year 1990, and with air quality analyses for 2000 and later years to set in evidence the decrease of concentrations and their space distribution variation.

Introduction
The health impact of air pollution has often been analysed using available air quality measurements. More recently, the space distribution of pollutants concentration has been taken into account using different modelling techniques, e.g. land use regression models and deterministic air quality models. These analyses usually refer to the latest years, due to the availability and space coverage of the monitoring stations. Recently the International Agency for Research on Cancer (IARC) has classified outdoor air pollution as carcinogen (Straif et al., 2013). Due to its long latency, the occurrence of cancer can be related to the subject exposure to air pollution during his lifetime. A correct evaluation of exposure should be therefore based on past concentration levels. Milan and the other cities in Lombardia Region experienced a dramatic reduction of pollutants concentration from the seventies to the beginning of the present century, making extrapolations from present values not feasible. Aside of the concentrations values, their space distribution is expected to be modified by the urban growth in the city suburbs and deindustrialization processes.

Methodology and Results
Even if Lombardia Region is one of the areas with longer monitoring records in Italy, PM10 started to be routinely measured in 1998 and before that date only a very limited number of TSP measurements were available. Even the number of stations measuring NO_2 and O_3 in 1990 was much smaller than the present one, and wide areas of the Region were not covered. Therefore, the reconstruction of past air quality can hardly be based only on measurements due to the limited number and the sparseness of available observations. The national emission inventory has data disaggregated at Province level from 1990. The digital description of land cover, a key proxy parameter for the space disaggregation of emissions, is available at European scale from 1990 too, thanks to the CORINE Land Cover project. It was therefore decided to perform a model reconstruction of air pollutants concentrations for year 1990 to obtain a first estimate of past air pollutants concentration and to verify the feasibility of a more thorough evaluation of past concentrations from 1980 onward. The modelling approach has been selected to obtain results comparable with air quality analysis performed by the Regional Air Quality Agency (ARPA Lombardia) and by the national project MINNI (http://www.minni.org/). The modelling system is based on the chemical transport model FARM (Mircea et al., 2014) coupled with the meteorological model WRF (http://www.wrf-model.org/) and has been configured with nested computational domains reaching the maximum resolution over Lombardia Region with a grid spacing of 4 km. Meteorological fields have been reconstructed downscaling ECMWF ERA-Interim meteorological analyses. Estimated concentrations have been compared with the available measurements for year 1990, and with air quality analyses for year 2000 evidencing the decrease of concentrations fields and partial variation of their space distribution.

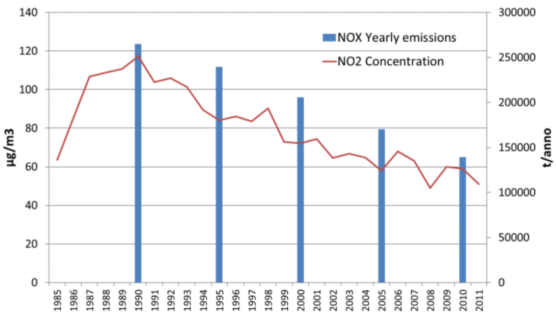

Fig.1 Lombardia Region NOx emissions (tons/year; blue) and Milan urban background NO_2 concentration ($\mu g/m^3$; red)

Conclusions
Retrospective air quality simulations can be performed for 1990 and later years with the same input data and modelling methodology used for recent years. Differences between past and present concentration fields can be quantified to improve population exposure estimate. A more demanding investigation is necessary to reconstruct earlier years, for which space disaggregated emissions are not available, and an industrial sources inventory should be built due to their emission relevance.

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PUBLIC HEALTH GAINS FROM STRICT REGULATIONS ON FINE PARTICULATE AIR POLLUTION

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Summary
The main aim of this work is to evaluate the implementation of recent air quality standards for fine particulate matter ($PM_{2.5}$) in the European Union (EU), United States (US) and other countries worldwide and to estimate the public health gains that could be expected if EU or US standards for long term exposure were adopted and enforced internationally. We first investigated premature mortality attributable to $PM_{2.5}$ in adults ≥30yrs and children <5yrs, applying a high-resolution global atmospheric chemistry model combined with epidemiological concentration response functions. To assess the impact of applying air quality standards for $PM_{2.5}$ pollution we performed sensitivity calculations where we set these standards as the upper concentration limits in the health impact function, thus assuming they are strictly implemented. The key finding of this study is that even small changes at the lower standards of annual mean $PM_{2.5}$ concentrations (e.g., < 20μg/m^3) can have a significant impact on mortality rates. Our results underscore the large positive impact on human health worldwide by implementing the recently lowered US air quality standard of 12μg/m^3 or even a lower limit for annual mean $PM_{2.5}$.

Introduction
Outdoor air pollution by fine particles ranks among the top ten global health risk factors that can lead to premature mortality (Lim et al., 2012). Epidemiological cohort studies, mainly conducted in the United States and Europe, have shown that the long-term exposure to $PM_{2.5}$ is associated with increased mortality from cardiovascular, respiratory diseases and lung cancer. Fine particles can cause health impacts even at very low concentrations. Populations in large parts of the world, especially in Asia, are exposed to very high levels of $PM_{2.5}$ pollution. Most of $PM_{2.5}$ originates from combustion engines, power plants, industry, household energy use, agriculture, biomass burning and natural sources like desert dust. Estimates of mortality attributable to outdoor air pollution are useful to justify air quality control policies and help improve public health.

Methodology and Results
For this work we used the EMAC atmospheric chemistry–general circulation model, applied at high resolution to compute global $PM_{2.5}$ concentrations, combined with population data, country-level health statistics and pollution exposure response functions. To estimate premature mortality attributable to $PM_{2.5}$ we follow the same methodology as Lelieveld et al. (2015) and the Global Burden of Disease for 2010 (Lim et al. 2012) applying improved exposure response functions that more realistically account for health effects at very high $PM_{2.5}$ concentrations. We primarily assume that all particles are equally toxic, but also include a sensitivity study that accounts for differential toxicity. We estimate the global premature mortality by $PM_{2.5}$ at 3.15 million/year in 2010. China is the leading country with about 1.33 million, followed by India with 575 thousand and Pakistan with 105 thousand. For the 28 EU member countries we estimate 173 thousand and for the US 52 thousand premature deaths in 2010. We find that emissions from residential energy use such as heating and cooking, prevalent in India and China, have the largest impact on premature mortality globally. We performed sensitivity studies to estimate the reductions in mortality that could be achieved if the $PM_{2.5}$ air quality standards of the EU and US and other national standards would be implemented worldwide. With the EU annual mean standard of 25μg/m^3 the global premature mortality due to $PM_{2.5}$ exposure would drop by 17%; while within the EU the effect is negligible. With the US standard of 12μg/m^3 premature mortality by $PM_{2.5}$ would drop by 46% worldwide; 4% in the US and 20% in the EU, 69% in China, 49% in India and 36% in Pakistan. These estimations take into consideration that about 22% of the global $PM_{2.5}$ related mortality cannot be avoided due to the contribution of natural $PM_{2.5}$ sources.

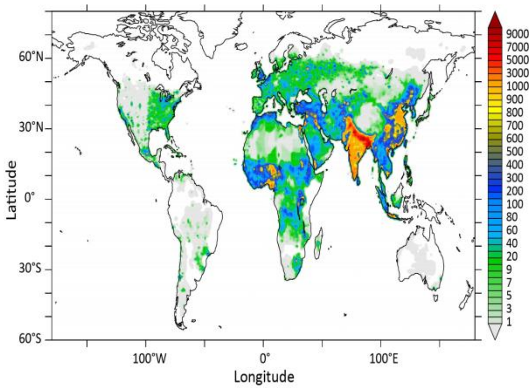

Fig.1 Mortality linked to outdoor air pollution in 2010. Units: deaths per area of 100km x 100km

Conclusions
Our results suggest the need to adopt globally a strict limit for annual mean $PM_{2.5}$ levels, like the US limit of 12μg/m^3 or even a lower limit to substantially reduce premature mortality in most of the world, while in strongly polluted regions like South and East Asia essentially any $PM_{2.5}$ reduction can significantly reduce premature mortality.

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THE USE OF INDICES TO DESCRIBE SHORT TERM EFFECTS OF AIR QUALITY AND BIOMETEOROLOGY ON MORBIDITY IN WESTERN GERMANY

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Summary
The influences of air quality and thermal stress on hospital admissions due to cardiovascular and respiratory diseases are assessed using Poisson regression models combined with distributed lag nonlinear models (DLNMs) (Gasparrini 2011). The use of corresponding indices is equally suited to the use of single metrics, thus gives the opportunity to facilitate communication to the public as well as to include all parameters of interest without the need to exclude some due to correlation of covariates.

Introduction
Several studies analyse either the impact of air quality or the impact of thermal stress on health outcomes - mostly mortality. Early studies only treat the weather or the air pollution as independent variable, without considering confounders. Later this changed to the use of either meteorology or air quality as confounder. However, these studies are still rare, and especially the combined effects can vary across locations.

Methodology and Results
The analysis was conducted in 39 administrative districts along a north-south gradient in the western part of Germany covering the period from 2001 to 2011. Data sets for each district included air quality (NO_2, SO_2, O_3 and PM_{10}), biometeorology (air temperature, wind speed, relative humidity and global radiation) and hospital admissions (case specific diagnoses based on ICD-10) on a daily basis. To assess if the commonly used indices UTCI (Jendritzky et al. 2012) and CAQI (van den Elshout et al. 2008) are suited to describe the association between air quality, biometeorological factors and cardiovascular and respiratory diseases, we used Poisson regression models combined with DLNMs. We controlled for a long term and seasonal trend, day of the week, holidays and influenza.

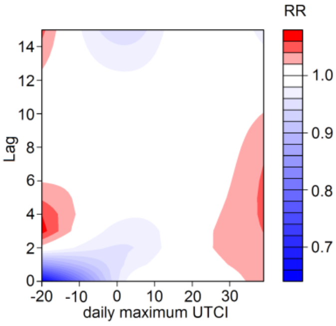

Fig.1 Bi-dimensional exposure-lag-response association for biometeorological parameters

The comparison of models using the pollutants and meteorological parameters with models using the indices shows that both methods have a similar adjusted R-square of 0.5 to 0.7 depending on the district.
The Bi-dimensional exposure-lag-response association reveals that cold stress leads to an increased relative risk (RR) after 2 to 6 days, while heat stress results in an immediate RR increase that lasts up to ten days (fig 1). The range from 10 to 25 degrees UTCI shows a RR of about 1. This is well in line with the definition of the "no thermal stress" at a range from 9 to 26 degree UTCI. The Results for the CAQI show that only very high values lead to an increase in RR (fig 2). The response is immediate and lasts up to 2 days.

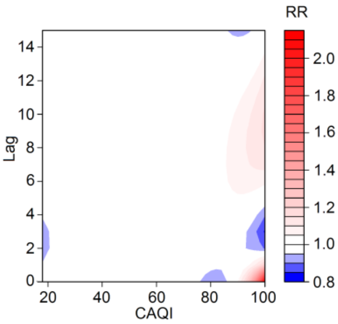

Fig.2 Bi-dimensional exposure-lag-response association for air quality

Conclusions
The Poisson regression model combined with a DLNM could show that the UTCI and CAQI are suitable to assess the effects of air quality and thermal stress on cardiovascular and respiratory hospital admissions in Germany. The RR around 1 for the range of 10 to 25 degree UTCI underlies the suitability of the index.
As some of the pollutants and meteorological factors are highly correlated, e.g. ozone and temperature, the use of indices gives the opportunity to include even the correlated measures. Another benefit from using the indices is that the model results are easily accessible by the public and stakeholders as the indices provide a summary of biometeorological stressors and air quality parameters.

Acknowledgement
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PHYSICO-CHEMICAL PROPERTIES AND BIOLOGICAL EFFECTS OF DIESEL AND BIOMASS PARTICLES

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Summary
Diesel and biomass combustion are main sources of fine and ultrafine particulate matter (PM) in North Italy. The particles here used were sampled under controlled laboratory conditions, characterized for their physico-chemical properties, and tested for their biological effects in a human pulmonary epithelial cell culture model. The results evidenced a higher PAHs and metals content in diesel particles, which also induced stronger cell responses such as cell morphology modification, gene modulation and interleukin release.

Introduction
Ambient particulate matter (PM) toxicity has been widely studied in the past decades for its effects on human health. WHO reported that 7 million worldwide annual premature deaths are linked to air pollution, confirming this as the largest environmental health risk in the world (WHO, 2014). In the effort of retraining ambient air quality, greatest awareness has now been gained on the necessity to re-evaluate the standards limits, aiming not only at low PM concentrations, but focusing on the reduction of specific components, sources and size fractions (Cassee et al., 2013). In the Lombardy Region diesel used for private and public transport and biomass burning for residential heating represents important sources of fine PM. Previous research has highlighted the complexity of studying combustion particle toxicity. Differences in fuel properties and combustion conditions can result in significant variation in the particles chemical content, greatly affecting the biological effects (Shen et al., 2014). In the present study, PM produced by diesel (DPM) and biomass (BPM) combustion under controlled laboratory conditions were evaluated to determine the physico-chemical properties and related biological effects of these ultrafine particles sources.

Methodology and Results
DPM and BPM were sampled on Teflon filters from an Euro 4 vehicle without DPF and from a 25 kW pellet boiler, respectively. Content of PAHs and metals were determined by GC/MS and ICP-MS respectively, and particles morphology analysed by TEM and SEM. Human bronchial epithelial cells (HBEC3) were exposed to particles for up to 2 weeks. Cell morphology was inspected daily by an inverted microscope. Changes in gene expression were evaluated by RT-qPCR, and the release of inflammatory mediators by ELISA. The scratch wound assay was used for cell migration analysis.
DPM had a higher concentration of PAHs and metals with respect to BPM. Genes related to xenobiotic metabolism were modulated by both PM, while genes involved in inflammatory response and oxidative stress were modulated only after exposure to DPM. Moreover, exposure to DPM increased the release of the cytokines IL-1β, IL-6 and IL-8, changed the cell morphology, and reduced migration.

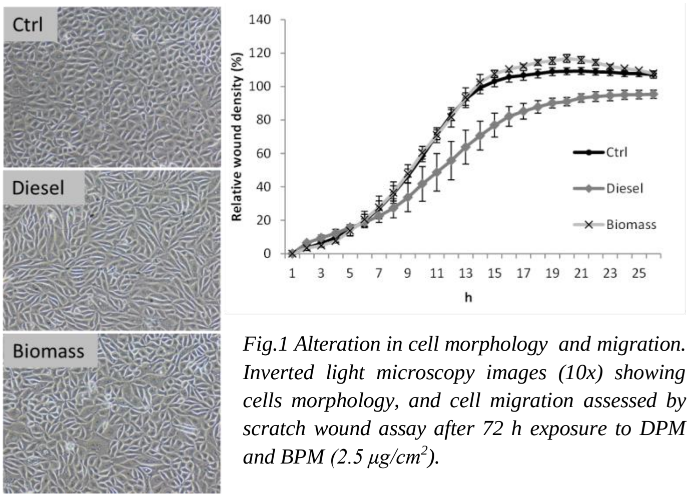

Fig.1 Alteration in cell morphology and migration. Inverted light microscopy images (10x) showing cells morphology, and cell migration assessed by scratch wound assay after 72 h exposure to DPM and BPM (2.5 μg/cm^2).

Conclusions
The higher PAH and metal content in DPM was accompanied by stronger biological effects. In HBEC3 cells, DPM activated the inflammatory response and oxidative stress pathways, changed cell morphology and reduced migration. In contrast, BPM produced by the combustible material and at the burning conditions here used resulted in only minor or no biological effects. The results here presented highlight the importance to evaluate the sources emissions in order to select more effective strategies to improve air quality.

Acknowledgement
INNOVHUB performed particles sampling. This research was supported by a grant of Cariplo Foundation to M.C.

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CORRELATION BETWEEN ANNOYANCE AND THE COMBINED EFFECT OF PARTICULATE MATTER

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Summary
The aim of this paper is to estimate the risk between exposure to particulate material concentrations (SP, PM_{10} and TSP) and perceived annoyance, reported by respondents in Vitoria Region (Brazil). For that, a survey by phone (panel survey) from 2011 to 2014 with a representative sample of the region was conducted. It was examined the behaviour of particulate matter, as PM_{10}, Total Suspended Particles (TSP) and Settled Particles (SP), monitored in the air quality stations.

Introduction
Particulate matter is an air pollutant that causes damage to human health, animals and plants, affects the climate and is a potential cause of annoyance through deposition on materials and buildings. The perceived annoyance caused by particulate matter is related mainly to the increase of dust in urban and residential environments when it settles. Settled particles can originate from many sources, e.g., paved and unpaved roads, buildings, agricultural operations and wind erosion that represent the largest contributions beyond the relatively minor vehicular and industrial sources emissions. Several studies have quantified the relationship between annoyance from air pollutants (Rotko et al., 2002; Amundsen et al. 2008; Nikolopoulou et al., 2011). However, it can be observed that each pollutant is included as single covariate in the regression model and, it is well-known that pollutants concentrations are inter-correlated. Therefore, the multicollinearity between pollutants concentration must be taken into account to evaluate their relationship with annoyance due to air pollution. In this context, this study presents a multivariate statistical techniques combination to analyse at the same model the combined effects of total suspended particles (TSP), PM_{10} and settled particles (SP).

Methodology and Results
The combination of logistic regression and PCA techniques was applied by Roberts & Martins (2006) to evaluate the associations of pollutants (PM_{10}, O_3, SO_2, NO_2 and CO) and their health effects avoiding the problem of multicollinearity. However, as pointed out by Zamprogno (2013), the PCA technique requires variables that are not correlated in time, i. e., stationary time series (serially independent) and air pollutants concentration time series can hardly be assumed stationary. Thus, it was necessary to use times series model to identify the existence of temporal correlation to eliminate then.

In the multiple logistic regression model the three first principal components (PC1, PC2 and PC3) were used as the covariates and a dichotomised mean of annoyance. The model have a good fitted, but there is no sense to analyse, individually, each parameters estimated here, they are important to calculate the relative risk shown in Table I. The relative risk (RR) of annoyance results were expressed by the interquartile variation range. Thus, the RR of annoyance estimated for the pollutant Settled Particles (SP) increases approximately by a factor of 1.5 considering the interquartile variation equal to 2g/m² 30 days. For the others pollutants the relative risk varied from 1.6 (PM_{10} mean) to 2.4 (PM_{10} maxim) and from 1.8 (TSP mean) to 2.2. (TSP maxim).

TABLE I- THE RELATIVE RISK ESTIMATED

Pollutants	RR	IC (95%)	Dif IC
SP	1.462	(1.070; 1.854)	0,784
PM_{10} (monthly mean)	1.649	(1.061; 2.237)	1,176
TSP (monthly mean)	2.181	(1.471; 2.891)	1,42
PM_{10} (monthly maxim)	2.411	(1.401; 3.421)	2,02
TSP (monthly maxim)	1.822	(0.592; 3.052)	2,46

Conclusions
The relative risk (RR) provide data on the strength of association between the risk factor (air pollution) in the study and the outcome (annoyance). In this context, the estimates relative risk showed that, in general, an increase in air pollutant concentrations (i.e., the particulate matter metrics examined here: TSP, PM10 and SP) significantly contributes in increasing the probability of being annoyed.

Acknowledgement
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ON THE USE OF CARBONACEOUS PARTICLE EXPOSURE METRICS IN HEALTH IMPACT CALCULATIONS

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Summary

Combustion-related carbonaceous particles seem to be a better indicator of adverse health effects compared to $PM_{2.5}$ and PM_{10}. Historical studies are based on black smoke (BS), but more recent use absorbance (Abs), black carbon (BC) or elemental carbon (EC) as exposure indicators. To estimate health risks based on BS, we review the literature regarding the relations between Abs, BS, BC and EC. We also discuss the uncertainties associated with the comparison of RRs based on these conversions. EC is reported to be between 5.2 % and 26 % of BS with a mean value for 15 relationships of 12 %. Correlations of different metrics at one particular site are higher than when different sites are compared. Comparing all traffic, urban and rural sites, there is no systematic site dependence, indicating that other properties of the particles or errors affect the measurements and obscure the results. It is shown that the percent increase in mortality associated with EC may be several times higher than for PM_{10}, but this is highly dependent on the relation used. RRs for all-cause mortality associated with short-term exposure to PM_{10} seems to be higher at sites with higher EC concentrations, but more data are needed.

Introduction

The results from many studies indicate that exposure to combustion-related carbon-containing particles is associated with more adverse health effects compared to exposure to undefined particulate matter ($PM_{2.5}$ and PM_{10}) (Janssen et al. 2011). Black smoke (BS) has been monitored as an indicator of air-quality worldwide since decades. But later, health-risk estimates are based on light absorbance (Abs), black carbon (BC) or thermo-optical methods (EC), as they are considered more specific for carbon-containing combustion particles. In this study our aims are: 1.) to review different transformations between BS and BC or EC reported in the literature. This is done to assess the degree of comparability between different epidemiological studies using the different metrics, and the possible ranges of increased mortality risks associated with black-carbon particles. 2.) To compare the estimated increase in mortality associated with short-term exposure to PM_{10} and EC (BC). We focus on short-term exposure studies, where risk estimates for either one of BS, BC or EC are reported together with risk estimates for PM_{10}. 3.) To analyse if the effect of PM_{10} on daily mortality depends on the EC concentration.

Methodology and Results

By using the different relations between EC and BS at various places, described in different articles, we have calculated the absolute health-risk increase for some cities with reported PM_{10} and EC (BC) concentrations. We have also analysed how the different measurement methods may affect the results in epidemiological studies. Many studies have addressed the question of what is the cause of the health effects associated with PM exposure (e.g. Grahame et al. 2014). Several authors discuss the importance of the carbonaceous particles as particularly important. Based on these results, we have analysed if there is any relation between the relative risks (RR) associated with PM_{10} and the concentration of EC. We show that the relative risks regarding all-cause mortality from exposure to PM_{10} will increase as a function of the levels of elemental carbon (EC), and this slope is significant (95 % CI).

Conclusions

During the last years, the health risks associated with combustion-related particles have received an increasing attention. The measurement methods for carbonaceous PM are important to address, since they may cause large uncertainties when used in health impact calculations in epidemiological research. In order to reduce the uncertainties regarding the importance of combustion-related carbonaceous aerosols, a more specific and standardized methodology for measuring combustion-related particles is urgently needed.

Acknowledgement

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PERSONAL EXPOSURE ASSESSMENT TO AIR POLLUTANTS USING PORTABLE SENSORS AND AGENT BASED MODELLING

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Summary

This study examines the feasibility of using multiple wearable sensors for tracking personal location and activities and assessing exposure at a personal level using Agent Based Modelling (ABM). Using this approach, an individual exposure model was developed that can feed into population-based exposure assessments without imposing prior bias, but rather basing its estimations onto emerging properties of the agent system behaviour. This approach permits the identification of daily variability of exposure and leads to useful conclusions regarding capping exposure to high air pollution levels.

Introduction

The downsizing of monitoring technologies and the respective costs make it possible for various environmental stressors and exposure factors to be measured more easily and frequently, thus providing a more reliable "time - geography of exposure" shifting the current paradigm from a population to an individual level. Data collected by "smart" devices can help provide more accurate exposure assessment for epidemiological studies and health impact assessment. This study is based on ABM, a technique that simulates the actions and interactions of autonomous software objects, the "agents", enabling a better understanding of the behaviour of individuals and populations in social and evolutionary settings. Our ABM models are fed with input from a web of wearable sensors tracking location, activity, but also climatic and air pollution parameters in cities.

Methodology and Results

A pilot multi-sensor campaign took place in Thessaloniki, Greece, examining the use of the Moves smartphone app and commercially available fitness monitors, such as the FitBit Flex, for tracking people's location and activities. 25 participants wore these devices along with a GPS sensor and an accelerometer for a week. Location, motion and intensity of activity data were used as input to an Artificial Neural Network (ANN) model, built to derive a time-location model based solely on sensor data as a more precise substitute to cumbersome time logs. Using Monte Carlo analysis, distributions of participants' movement and activities were extrapolated to a larger population. Furthermore, using a geographically explicit agent-based model, the trajectory of individual "agents" was modelled and geo-referenced. Coupling the agent trajectories with high spatial resolution urban air quality modelled maps of hourly concentration of PM in Thessaloniki, personal exposure was estimated. Inhalation-adjusted exposure to air pollutants was then evaluated by assigning pollutant concentrations to an agent based on his/her coordinates, activities and the corresponding inhalation rate. PM levels and size distribution varied among different parts of the urban agglomeration and hours of the day, as well as among different seasons. On average, personal exposure results were between 10 and 20% more accurate than the equivalent estimate using ambient air concentration of PM as exposure proxy.

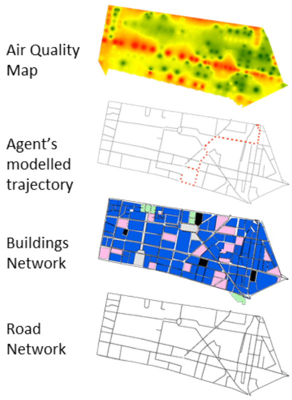

Fig.1 Exposure assessment using ABM

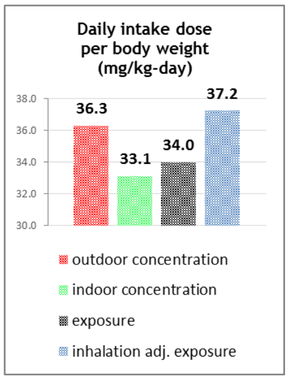

Fig.2 Daily intake dose per body weight for a randomly picked agent

Conclusions

An improvement of exposure assessment, extending it to personal intake dose, allows better conclusions regarding the association between air pollution and health at the population level. The dynamic nature of intake dose assessment at the individual level supports the derivation of guidance regarding behavioural options that limit exposure to high pollution levels. This study represents the first step in the development of a methodological approach to estimate the external exposome, which encompasses the totality of human environmental exposures at an individual level, taking into account different activity patterns, consumer behaviours and lifestyle factors. Such a model would be useful for assessing exposure for specific vulnerable subgroups, such as children, the elderly and people with low socioeconomic status.

Acknowledgement

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DESERT DUST ADVECTIONS IN SOUTHERN EUROPE DURING 2001-2010: FREQUENCY OF THE EPISODES, CONTRIBUTION TO GROUND-LEVEL PM10 CONCENTRATIONS, AND SHORT-TERM HEALTH EFFECTS

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Summary
This study aimed to estimate the frequency of desert dust advection episodes in Southern Europe over a long time period, and to investigate the health effects of PM10 on mortality and hospitalizations, also comparing the relative effects of desert vs non-desert PM10. To accomplish these goals, we have used several atmospheric models to identify dust episodes, and we adopted standard statistical approaches to quantify ground-level contributions. These contributions have been then related to health endpoints via time-series analysis. We identified many desert dust episodes in the study area, with clear north-south gradients. These episodes affected both mortality and hospitalization endpoints, with risk excesses comparable to those found for PM10 originating from local sources.

Introduction
While there is a large consensus on the causal role of total PM on health endpoints, the evidence on the association between short-term exposure to desert dust and health outcomes is still controversial. In this study we aimed at estimating the short-term effects of particulate matter ≤ 10 µm (PM10) on mortality and hospital admissions in 13 south-European cities, distinguishing between PM10 originating from desert and from other sources. This was accomplished by applying standardized procedures of data collection and analysis.

Methodology and Results
We identified desert dust advection days in multiple Mediterranean areas for 2001-2010 by combining modelling tools, back-trajectories and satellite data. For each advection day, we estimated PM10 concentrations originating from desert, and computed PM10 from other sources by difference. We fitted city-specific Poisson regression models to estimate the association between PM from different sources (desert and non-desert) and daily mortality and emergency hospitalizations. Finally, we pooled city-specific results in a random-effects meta-analysis. On average, 15% of days were impacted by desert dust at ground level (desert PM10 > 0 µg/m3). Most episodes occurred in spring-summer, with increasing gradient of both frequency and intensity North-South and West-East of the Mediterranean basin.
We found significant associations of both PM10 concentrations with mortality. Increases of 10-µg/m3 in non-desert and desert PM10 (lag 0-1 days) were associated with increases in natural mortality of 0.55% (95% CI: 0.24, 0.87%) and 0.65% (95% CI: 0.24, 1.06%), respectively. Similar associations were estimated for cardio-respiratory mortality and hospital admissions.

Conclusions
PM10 originated from desert was positively associated with mortality and hospitalizations in Southern Europe. Policy measures should aim at reducing population exposure to anthropogenic airborne particles even in areas with large contribution from desert dust advections.

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ON THE IMPACT OF AIR QUALITY ON HUMAN HEALTH: APPLICATION OF AN AIR QUALITY INDEX FOR THESSALONIKI, GREECE

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Summary
In this study, we present the implementation and evaluation of an advanced air quality index for the coastal Mediterranean city of Thessaloniki, Greece. The selected index, namely the Aggregate Risk Index (ARI), was integrated into an operational air quality forecasting system, comprised of the meso-scale meteorological WRF model and the air quality CAMx model. Results from the operational implementation of the coupled WRF/CAMx modelling system for a six-month period in the year 2012 were used for evaluating the respective ARI estimates. The evaluation process was carried out using health data provided by a major hospital in the greater Thessaloniki area. Several different scenarios were investigated in order to verify the presence of any correlation between the predicted ARI values and the number of either hospital admissions or examined patients. This analysis revealed the existence of a time lag between the ARI forecasts and health data. In particular, it was found that the health data of the current day correlate better with the simulated daily maximum ARI values of the previous two to three days. This study suggests that ARI is a promising tool for assessing the impact of air quality on human health.

Introduction
Extensive research over the past decade has shown that exposure to air pollutants is strongly connected to health endpoints such as increased hospital admissions for respiratory and/or cardiovascular diseases, and mortality. Further, there is a profound relation between human health and well-being from the one side and air pollution levels from the other. Therefore, it is not surprising that the impact of deteriorated air quality on human health has become a critical component in relevant policy discussions. Taking this into consideration, we implemented an advanced air quality index as part of an operational air quality forecasting system. The goal of this study is to evaluate the suitability of the selected index as a tool for assessing the impact of air quality conditions on human health.

Methodology and Results
The air quality modelling system employed consists of the meteorological WRF model off-line coupled with the photochemical air quality CAMx model (Fig. 1). The air quality index integrated into the WRF/CAMx modelling system is ARI, described in detail by Sicard et al. (2011). The modelling system was implemented operationally over a high resolution (2 km) domain, focused on the city of Thessaloniki, during a six-month period spanning January through June 2012. Domain-averaged values of the predicted daily maximum, minimum and mean ARI, classified per targeted pathology, were compared to health data acquired from the "Georgios Papanikolaou" General Hospital of Thessaloniki. The conducted analysis focused on examining potential associations between the predicted ARI values and the health data. At a first stage, the health data of the current day were contrasted to the forecasted ARI data for the same day, revealing the absence of any statistically significant correlation. At a second stage, the health data of the current day were compared against the modeled ARI data of the previous N days. This particular time lag scenario revealed the existence of statistically significant correlations between ARI and the health endpoints represented by the provided medical data. It was found that the forecasted daily maximum ARI of the previous 2-3 days correlates with the hospital admissions of the current day. For instance, the correlation coefficient between the daily maximum value of ARI of the previous 2 days and daily hospital admissions for cardiac diseases was found equal to 0.40 (statistically significant at the α=0.05 level). Similar results were also obtained for other pathologies, such as for cardiovascular and respiratory diseases.

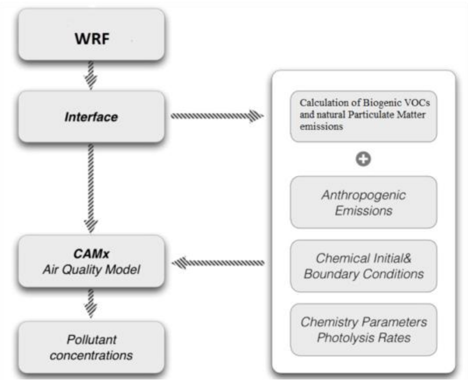

Fig.1 Flow chart of the WRF/CAMx modelling system.

Conclusions
The current study has shown that ARI can be exploited as a tool for assessing the impact of deteriorated air quality on human health. The conducted preliminary analysis revealed that forecasts of this particular index might be of great usefulness to authorities involved in the health sector.

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ECONOMIC IMPACTS FROM PM2.5 POLLUTION-RELATED HEALTH EFFECTS IN CHINA: A PROVINCIAL LEVELED ANALYSIS

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Summary
This study aims to evaluate the PM2.5 pollution-related health impacts on the national and provincial economy by combining GAINS-China model and a Computable General Equilibrium (CGE) model. Applying our approach to 30 provinces in China shows that provinces with high PM2.5 concentration may have a substantial impact on their health and economy. PM2.5 pollution leads to additional health expenditure and work time loss. Comparing with health expenditure, work time loss has more significant negative impact on the economy. Air pollution control technology also costs a lot, which is much higher than health expenditure. However, considering the cost and benefit, the net benefit is considerable in most of the provinces, especially in developed regions.

Introduction
With fast growth and development, China is facing severe challenges relating to its environment, particularly the notorious haze pollution in recent years. Exposure to a high concentration of PM2.5 increases both mortality and morbidity (Pope III, Burnett et al. 2002). Health problem can lead to additional health expenditure and work time loss. The economic impact from PM2.5 pollution-related health effects in China should be a concern to the policymaker. However, most of the current studies are about PM10 pollution focused only on one city, province or region levels, which cannot reflect the regional disparity of economic damage to 30 provinces in China (Matus, Nam et al. 2012). Therefore, this study aims to forecast and evaluate the long-term economic impacts caused by PM2.5 pollution in 30 Chines provinces and reveal its regional disparity.

Methodology and Results
We develop an exposure-response model that combines the GAINS-China model and a CGE model. GAINS-China provides annual average PM2.5 concentration and air pollution control cost for 30 provinces. Exposure-response model is used to quantify the health endpoint due to PM2.5 pollution, including mortality, chronic bronchitis, asthma, respiratory hospital admission, Cerebrovascular hospital admission, Cardiovascular hospital admissions and work loss day. Work time loss due to mortality and morbidity is the input data to CGE model, which simulates the economic impact of PM2.5 pollution for each province. Results show that PM2.5 pollution will cause national GDP loss of 1.94% and additional health expenditure of 140 billion Yuan in 2030. Provinces with high PM2.5 concentration have high GDP loss (Fig.1), for instance, Tianjin (3.12% loss in GDP), Shanghai (2.81%), Henan (2.71%), Beijing (2.65%) and Hebei (2.57%). By contrast, improving air quality by adopting air pollution control technology could save health expenditure, increase labour supply and bring GDP gain. By considering GDP recovery, health expenditure saving and additional control cost, net benefit is positive for most provinces (Fig.2). Net benefit is 0.80% of GDP in 2030 in China. At the provincial level, the net benefit is positive in Tianjin (2.1% of GDP), Shanghai (2.07% of GDP), Beijing (1.9% of GDP), Henan (1.6% of GDP), Jiangsu (1.6% of GDP), and Hebei (1.2% of GDP), whereas negative in some western provinces such as Ningxia, Inner Mongolia, Guizhou, Gansu and Heilongjiang in 2030.

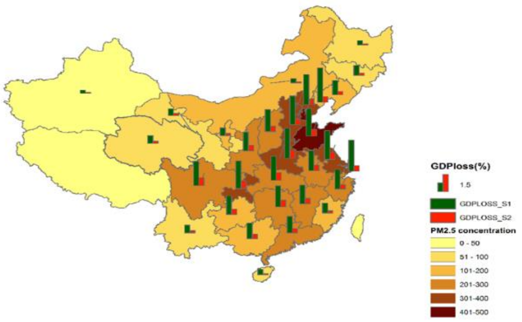

Fig.1 PM2.5 concentration and GDP loss in 30 provinces in 2030

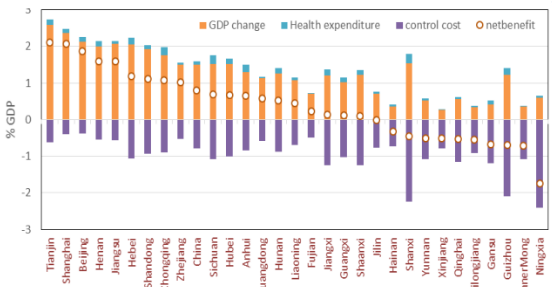

Fig.2 Net benefit of air pollution control technology in 2030

Conclusions
Air pollution control technology can reduce PM2.5 concentration and increase labour supply, thus bring significant positive economic benefit, especially for more developed provinces.

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MEASUREMENT OF AIR POLLUTANTS AND PROCESS STUDIES

OUTDOOR $PM_{2.5}$ AND BC EXPOSURE ASSESSMENT IN URBAN SLUMS OF MUMBAI, INDIA

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Summary
The aim of this study is to assess the outdoor $PM_{2.5}$ and BC exposures in four urban slums of Mumbai and their intra and inter spatio-temporal variations using mobile monitoring technique. DustTrak and microAeth were employed to measure the real time $PM_{2.5}$ and BC concentrations. The $PM_{2.5}$ concentrations are observed to be similar in all of the four slums, whereas BC concentrations show heterogeneity among the four slums, with high concentration observed in three of the four slums which are in the periphery of heavy traffic roads. Multi variable regression analysis shows that type of road and type of slum are the significant predictors of outdoor $PM_{2.5}$ and BC concentrations with the model explaining 71% and 47% variability in BC and $PM_{2.5}$ concentrations, respectively. This study shows that the people living in the slums are exposed to high levels of $PM_{2.5}$ and BC, with the population residing along heavy and medium traffic roads being the most exposed.

Introduction
About 41% of the inhabitants in Mumbai live in slums. Most of these slums are located in the periphery of major traffic highways, railway lines and landfill sites, raising concerns of high air pollution exposures. The disease pattern analysis in various slums of Mumbai shows that 18-45% of the diseases reported are potentially related to air pollution. However, so far no extensive studies have been conducted to investigate the existing levels of air pollution exposures of the Mumbai slum population. Hence the present study was conducted in four urban slums in Mumbai to assess the outdoor air pollution exposures of $PM_{2.5}$and Black Carbon and their spatio-temporal variations both within and between the slums.

Methodology and Results
Eleven days of mobile monitoring were conducted in four urban slums of Mumbai namely Santosh Nagar, Hanuman Nagar, Malwani and Subhash Nagar. In each monitoring trip, a person outfitted with a back pack containing DustTrak for measuring real time $PM_{2.5}$ concentration, microAeth for measuring real time black carbon concentration and a GPS unit, walked along a pre-designed path in each neighborhood. Average $PM_{2.5}$ and BC concentrations were 34±8 μg/m^3 and 5916±3564 ng/m^3, respectively, among all the four slums. $PM_{2.5}$ concentrations exhibited intra and inter-slum homogenous spatial distributions (coefficient of divergence, COD = 0.06-0.2) whereas BC showed considerably heterogeneity (COD range 0.30-0.50). Higher BC concentrations were observed in three of the four slums which are in the periphery of heavy traffic roads. Further analysis shows that the local sources contribute 64% -75% to BC where as it is only 19%-37% for $PM_{2.5}$ concentration which explains the higher within slum spatial variation in BC concentrations compared to $PM_{2.5}$. Multi variable regression models developed to examine the contributions of different exposure predictor variables in predicting the outdoor $PM_{2.5}$ and BC concentrations, show that type of road and type of slum are the significant predictors of outdoor $PM_{2.5}$ and BC concentrations. The model explained 71% and 47% variability in BC and $PM_{2.5}$ concentrations, respectively.

Fig.1 monitoring locations and monitoring routes

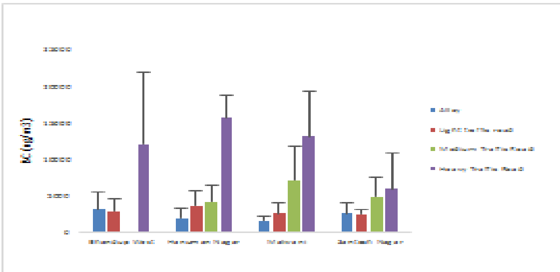

Fig.2 Average BC concentrations in four slums

Conclusions
The study shows that the people living in the slums are exposed to high levels of $PM_{2.5}$ and BC, with the population residing along heavy and medium traffic roads being the most exposed. The extrapolation of these results to all the slums of Mumbai suggests that about half of the city's population is indeed at higher risk regarding air pollution exposures, with the poor ventilation and air tightness of the slum homes raising the concerns even more.

A NEW LONG TERM FINE PARTICLE MONITOR FOR THE URBAN ENVIRONMENT

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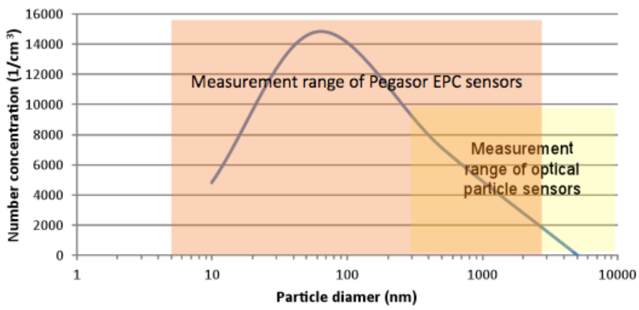
Summary
WHO considers fine particles in our urban air to be one of the most significant threats to human health and yet we still do not monitor them adequately or properly. This paper will describe a new monitor specifically designed to monitor the full range of fine particles on a long term basis, without the use of solvents or radioactive sources; a robust monitor delivering relevant information.

Aerosol charging and electrometry instruments have always suffered from the fact that once they are turned on they immediately begin to degrade towards an all-too-frequent user maintenance interval and so have never been considered as long term monitoring solutions. The Pegasor AQUrban uses electrical particle charging (EPC) but instead of direct electrometry of the charge carried by the deposited aerosol particles, AQUrban measures that charge by difference, comparing the energy output from the corona and the returned energy from unattached air ions. The result is a fine particle monitor that operates for many months with no user maintenance and that sees ALL the fine particles, right down to <10nm instead of only down to c300 nm, the limit of detection of most deployed optical devices.

AQUrban reports mass, number and surface are concentration to Cloud based storage where it can immediately be accessed through many devices including Smart City nets.

Introduction
Aerosol Electrometry is a well established method of aerosol detection and short term monitoring based on the attachment of air ions to the surface of aerosol particles such that the surface becomes saturated before the supply of air ions is exhausted. Corona discharge is used to create an excess of air ions within a flow of clean air which is then turbulently mixed with the sampled aerosol within an air ejector that is used to pull the sampled atmosphere into the sensor. The air ions are highly mobile and very quickly become attached to the sampled aerosol particles. The mixture of aerosol and unattached air ions passes directly through an ion trap that uses an electrical field to remove the unattached air ions to the surface of the trap where the current that is created is measured using highly sensitive electrometers. The aerosol particles, which are much less mobile, pass directly through the ion trap and are returned to the atmosphere. The entire sensor is housed within a Faraday cup to minimise external effects, and can be used to monitor aerosols across a wide range of non condensing conditions.

Methodology and Results
Our investigations of this technology have shown that the lower limit of detection is <10nm. Developments in electrometer design have greatly increased the linear dynamic range of such devices and we have successfully applied this sensor technology to raw vehicle emissions at the tail pipe, as well as to indoor air and urban air applications. Work has been carried out at LAT , University of Thessaloniki which has shown that the charging efficiency is largely unaffected by the chemical nature of the aerosols and that robust extrapolation from surface area, which is the primary parameter of measurement, to both number and mass concentrations is possible. Trial units are on site in a number of European and Asian Cities and we shall be presenting data from these sites in this presentation.



Conclusions
Current methods of monitoring mass concentration of fine particles within urban air are no longer sufficiently sensitive. Recent reductions in mass concentration in our urban air have not been reflected in a corresponding reduction in respiratory health effects. Indeed, the incidence of respiratory disease associated with urban living has gone up whilst mass concentrations have gone down. At the same time, probably as a result of modern abatement technologies, the number concentration of fine particles has risen and has been shown to be a reliable measure and predictor of respiratory disease incidence. Pegasor will demonstrate that their AQUrban fine particle monitor is sensitive to very real changes in fine particle concentration, that are not detected by other technologies

CHAMBRE – THE DEVELOPMENT OF AN ATMOSFERIC SIMULATION CHAMBER AT GENOA UNIVERSITY

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Summary
We present the characterization and first experiments results of the atmospheric chamber ChAMBRe (Chamber for Aerosol Modelling and Bio-aerosol Research) which has been developed and equipped to study the bioaerosol atmospheric interactions, the investigate on aerosol optical properties and to test innovative instruments and methodologies for particulate matter collection.

Introduction
Environmental simulation chambers are small to large-scale facilities where atmospheric conditions can be monitored in real-time under control to reproduce realistic environments and to study interactions among their constituents. Up to now, they have been used mainly to study chemical and photochemical processes that occur in the atmosphere, but the high versatility of these facilities allows for a wider application covering all fields of atmospheric aerosol science. A stainless steel atmospheric simulation chamber (volume approximately 3 m^3, see Figure 1) has been recently installed at the National Institute of Nuclear Physics in Genoa (INFN-Genova, www.ge.infn.it) in collaboration with the Environmental Physics Laboratory at the Physics Department of Genoa University (www.labfisa.ge.infn.it).

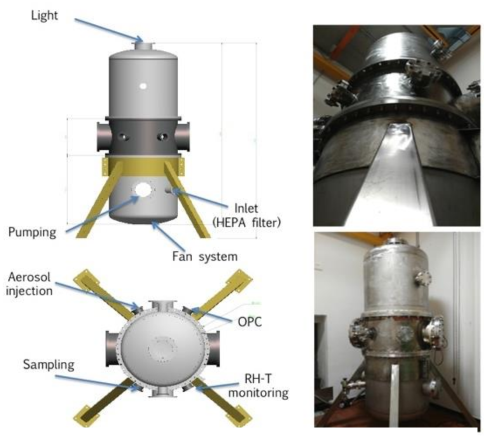

Fig.1 ChAMBRe layout structure and pictures

Methodology and Results
The scientific activities at ChAMBRe focus on the following topics:

1**) Bioaerosol properties**

The biological component of atmospheric aerosol (bio-aerosol) is a relevant subject of science but many of its aspects still require deeper investigation. A strong improvement in the understanding of microorganisms behaviour in the atmosphere can be provided by atmospheric chamber experiments, that allow for a scientific intermediate approach between "in vitro" and "in vivo" analysis. Aerosol with realistic composition, including living micro-organisms, can be injected in artificial environments with controlled physical and chemical parameters and then accurately analyzed. In particular, a systematic approach can be used for a better description of micro-organisms viability, of colonies growing modulation of and other issues relevant to their spread and their pathogenicity. Very promising results in this direction were obtained by the authors at the CESAM facility at CNRS-LISA (Brotto et al, 2015) and will be presented here, while similar results were obtained nearly at the same time at AIDA chamber at KIT (Amato et al, 2015).

1**) Aerosol optical properties – methodologies and instruments testing**

The instrumental development efforts at the Environmental Physics Laboratory of the University of Genoa, recently resulted in a new Multi Wavelength Absorbance analyzer (Massabò et al. 2015) which measure the light absorption on aerosol loaded filters at five wavelengths from UV (absorption bands of organic compounds, mineral dust) to near infrared (carbon soot, ...). Furthermore, a new data reduction methodology has been introduced to disentangle the concentration of Black and Brown carbon in atmospheric aerosol, demonstrating the need to mitigate not only exhaust but also non-exhaust emissions, as a potentially important source of PM10. The atmospheric chamber is an effective tool to produce known aerosol mixtures and to test the performance of the optical technology. Actually, there is an on-going collaboration with the CNRS-LISA team working at CESAM following that procedure.

Acknowledgement
We would like to acknowledge prof. J.F. Doussin and LISA laboratories (http://www.lisa.univ-paris12.fr/en) for providing us part of the chamber structure and for the very useful and fruitful technical discussions

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QUANTIFYING AIR POLLUTION EXPOSURE USING WEARABLE SENSORS AND MOBILE PHONES

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Summary
Quantifying human exposure to air pollutants is a challenging task. In urban areas, air pollution presents a high spatial and temporal variability. At the same time, every individual has unique activity-patterns that will result in a different exposure to air pollution. In this work we explore how new developments in sensor technology (i.e. low-cost sensors, smart phones) can enable us to monitor personal exposure to air pollutants while people are performing their daily activities.

Introduction
Exposure assessment has been defined as "… the process of estimating or measuring magnitude, frequency and duration of exposure to an agent…" (Zartarian et al., 2007). The traditional method of assessing human exposure is to estimate population-wide annual (long-term) or daily (short term) average exposure concentrations, using fixed monitoring networks and air quality models. This type of assessment, operating on aggregated data does not provide a representative measure of an individual's personal exposure as it assumes exposure of individuals to the air pollution levels at their residential address and ignores the impact of individual mobility and activity patterns, especially time spent away from home.
Personal exposure assessment is evolving quickly and latest advances in technology enable the tracking of individuals while simultaneously estimating or measuring pollutant concentrations (Castell, et al., 2014).

Methodology and Results
In this work, we present two methods for monitoring the movement of individuals and assess their exposure to air pollutants during their regular daily routines. The first approach represents a direct exposure from measurements made while the subject is carrying a low-cost air quality sensor and a smart phone while moving through the environment, for example on foot or by bicycle. The data from the sensor is combined with the GPS data to estimate exposure. The second approach is an indirect exposure estimation where the individual only carries a smartphone. The GPS data obtained from the mobile phone is integrated with air pollution data obtained from air quality models to estimate the individual exposure along a given track.
In both approaches the exposure is computed by averaging the concentration along a line segment and multiplying it by the time spent on this segment. Moreover, if we know the heart rate of the individual it is possible to estimate the inhalation rate (ventilation) and asses the inhaled dose over a track. This is important because differences in the ventilation will influence the inhaled doses of air pollution. Zuurbier et al. (2009) shows that ventilation levels of cyclists are on average two times higher than those of bus and car passengers.
Both of the both approaches have been tested in Oslo, Norway. The advantage of using a wearable sensor is that it is possible to capture different micro-environments (e.g. inside the bus, in the office), however data accuracy from low-cost sensors presents a challenge. The advantage of merging the GPS data with an air quality map is that the individual does not need to carry a sensor, making the approach applicable for addressing larger populations. In the second approach, it is also possible to produce exposure estimates over hypothetical routes or routes that the individual plans to take in the future. The main disadvantage is that only outdoor air pollution is estimated and it is not possible to estimate the exposure in micro-environments.

Conclusions
The initial field trials in Oslo indicate that low-cost sensor technologies offer the possibility to enhance existing methods for quantifying exposure to air pollutants. However, the main challenges to using these technologies include precision and accuracy of the low-cost sensors measurements. Results show that the combination of tracking devices (e.g. GPS from mobile phone) and air quality maps can provide an automated system to provide personalized air quality information. The methodology is able to incorporate activity sensors to monitor heart rate for estimating personal air pollution inhalation dosage. This information will be of interest to citizens.

Acknowledgement
CITI-SENSE has received funding from the European Union's Seventh Framework Programme for research technological development and demonstration under grant agreement no 308524.

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PROVIDING VERTICAL GRADIENT CONCENTRATION MEASUREMENTS FOR INTERCONNECTED STUDIES ON AIR QUALITY AND CLIMATE CHANGE

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Summary
The recently built Atmospheric Station (AS) Křešín u Pacova, central Czech Republic, is focused on the background measurement of greenhouse gases, selected atmospheric pollutants and basic meteorological characteristics. The footprint of the 250 m tall tower of the AS covers predominantly western and central Europe. The example of ozone is used to demonstrate the usefulness of automated statistical procedures allowing for easy, fast and especially objective outlier measurement identification during the validation of highly timely resolved concentration data.

Introduction
Air quality, composition and climate change are interconnected research areas as greenhouse gases are often emitted from same sources as air quality parameters. Further, many chemical species are significant players in both climate change and air quality. The environmental fate and cycling of persistent substances is likely to be changed due to climate change and changes in air pollution meteorology in general. Well designed research infrastructures are needed in order to ensure high quality measurement data for such multidisciplinary research.

Methodology and Results
The AS consists mainly of a 250 m tall atmospheric tower and is equipped with continuous gas (CO_2, N_2O, CH_4, CO, O_3, Hg) and particle analyzers, a flask sampling system, meteorological sensors and a ceilometer. The station was built in 2013 and equipped according to the recommendations of the Integrated Carbon Observation System. Air quality measurements follow recommendations of ACTRIS, GMOS, EMEP and GAW. Air sampled at the AS originates predominantly from western and central Europe as calculated by the STILT model (Lin et al., 2003) for individual seasons of the chosen representative year 2011 (Fig. 1). Ozone measurements are conducted by three Thermo Scientific 49i instruments located in air-conditioned racks in 50, 125 and 230 m height on the tower. In order to ensure an objective criterion for identifying outliers in the highly variable measurements, advanced statistics (non-parametric kernel regression, changepoint analysis) were applied to the 1 min measurement data series (Fig. 2) in an automated procedure. Comparison with manually validated data proved it to be a useful tool helping the validator to objectively decide on flagging outlier measurements.

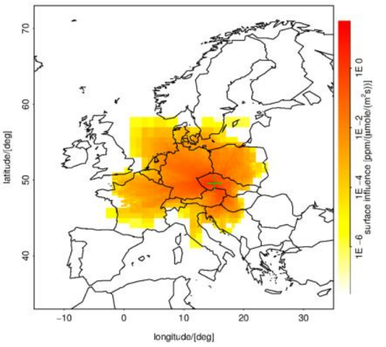

Fig.1 Summer (Jun, Jul, Aug) 2011 footprint of the AS Křešín u Pacova

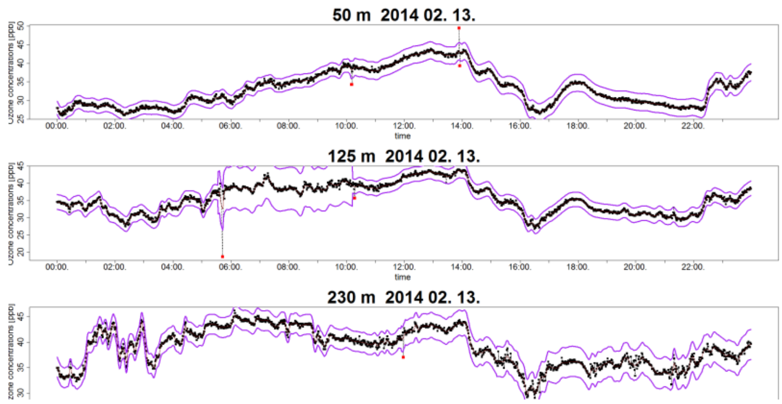

Fig.2 Measurement records of ozone concentrations in three heights on 13 February, 2014 with critical boundaries in blue and red values automatically flagged as outliers

Conclusions
Due to a broad spectra of monitored parameters, production of large unique datasets, ensuring of high quality measurements and vertical concentration sampling design the AS Křešín u Pacova is a suitable infrastructure for conducting multidisciplinary research in both air quality and climate change.

Acknowledgement
This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic within the National Sustainability Program I (NPU I), grant number LO1415.

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MEASUREMENTS OF PM FLUXES AND SIZE SEGREGATED CONCENTRATIONS ABOVE THE CITY OF NAPLES

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Summary

A super-site for the measurement of atmospheric pollutants from urban sources has been established in Naples, Southern Italy, within a project supported by the region Campania (AriaSaNa) targeting a better understanding – through observations and modelling - of pollutants dynamics in the Mediterranean region of Campania, in order to improve support to policy making. In this work the authors will present the results from the first year of activity for the measurements of PM.

Introduction

With a population of circa 4 million (around 1 million within the city), the metropolitan area of Naples(Campania, Southern Italy), has one of the highest densities in Europe, with consequent impacts in terms of emissions associated with diesel/gasoline exhaust, industrial emissions, agricultural burning and waste disposal problem. The area is characterised by complex layout of the coast and surrounding mountains, which favour the development of combined sea breeze upslope winds and the evolution of return flows with several layers of pollutants and subsidence. This study aims at detecting the influence of the different sources of PM on the air quality in Naples.

Methodology and Results

The super-site, located at the meteorological observatory of Largo San Marcellino (NA), consists of an eddy covariance tower on the rooftop of the building: a fast response ultrasonic anemometer (Gill WindMaster) has been mounted on a 10-m mast, alongside three insulated inlet lines through which the air is sampled for reactive, non-reactive gases and particulate. The height of the terrace is on average 35 m above the irregular street level, resulting in an overall measuring height of 45 m. Mixing ratios of CO_2, CH_4 and H_2O are measured by an infrared spectrometer (10 Hz, Los Gatos Research); O_3 mixing ratios are measured by a fast analyser (10Hz, FOS Sextant) for the calculation of fluxes, and referred to concentrations measured by a slower analyser (2B-Technologies, 205). NO is continuously quantified (8 Hz) using an analyser by Eco Physics (model CLD 88p, associated with a photolytic converter PLC 860). Size segregated aerosol are measured by gravimetric method at an hourly/daily frequency through a SWAM 5A Dual Channel (PM10 and PM2.5, FAI Instruments). A faster optical particle counter (4 Hz, FAI Instruments) is set up for the estimate of fluxes - as well as concentrations – of 22 classes of particles diameter. All analysers outputs are synchronised with the ultrasonic anemometer through a common acquisition at 10 Hz using a CR3000 datalogger (Campbell Scientific). A full weather station is also available as ancillary measurements at the site including two webcams to record exceptional events to aid interpretation of the results. During the first year after the installation of the supersite, size segregated particles concentrations and fluxes were recorded. We could observe several events of pollution from separate sources, and found that PM composition is mostly fine particulate: in fact, PM1 explains >70% of PM10 variation.

Fig.1 The EC tower at Largo San Marcellino, featuring the ultrasonic anemometer, the inlet lines for the gasses and the sampling head for PM.

Conclusions

The Largo San Marcellino supersite provided during its first year a continuous dataset for several urban pollutants in terms of concentrations and fluxes.

The dataset allows to explore the effect of seasonality and meteorology for the measured pollutants over the city of Naples, as well as the identification of the main urban pollution sources, presenting different characteristics among road, sea and air traffic.

Acknowledgement

This work was supported by Regione Campania (under the AriaSaNa project). We acknowledge prof. P.Petrosino at the Department of Earth Science of Federico II University, for the usage of the department laboratories, and the kind collaboration.

OPERATION OF A LOW-COST NO_2/O_3 SENSOR NETWORK IN ZURICH: PERFORMANCE ANALYSIS AND APPLICATIONS

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Summary
We engineered together with Decentlab GmbH (Duebendorf, Switzerland) eight NO_2/O_3 measurement nodes. After a three months lasting calibration period, the nodes were deployed in the city of Zurich forming a small sensor network starting in June 2015. Our research focuses on the performance of the individual sensors in terms of calibration requirements, accuracy and long-term stability as well as the development of efficient and effective algorithms for quality assurance and control procedures in low-cost air quality monitoring networks. Moreover, it includes the assessment of urban air quality based on data from low-cost sensors.

Introduction
Recent progress in gas sensor technology has yielded inexpensive devices (~100 $) which are sensitive to ambient pollutant concentrations. This allows the deployment of sensor networks consisting of a large number of nodes (Mead et al., 2013). The usefulness of such networks depends strongly on the value of the information they provide.
We identified two main research questions from this situation:
The first one addresses the generation of routines for the performance analysis of individual sensors w.r.t. calibration requirements, accuracy and long-term stability. In addition, it includes the investigation and development of efficient and effective algorithms for quality assurance and control (QA/QC) within a low-cost sensor network.
The second question focuses on the identification of application fields where dense sensor networks provide additional value compared to existing measurement facilities. These may be found in highly resolved air quality assessment in urban environments and the computation of exposure values. Both applications, however, require a sufficiently high accuracy of the deployed sensors.

Methodology and Results
Decentlab GmbH and Empa engineered eight sensor nodes denoted as Aircubes (box 1: 2 Aeroqual O_3 SM50, GSM module; box 2: 3 Alphasense NO_2 B42F, temperature and humidity; Fig. 1). At first, the Aircubes were operated in parallel to reference instruments at air quality monitoring stations for sensor calibration during 3 months. Since June 2015, they have been operating in a small sensor network in Zurich. The network covers a wide range of urban pollution situations and complements the six air quality monitoring stations in the city of Zurich operated for regulatory purposes by the municipality and the federal authority.
The data from the sensor network is analysed in terms of accuracy and long-term stability of the individual sensors. Algorithms for quality assurance and control within air pollution sensor networks are developed and applied to the data. Such concepts are a prerequisite for minimizing manpower as a substantial cost factor in network operation. Hereby, we make use of the dense reference networks in Zurich which provide accurate information on the pollutant situation in Zurich. Moreover, two-week NO_2 passive sampler measurements at the sensor locations allow a direct assessment of the sensor data. In addition, we present the usability of the sensor data for applications such as the mapping of air pollution concentrations in urban environments (Mueller et al., 2015) focusing on high temporal resolutions (~1h).

Figure 4: Aircube mounted at a utility pole in the city of Zurich.

Conclusions
Dense sensor networks offer a unique potential for air quality monitoring, especially in cities. However, the use of state-of-the-art low-cost sensors within sensor networks requires novel and dedicated routines for sensor calibration and for quality assurance and quality control. Continued operation of the deployed sensor network in Zurich will shed light on the long-term stability of the sensors under field conditions and elucidate the quality of the obtained data and therefore its usefulness for urban air quality assessment.

Acknowledgement
This work was supported by the Swiss State Secretariat for Education, Research and Innovation (SERI) within the COST Action TD 1105 EuNetAir and the Swiss Federal Office for the Environment (FOEN).

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BIOTAIR: BIOFILTRATION FOR ROAD TRAFFIC EMMISSIONS, APPLICATION TO A ROAD TUNNEL

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Summary
The objective of BIOTAIR was to assess the effectiveness and sustainability of biofiltration technology to treat road airborne effluents. To this end, three scale reduced biofiltration devices, have been set up on a platform situated above a road tunnel near Paris. Two of them were supplied with an air stream (1 to 3 m^3/sec) extracted from the tunnel. The two biofilters had a respective substrate thickness of 50 (BF_{50}) and 100 cm (BF_{100}). The third biofilter (thickness of 50 cm) was not supplied with stale air and was assigned the role of the witness. The observation over 18 months and a complete meteorological cycle shows a technique we can consider effective on many pollutants and with a predicted good durability.

Introduction
In order to reduce the impact of road emissions on the air quality in major cities, and to complete the actions on traffic and new requirements on the motors exhaust, the original idea of this project was to adapt a reliable water treatment technology to stale air extracted from a real road tunnel.

Methodology and Results
Four measurements campaigns were conducted on this site over the 18 months During each period of measurements several air pollutants (nitrogen oxydes, particulates, BTEX and ammonia) have been watched using different methods (continuous measurements, passives tubes and samples). The target was to indicate the reduction achieved for each pollutant between upstream and downstream of biofilter. The chemical compositions of water (pH, NO_3-) and soil (Polycyclic Hydrocarbons Aromatics PHA, Total hydrocarbons, metals) were also observed. A monitoring of the development of microbial activity was conducted through analysis of DNA from the ground massive sequencing of 16 S DNA. A Life Cycle Analysis (LCA) completed the study. The results are satisfaying for nitrogen dioxide with an average reduction during the project of 58% by the BF_{50} and 81% by the BF_{100}, (dissolution of this pollutant in aqueous phase) The level of NO_3^- in water is acceptable due to small volumes of water released into the environment. The purification yields observed on particles are satisfying. For the BF_{100} the purifyng rate is 61% for PM_1, 93% for particles between 1 and 2.5µm and 91% for them between 2,5 and 10 µm. Also, for Ammonia and BTEX the yields are at least of 40% high. The monitoring of the solid shows that for all compounds, the values observed after 18 months in the 3 biofilters are similar and at the same order than in the initial substrate. The monitoring of microbial indicate that all factors consider (sampling periods, depths, or substrate thickness) the seasonality is the major influence factor to the structuration of bacterial communities. Moreover, some species or microbial genera well know for they bio-remediation activities were found in the two active biofilters whereas they were not in the witness. Finally the LCA has helped to clearly demonstrate the major impact of electric consumption (80%) compare to the other criteria (construction, water consumption). The double impact of the thickest biofilter compare to the small one was also observed on the three majors categories (impact on human health, depletion of resources, and impact on biodiversity).

Fig.1 Overview of the experimental site with : the shelter receiving the extraction fan module, the pipe carrying the exhaust coming from tunnel, the biofilters fed from below with exhaust air and at the foreground the witness biofilter. On the two actives biofilters the sampling chambers linked with the equipments measurements and in the background stand the water tanks used for the irrigation of the biofilters

Conclusions
All the experimental data allow to conclude that the biofiltration treatment has a real potential to reduce air pollutants from road traffic and a rather good predectible durability. An optimization of design, sizing, and implementation could further significantly strengthen this potential and reduce the consummation of electricity for installation on an entire tunnel.

Acknowledgement
This work was supported by the ADEME (n° contract 1162c0010)

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HOURLY REPARTITION OF HYDROGEN SULPHIDE FROM GAS MEASURE DOWNWIND OF A LANDFILL

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Summary

The main goal of this study is to determine the biogas impact of landfill on surround area. In absence of allowed measurement, we have performed measurements downwind of the landfill position in order to found the point of maximum concentration of the gas tracer H2S. We observed a behaviour revealing the influence of sun energy effect on gas emission. Using the maximum value and the win data, we estimated the emission of the landfill. We obtained the calculated concentration in H2S for the region downwind of the landfill and evaluated the impact of the biogas emit on neighbouring populations.

Introduction

Household and similar wastes are become a real problem in modern society and the increasing quantities requiring disposal led to the use waste incinerator and the open landfill for surplus. The open landfill, with flying plastic bags and biogas emission, creates nuisance for the neighbouring environment and population. The main gases produced by waste decomposition are VOCS (Volatile Organic Compounds) and hydrogen sulphide (H2S). In our study located in Guadeloupe, a Caribbean island, we used hydrogen sulphide as a tracer gas to determine the impact of a landfill over the downwind neighbouring lands.

Methodology and Results

We performed measurements in heigt positions determined along three directions from the center of the landfill to the downwind region (Fig.1). From April to May of 2015, we obtained the H2S concentration values in a range between 0 to 5ppm. For every measurement day, we have observed the maximum value positioned at the same point. The analysis of the daily behavior of the H2S has permitted to correlate the gas concentration levels and the hours. From 0 ppm, in the night, until early morning hours, the H2S concentration is increasing. Taking the value 1 ppm around 5 am, the concentration reaches her maximum value around midday(Fig.2). After, it decreases and returns to 0 ppm just before the sunrise. This belt behavior, due to the H2S waste production, is probably related to the thermal energy delivered by the sun. In absence of available data from the landfill, we have calculated an approximation of the emission value of the landfill with our measures of H2S concentration and the wind data (speed, direction). We find a flux emission of H2S close to 100 kg s^{-1}. We used this value of the landfill emission flux to determine, with the wind data, a hourly repartition of H2S concentration over the neighboring area. With this result we can evaluated the impact on population leaving downwind of this biogas emiting point.

Fig.1 Landfill area and measure points

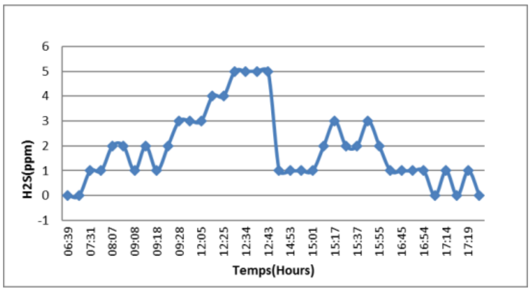

Fig.2 H2S daily behaviour concentration

Conclusions

We find a dependence between sun hours and concentration of H2S downwind of the landfill. The total emission flux of H2S has been evaluated using wind speed and direction, and the maximum concentration in one point. We calculated the hourly impact on neighbouring population.

Acknowledgement

We acknowledge PR Olivier GROS for his help for the measurements on the "Rivière Salée", which performed with the Marine laboratory boat.

LONG-TERM OIAP SPECTROSCOPIC DATASETS, TYPICAL AND ABNORMAL VARIATIONS AND TEMPORAL TENDENCIES IN BACKGROUND AND URBAN CO AND CH_4

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Summary
Goal of present work is investigation of anthropogenic impacts on air quality and atmospheric composition in background and urban regions. The results of regular ground-based spectroscopic measurements of CO and CH_4 atmospheric total content (TC) in Moscow, Beijing, Zvenigorod (ZSS station, Moscow region, 53 km west from the center of Moscow) and the station ZOTTO (Central Siberia) are analyzed. For ZSS the longest in the world measuring data-set of these impurities TC (from 1970 for CO and from 1974 to present for CH4) was analyzed. Regional and local characteristics of CO and CH4 total contents (TC) variability are discussed.

Introduction
Global climate changes always accompanied by regional and local changes in atmospheric composition. The relationships between them especially in urban regions are different for different time-periods and sites. This work continues a series of previous articles devoted to the study of air pollution in different regions of Russia and China (G. Golitsyn at al, 2015, E. Grechko at al, 2009, V. Rakitin at al. 2011).

Results
Several characteristic periods of interannual variations of total CO at ZSS are highlighted: an increase in the 70-80s of last century (0.8%/year), the stabilization in the 80s and a decrease since 2001 (1%/year for winter). The influence of the Moscow metropolis on the CO content at the ZSS was small (Moscow's influence leads to a 10% increase in background columns less than at 5 % of all ZSS measurements number), see Fig.1. The rate of decrease of CO TC Moscow anthropogenic portion is 1.4 % per year for 1992–2014 years in spite of multiple increase of the motor vehicles number. There are no significant changes in CO TC over Beijing during whole period of measurements (1992–2014 years), see fig. 2. Relatively small CO decrease was observed in Beijing in 2006-2014 years comparing with time-period of 1992-2005. AIRS v6 satellite data has demonstrated CO TC stability in Moscow rural region and it decrease over all Chinese regions in 2007-2014 years. The variations of CO in the Moscow region (site ZSS) during the wildfires of summer 2010 and in Central Siberia (station ZOTTO) during the forest fires of 2011 and 2012 were Investigated. It's found that the total content of CO during these episodes of abnormal disturbances exceed 2-5 times the typical background TC. CH_4 content on ZSS increased during the whole observation period (0.5 % / year in 1974-2014). Also some results of validation satellite and ground-based spectrometers for background conditions and diurnal means of CO and CH_4 TC are presented.

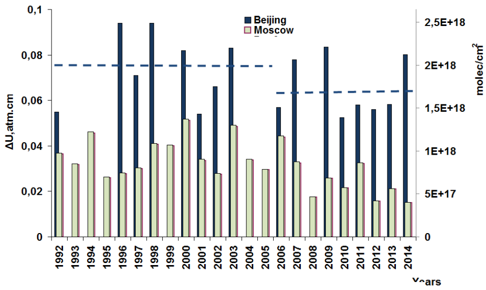

Fig. 1. An impact of different sources on CO TC in Zvenigorod.

Conclusions
Typical levels of atmospheric CO and aerosols pollution in Beijing is 2–5 times stronger in comparison with Moscow ones. Reasonably typical of atmospheric pollution events for Beijing with extreme values of CO TC and aerosols concentrations were observed in Moscow during wild fires of 2002 and 2010 years only. Trajectory cluster analysis using has allowed investigation of location of CO and aerosols emissions sources. Relatively stronger atmospheric pollution of Beijing partially due to the atmospheric transportation from distant industry regions of China located at 100-500 km from Beijing toward south, south-east and east directions. Satellite observations (products AIRS v6 and IASI) demonstrates good agreement with spectroscopic ground-based data in background sites and underestimates CO TC in polluted conditions (wild fires, Beijing region) at 1,5-3,8 times.

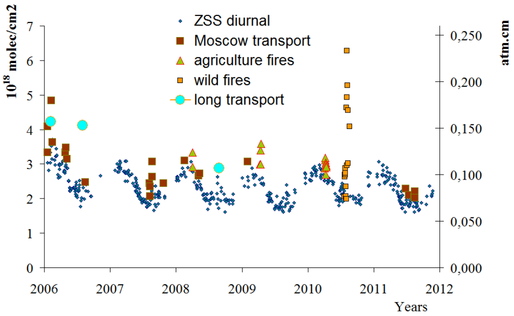

Fig.2. Annual variations in anthropogenic portion of CO TC in Moscow and Beijing

Acknowledgement
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STUDY OF CHEMICAL TRANSFORMATION IN A PHOTOCHEMICAL CHAMBER OF EXHAUST EMISSIONS FROM SMALL BIOMASS BURNNING STOVES

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Summary

Photochemical chamber experiments were conducted to investigate the chemical and physical transformations of secondary aerosol formed from wood and pellet stoves emission. The ozone and particles concentration increase during UV irradiation show that biomass emission are allow to occur, and the amount is depend of the initial NOx and particles concentration inside the chamber. Pellet vs wood comparison shows that secondary particles formation takes more time on the former.

Introduction

Small combustion devices for heating purposes are one of the most important sources of particles in Chilean ambient air. The emission from biomass stoves are an important source in Chile's central and south part, hence there is a big concern about the control's politics to be implemented in the next years. Biomass combustion also emits significant quantities of organic gases and vapours, those are also susceptible to react in the atmosphere and contribute as secondary aerosol. Photochemical chambers offer good way to investigate secondary chemistry details under controlled conditions. Here, chemical transformation of the particle emissions emitted from a pellet and wood stove were investigated on a photochemical chamber.

Methodology and Results

A Dynamic Photochemical Chamber (DPC) was developed by Harvard University. DPC is a Teflon bag-style of 14 m^3 cube-shape, mounted inside of a wooden enclosure. 180 UV lights (340 nm) were used to irradiate the fresh biomass emissions captured inside the chamber. In order to fill the DPC with primary emission a small amount of pollutants coming from pellet and wood stoves (once at a time) was transport directly to the chamber for 5-10 minutes (without any dilution). Pollutants captured inside the chamber were leaved on darkness (UV lights OFF) for 30 minutes to have a homogeneous air inside the chamber. After that, UV lights was turned ON. NOx, CO, Ozone, $PM_{2.5}$, DMPS (differential mobility particle measurement) and ACSM (Aerosol Chemical Speciation Monitor) monitors was used to measure gases and particles transformation. Monitors was always measuring during all chamber process (cleaning, filling, darkness and UV irradiation). During UV irradiation mass concentrations of particles and gases showed very high variability among different experiments. To see ozone concentration increase inside the chamber (Figure 1) it was necessary to reach NOx concentration close to 1 ppm during the filling process. A very high variability in secondary aerosol formation was observed that was proportional to the high amounts of precursor primary emissions concentrations. Secondary particles formation are quenched on very high particles concentration. With the increase of UV irradiation time the secondary particles are growing to higher diameters (Figure 2), composed mainly of nitrates and organics particles. Pellet vs wood comparison shows that secondary particles formation takes more time on the former.

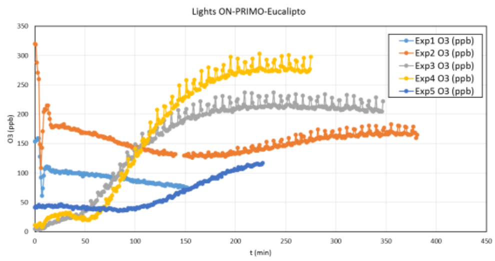

Figure 1: Ozone concentration inside the chamber for five experiment

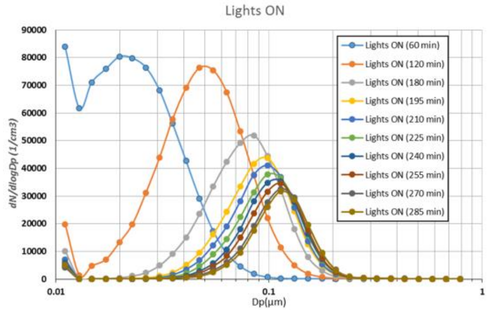

Figure 2: Particle number concentration during UV irradiation.

Conclusions

Secondary particles formation coming from biomass stoves emission occurs a very high NOx emission. With less initial particles concentration secondary aerosol take less time to react, and reach higher values of secondary aerosol inside the chamber. Pellet vs wood comparison shows that secondary particles formation takes more time on the former.

Acknowledgement

We acknowledge to Vehicular Control And Certification (3CV) and Energías del Sur enterprise for the their collaboration in all the experiments.

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HIGH RESOLUTION MAPPING OF THE TROPOSPHERIC NO_2 DISTRIBUTION IN THREE BELGIAN CITIES BASED ON AIRBORNE APEX REMOTE SENSING

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Summary

An algorithm is presented to retrieve tropospheric nitrogen dioxide (NO_2) vertical column densities (VCDs) and to map the NO_2 spatial distribution at high resolution, based on the DOAS analysis of Airborne Prism EXperiment (APEX) observations. APEX, developed by a Swiss-Belgian consortium on behalf of ESA (European Space Agency), is a pushbroom hyperspectral imager with a high spatial resolution and high spectral performance. APEX data has been acquired under clear sky conditions over the three largest and most heavily polluted Belgian cities, i.e. Brussels, Antwerp and Liège, on April 14 and 15, and June 30, 2015. Additionally, a number of background sites have been covered for the reference spectra. The APEX instrument was mounted in a Dornier DO-228 airplane, operated by Deutsches Zentrum für Luft- und Raumfahrt (DLR). The presented work is performed in the framework of the BUMBA project (Belgian Urban NO_2 Monitoring Based on APEX remote sensing), which aims at the validation and improvement of the novel RIO-IFDM high resolution air quality model (Lefebvre et al., 2013). The RIO-IFDM model is developed in order to provide a risk assessment service for air quality and pollution.

Introduction

Nitrogen dioxide (NO_2) is an atmospheric trace gas and a key pollutant that deserves considerable attention as it (1) indirectly affects the climate system, (2) is assumed to be a proxy for air pollution in general and (3) can have a direct health impact. The main anthropogenic sources of NO_2 in an urban environment are industrial and traffic related activities. NO_2 is a pollutant with a strong local character and exhibits concentrations that can be highly variable in space and time. The global scale and coarse resolution of typically several tens of kilometers make spaceborne observations inadequate to detect the small scale variability and to resolve individual emission sources. For the reasons stated, the accurate monitoring and mapping of the NO_2 levels at high spatial resolution are of great relevance.

Methodology and Results

The VCD retrieval algorithm based on APEX spectra, being solar radiation backscattered by the atmosphere or ground surface, consists of the following main steps: (1) spatial aggregation of the observed radiance spectra in order to increase the signal-to-noise ratio (SNR), (2) spectral calibration based on a high resolution solar spectrum (425 - 600 nm) (3) DOAS analysis of the pre-processed spectra in the visible wavelength region (458 nm - 510 nm), with reference spectra containing low NO_2 absorption, (4) air mass factor calculations based on the VLIDORT 2.6 radiative transfer model, accounting for albedo, aerosol and NO_2 profile shapes and viewing and sun geometry, in order to convert slant (DSCDs) to vertical columns, and (5) georeferencing and visualization of the NO_2 spatial distribution in a GIS environment. Preliminary results for a flightline acquired above Antwerp are shown in Fig. 1. The flightline, acquired on April 15 around 11:20 LT under clear-sky conditions and moderate WSW wind (3-4 Bft), covers the Antwerp city center and a small eastern part of the harbor. Clear patterns of enhanced NO_2 can be distinguished with a mean VCD of 2.3 x 10^{16} molec cm^{-2} and maxima up to 6 x 10^{16}. The detection limit is approximately 4.4 x 10^{15} on the slant columns and 2.2 x 10^{15} on the VCD. The observed NO_2 plumes are transported east-northeast from the harbor area, consisting of some heavy industry.

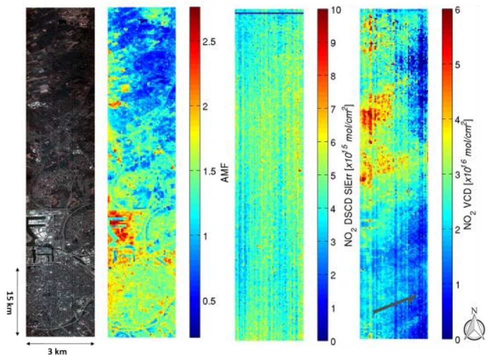

Fig.1 AMF, slant error and VCD for Antwerp flightline 08, acquired on April 15 around 11:20LT

Conclusions

This study demonstrates that the atmospheric NO_2 distribution in an urban environment, and its fine scale variability, can be mapped accurately with high spatial resolution and in a relatively short time frame. For example the Antwerp area (harbor + city center) covering approximately 500 km^2 is mapped in less than 90 minutes. In addition to the increased understanding of trace gas distribution and related chemical processes in urban areas, the outcome of this study is very valuable for the calibration and validation of satellite products, chemical transport models (CTM) and high resolution air quality models.

Acknowledgement

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SPATIAL DISTRIBUTION OF PARTICULATE MATTER AND NO_2 ALONG THE BUSY FEDERAL HIGHWAY B14 IN THE CITY OF STUTTGART - RESULTS OF MOBILE AND DIFFUSIVE SAMPLER MEASUREMENTS

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Summary
For the first time mobile measurements of particulate matter and NO_2 were combined with passive sampler measurements and stationary measurements. The mobile measurements were carried out using a bicycle equipped with measurement instruments along the busy main road B14 with a number of of 80,000 to more than 100,000 vehicles per day. The road leads several kilometers through the city of Stuttgart. The NO_2 / NO_x diffusive samplers in combination with the steady-state measurements were arranged so that both the horizontal and the vertical distribution of concentrations could be measured. To determine the urban background concentrations of some measurements off the main road (in the adjacent park and in the outlying market square) were per-formed.
Summary

Introduction
LUBW (State Institute for Environment, Measurements and Nature Conservation Baden-Württemberg) operate in the local state of Baden-Württemberg a monitoring network to determine the ambient air pollution. Among others so called spot stations are located at highly polluted sites. One station in Stuttgart, the station "Am Neckartor", has attained celebrity in Germany through the last 10 years, because of its high number of exceedances of the limit values of PM10 and NO_2 concentrations.. The measurement station is located right next to the already mentioned, busy main road B14 in the adjacent walkway in about 3 meters from the edge of the roadway. There are only buildings on the road side where the measurement station is located. The opposite road side is open to a park. The city center of Stuttgart is located in the so-called "Stuttgart basin", surrounded by hills of 200 to 300m. Thus the average wind speed in the city is low and the ventilation is inhibited.
The mobile measurements were deliberately carried out with a bicycle rather than with a car, be-cause the bike was moving on the sidewalk, so that the measuring results obtained were comparable with those at the measurement station. The diffusive samplers locations along the road were accordingly (uniform height and uniform distance from the road), so that they were comparable as well.

Results
The results showed a very high spatial variability. For NO_2, the concentrations in the park, which can be considered as urban background level, only 30 to 50% of the measured values directly on the kerbside. The vertical decrease of approximately 3 m as standard measuring height up to 15 m in height (height of the buildings close to the measurement station) also was about 50%. Comparison of PM10 and PM2.5 concentrations on the road with urban background concentrations showed a less striking difference, however was still very clearly measurable. The mobile measurements along the road showed in addition a very large variability, depending on the aeration of the corresponding road sections. At road crossings or larger gaps between buildings in the otherwise almost seamless roadside, the concentrations decreased immediately strong; turn more of NO2 than for PM10 and PM2.5.

Conclusions:
The absolutely highest concentrations were determined at the spot measurement station "Am Neckartor", although there is not the highest traffic numbers and in contrast to other road sections there are buildings only at one sided development Of the road. This unexplained result is currently investigated in a further study, the results of which will also be presented.

BIOMONITORING OF PAHS AND OXYGENATED DERIVATIVES (OPAHS)

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Summary

An analytical method for the quantification of the 16 priority US-EPA PAHs and 12 oxygenated PAHs in *Taxus baccata* leaves was developed and optimized. This is the first method developed, which is able to quantify PAHs and Oxy-PAHs in a plant species during the same analytical run. Emphasis is given to the optimization of the pressurized solvent extraction, clean up using solid phase extraction and high resolution mass spectrometry. The developed method is used to quantify PAHs and oxy-PAHs concentration levels in *Taxus baccata* leaves sampled in Ghent, Belgium during spring 2015.

Introduction

PAHs and their derivatives are widespread in the environment. They are formed during incomplete combustion processes (including both natural and anthropogenic sources). Oxygenated PAHs are also formed by secondary reactions in the atmosphere (Walgraeve et al., 2010). These persistent organic pollutants are harmful for humans and oxygenated PAHs contribute to the generation of reactive oxygen species ROS) in lung cells. In Flanders, mainly non-substituted PAHs are measured on particulate matter samples. The high volume sampling of particulate matter is however expensive, time consuming and labour intensive. An alternative with respect to the conventional techniques is biomonitoring. Hereby, plant species are investigated with respect to their PAHs/oxy-PAHs concentration levels, which are indicative for the pollutant concentrations in the atmosphere. The more volatile PAHs and oxy-PAHs are absorbed, while less volatile PAHs and oxy-PAHs are physically deposited on the plant surface.

Methodology and Results

Pressurized liquid extraction with dichloromethane as extraction solvent was applied. Different PLE extraction temperatures (between 50 and 200 °C) were evaluated. The possibility for in-cell clean up with Florisil was checked. Based the recoveries and matrix effects factors, an extraction temperature of 200 °C using 1 g Florisil in the cell was finally selected as the optimal condition. The clean up was not sufficient and further clean up was necessary. For the purification step, elution over solid phase extraction cartridge (Florisil) was optimised. Different solvents (cyclohexane, dichloromethane) and mixtures were evaluated and breakthrough profiles were obtained. The obtained cleaned up extract was finally analysed with GC-HRMS (mass resolution: 10 000). The mass spectrometer was run in multiple ion detection (MID-mode). This enabled to detect and quantify the compounds with high confidence.

Recoveries of the target compounds were ranging from 29 % to 110 %. Matrix effects were determined and ranged from 60 % to 140 %. The method was applied to *Taxus baccata* samples obtained from several sampling locations (traffic congested sites, background sites) in Ghent. This is the first biomonitoring study in Ghent for PAHs and oxy-PAHs. The concentration levels were in the lower ng/g dw. The presence of significant amounts of Oxy-PAHs in *Taxus baccata* was confirmed. This means that these oxygenated PAHs are important pollutants and should be included in future monitoring studies. Diagnostic ratio's showed the 16 US-EPA PAHs were the result of pyrogenic processes and traffic emissions in particular.

Conclusions

A new analytical method based on high resolution mass spectrometry was developed to determine trace concentration levels in a common plant in the area around Ghent. The different steps in the analytical process were thoroughly investigated and optimized. Recoveries and matrix effects were determined. The final method was applied in a measuring campaign conducted in Spring 2015. The results indicate that oxy-PAHs concentrations are significant when compared with the PAHs concentration levels.

Acknowledgement

This work was supported by the DA grant of Ghent University (UGent).

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SOURCE APPORTIONMENT AND EMISSION MODELS-INVENTORIES

MEASURING LANDFILLS CH_4 EMISSION WITH AIRCRAFT, EDDY COVARIANCE AND CHAMBERS TECHNIQUES

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Summary
We report on the combination of multiple techniques (aircraft, eddy covariance and chambers) to assess CH_4 emissions of several landfills in Italy. Chambers were able to characterize the spatial variability of the continuum of the landfill but not the presence of preferred localized fugitive emissions. The deploying of light aircraft and payloads in remote access areas to characterize large-scale emissions with the presence of multiple sources supported measures in areas not covered by the eddy covariance tower footprint. Landfills emissions where biogas extraction was present were on average an order smaller than landfill without any extraction, demonstrating the benefit of biogas extraction not only in terms of energy production but also of avoided GHGs emissions.

Introduction
Landfills are high emitting hot spots but their contribution to total GHGs budget in Europe is largely unknown (e.g. Bogner et al., 2008). Monitored landfills differ in terms of topography, presence of biogas extraction, age and type of waste, and maintenance, resulting their actual emission to the atmosphere basically not deliverable from inventorial methods. Here, we show the combination of multiple techniques to assess CH_4 emissions of several landfills in Italy.

Methodology and Results
From the one hand landfills emissions can respond on short time-scales driven by controls such as atmospheric pressure and temperature, on the other hand they exhibit high spatial variability that needs to be sampled. We developed an experimental framework capable of integrating measurements at different spatial and temporal scales: (1) cavity ring down spectroscopy (CRDS) coupled with soil chambers (monthly campaigns); (2) open-path CH_4 laser devices on eddy-covariance stations (in continuous); (3) open-path CH_4 laser devices on a SkyArrow ERA (Environmental Research Aircraft) platform to sample atmospheric transport coupled to CH_4 plumes (campaigns).
CH_4 emission measured with eddy covariance were on average 0.49 and 6.34 µmol m^{-2} s^{-1}, while measured with CRDS on the same landfill were on average ten times lower, suggesting that chambers were able to characterize the spatial variability of the continuum of the landfill but not the presence of preferred localized fugitive emissions. Landfills emissions where biogas extraction was present were on average an order smaller than landfill without any extraction, demonstrating the benefit of biogas extraction not only in terms of energy production but also of avoided GHGs emissions (Fig. 1).
Aircraft flights were designed to sample the plumes developing downwind individual landfills, arriving to quantify the emissions of a larger areas with five landfills in Giugliano at an average of 33 µmol m^{-2} s^{-1} (Fig. 2).

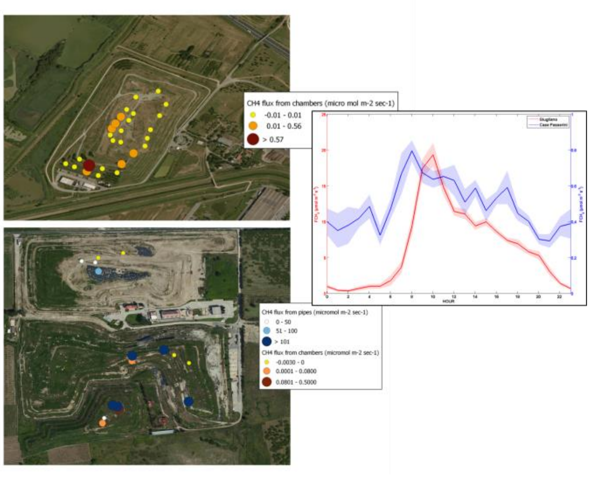

Fig.1 CH_4 emissions detected with chambers and eddy covariance station.

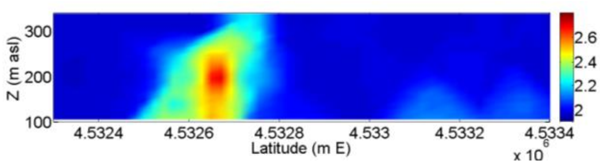

Fig.2 CH_4 emissions detected with aircraft (x=424426.4 m E).

Conclusions
We showed the benefit of deploying light aircraft and payloads in remote access areas to characterize large-scale emissions with the presence of multiple sources, not covered by the eddy covariance tower footprint. The main limitation of aircraft measurements remains the capability to fly very close to ground not sampling part of the plume when flying very close the emission source; this limitation will be overcome with the integration of ground mobile measurements and UAV equipped with low weight sensors.

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COMPARING A NEW GIS-BASED APPROACH FOR CALCULATING AREA-BASED PM2.5 EMISSIONS LOADS WITH RESULTS FROM THE GAUSSIAN AIR POLLUTION DISPERSION MODEL OML-HIGHWAY

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Summary
This study documents a new approach to quantifying pollutant dispersion from road traffic a in a geographic information system (GIS) environment. The method is based on a loaded road network (from a travel demand model) and emissions factors. It aims to provide an easy-to-use tool for estimating emission loads that is more precise than using e.g. traffic density and at the same time less resource intensive than line dispersion models using Gaussian plume equations. The results of this method will be compared to outputs from the Gaussian dispersion model OML-Highway (Danish Centre for Environment and Energy) to enable a relative assessment of the new approach compared to a more involved methodology. The study focuses on the US 50 highway in the Sacramento Area Council of Governments (SACOG, CA) region.

Introduction
Studies relating road traffic emissions to issues such as environmental justice or public health require some measure of the emission load that people are affected by in locations such as their residence or place of education. Proxy measures range from distance to roadways over traffic loads (e.g. vehicles hr^{-1} or annual average daily traffic) to traffic densities (vehicle kilometres travelled – VKT – per areal unit) within and around the land-use units of interests. These approaches require the use of a GIS to calculate spatial parameters and also – for traffic loads or densities - information on vehicle loads of the network. At the other end of the scale of resource intensity and data demand, we find line source dispersion models, which generally rely on Gaussian plume equations. They require additional data on vehicle emissions (from e.g. emissions inventories), background emissions (from e.g. monitoring stations), meteorological conditions and topography (e.g. road widths and elevations or building heights along the network).

While proxy measures are relatively easy to calculate, they do not take into account variations in line source emission rates caused by different traffic speeds and vehicle types, for example. Full-scale dispersion models, on the other hand, provide a more differentiated view of emission loads but come with considerable data demand and require a high level of expertise from their users. Furthermore, not all of these models include a GIS interface thus requiring extra steps to allow an intersection with spatial population data. This study presents an intermediate approach using road network emission loads allocated to land use parcels and comparing these to outputs from the OML-Highway line source dispersion model.

Methodology
The approach presented here uses loaded road network data from the SACOG travel demand model SACSIM and the California Air Resources Board’s Emission Factor Model EMFAC2011 to calculate $PM_{2.5}$ emission loads for land use parcels in grams/1000m² of parcel area as 24 hour totals using the ArcGIS application. The process includes the following steps: (a) calculating line source emission loads for each network segment based on traffic loads and speeds using EMFAC2011 emissions factors for the SACOG region, (b) normalising these loads to network buffer areas, (c) intersecting the buffers with land use parcels and (d) calculating additive buffer loads for each land use parcel or fraction thereof which intersects the network buffers. The OML-Highway Gaussian line source dispersion model is then used to calculated emission loads (in $\mu g/m^3$) for receptors in each parcel found along the US50 corridor in the region. The model runs as an extension in ArcGIS. For further comparison, traffic density in VKT/1000m² will also be calculated as a proxy measure for the parcels concerned.

Appropriate (spatial) statistical methods will be used to assess how closely the results from the three methods are related. Since they provide different units as their outputs, this assessment will focus on the relative variations of the emissions loads at the different receptor locations rather than absolute values. The work is ongoing (e.g. Gaffron & Niemeier 2015) and final results will be presented at the conference.

Applicability
The new method for calculating emission loads from road traffic is intended to serve as an intermediate approach to proxy measures and Gaussian dispersion models. The study will show to what extent the method presented here provides a more reliable picture of emission loads than the proxy measures often used in studies on environmental justice or public health while being less resource intensive than dispersion modelling. Due to lower demand on data input, the new method can be used to study large areas. It can also include non-exhaust emissions, as long as such information is provided by the relevant emissions inventories.

Acknowledgement
This work was made possible by a research fellowship from the German Research Foundation (*Deutsche Forschungsgemeinschaft*).

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MAPPING OF PRIMARY AND SECONDARY AEROSOL IN THE PO VALLEY DURING WINTER

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Summary
In February 2014, the chemical composition of submicron aerosol was simultaneously measured during the PoAir experiment with aerosol mass spectrometers at five sites in the Po valley: three urban background sites (Milano, Bologna, Padova) and two rural background site (San Pietro Capofiume, SPC, and Ispra). The goal of the experiment was to investigate local and regional sources, properties, and spatial distribution of submicron aerosol components and organic aerosol (OA) with high time resolution and, for the first time, at the regional scale in one of the European pollution "hot-spots".

Introduction
More than 20 million people living in the Po Valley are exposed to Particulate Matter (PM) levels well above the limit set by the World Health Organization and by the European Air Quality Directive, especially during the colder season. Most of the policy measures to limit air pollution and reduce pollution health effects focus on urban areas, where the largest fraction of population lives. The aim of this study is to answer the question "Hot spots or the background, which should be the priority for control of PM sources and precursors?", specifically for the Po valley.

Methodology and Results
High Resolution – Time of Flight – Aerosol Mass Spectrometer (HR-TOF-AMS) measurements of non refractory PM_1 (nr-PM_1) were performed in Bologna and Milan, while Aerosol Chemical Speciation Monitors (ACSM) were deployed in Padova and SPC. PM1 was measured gravimetrically (Milan and Padova) and determined from beta attenuation data (Bologna and SPC). Black carbon (BC) was measured with a Multi Angle Absorption Photometer (MAAP) in Bologna, Milano, SPC, and Ispra, while elemental carbon (EC) was measured at Padova with a thermal-optical method. Co-located measurements included NO_x, O_3, off-line polycyclic aromatic hydrocarbons (PAHs), and off-line levoglucosan, as a tracer for biomass burning. The average PM_1 concentration was close to 10 µg m^{-3} in Bologna, SPC and Ispra, and about 25 µg m^{-3} in Padova and Milan. PM_1 chemical composition (Figure 1) was quite similar across the basin, showing a slightly larger contribution of BC at the urban sites, due to the proximity of traffic emission sources. Ammonium nitrate aerosol accounted for up to 50% of PM_1. The large emissions of nitrogen oxides, mainly from traffic, and of ammonia, from agricultural activities, are responsible for the elevated concentrations of ammonium nitrate across the basin. OA accounted for 33-44% of PM_1. OA sources were identified using the multi-linear engine (ME-2) algorithm (Paatero, 1999) implemented with the toolkit SoFi, developed by Canonaco et al. (2013). Depending on the site, we identified up to three primary OA sources, i.e. hydrocarbon like OA (10-20% of OA), biomass burning OA (14-36% of OA), cooking OA (5% of OA), and up to two different types of oxidized OA (OOA1 and OOA2), proxy of secondary/processed organics. OOA accounted for the largest fraction of OA (52-63%), highlighting the relevance of secondary organic aerosol (SOA).

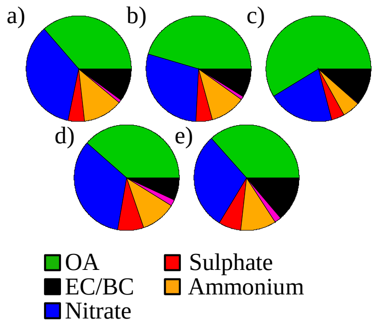

Fig.1 Campaign average PM_1 chemical composition at (a) Padova, (b) Milano, (c) Ispra, (d) SPC, and (e) Bologna.

Conclusions
Secondary aerosol dominate over primary aerosol components. Effective air quality measures should aim at reducing PM precursors and should focus on urban, as well as rural emissions.

Acknowledgement
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ESTIMATION OF THE CONTRIBUTIONS OF INDUSTRIAL AND RESIDENTIAL COMBUSTION SOURCES TO THE PM_{10}, $PM_{2.5}$ AND B(A)P LEVELS OVER THE APULIA REGION (SOUTHERN ITALY)

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Summary

The objective of this study was to evaluate the contributions to the PM_{10}, $PM_{2.5}$ and B(a)P levels over the Apulia region (Southern Italy) of a large steel plant, a very powerful coal fired plant and of biomass burning for residential heating. The corresponding contributions were estimated using the photochemical FARM Model. The results of the simulation indicate that contribution of biomass burning is more relevant than those originated by steel and power plant activities.

Introduction

The results of air quality simulations, performed over the Apulia region for the 2013 year, and the experimental data collected by the regional monitoring network evidence exceedances of EU air quality standards for PM_{10}, $PM_{2.5}$ and B(a)P in some small towns, located in the Salento peninsula, having an agricultural vocation. According to the emission inventory, the most relevant sources in this area are the largest steel plant in Europe (Taranto area), the second most powerful coal fired plant in Italy (Brindisi area) and biomass burning for residential heating. In order to plan the most appropriate measures to improve the air quality in these areas , it is therefore necessary to identify the actual contributions of the mentioned pollutant sources to PM_{10}, $PM_{2.5}$ and B(a)P concentrations.

Methodology and Results

The modelling assessment over Apulia Region has been carried out for 2013 with a modelling system based on the Flexible Air quality Regional model (FARM, Mircea et al., 2014). FARM implements the SAPRC99 gas-phase chemical mechanism and the AERO3 aerosol module derived from CMAQ model. Simulations have been performed on a 316 km x 248 km domain covering the entire region with 4 km grid spacing. The emission data were derived from the regional INEMAR inventory, updated to the year 2013, while the emissions from the neighbouring regions were taken from the Italian official inventory. Meteorological fields came from RAMS prognostic model (Cotton et al., 2003), while boundary conditions have been provided by FARM simulations performed at national scale. The comparison between the baseline simulation and the experimental data, provided by the regional monitoring network, evidenced the capability of the modelling system to reproduce the PM_{10}, $PM_{2.5}$ and B(a)P levels across the region and suggested its use for further source apportionment studies. Three emission scenarios have been considered in which the emissions respectively from biomass burning for domestic heating, the steel plant and the coal power plant were turned off. Figure 1 shows the contributions of these sources, highlighting the relevant contribution of biomass burning for domestic heating to the PM_{10} annual mean concentrations.

Contribution (%)	PM10	PM2.5	B(a)P
biomass burning from domestic heating	49.2	54.8	98.9
steel plant	9.3	12.4	10
coal power plant	7.4	4.7	1

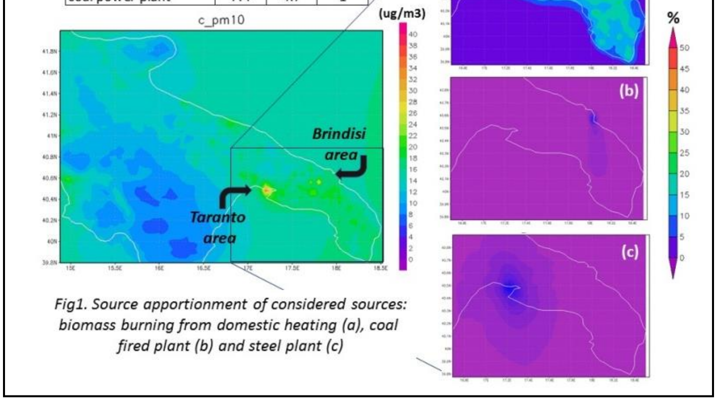

Fig1. Source apportionment of considered sources: biomass burning from domestic heating (a), coal fired plant (b) and steel plant (c)

Conclusions

In this study the FARM photochemical model has been applied to investigate the impact of important emission sectors to the PM_{10}, $PM_{2.5}$ and B(a)P pollution over Salento Peninsula. This source apportionment study evidences that the contribution of biomass burning from domestic heating is locally more relevant than those from the coal power plant and the steel plant activities. According to this study, actions to reduce the emissions from biomass for residential heating represent an essential control strategy aimed to improve the air quality within the Region.

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IMPROVED MODELLING OF AMMONIA BY USING MANURE TRANSPORT DATA

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Summary
In this work, the use of manure transport data as a proxy for time profiles of ammonia emission from manure application was explored. Manure transport data reflect national regulations as well as meteorological conditions influencing temporal manure application patterns. We used manure transport data from Flanders (Belgium) to derive the emission variability of emissions from manure application. This, combined with improved temporal variability for livestock housing and mineral fertilizer based on Skjøth et al. (2011) strongly improves model performance for ammonia in north western Europe, mainly by a better representation of the spring maximum. The impact on model performance for secondary inorganic aerosols (SIA) is negligible.

Introduction
Accurate representation of ammonia emission patterns from agriculture in chemistry transport models (CTMs) is important for the evaluation and prediction of particulate matter episodes. The temporal variability of ammonia emissions from manure application is currently not well represented in CTMs. In this study we examine the use of Flemish manure transportation data to model the temporal variability in ammonia emissions from manure application and assess the impact on model performance for ammonia and SIA for CTM LOTOS-EUROS.

Methodology and Results
Manure transportation data were used as a proxy to estimate the variability in ammonia emissions from manure application in Flanders. Figure 1 shows the amount of manure transport reported on a daily basis for 2008. Substantial differences in temporal pattern between years are observed. Air quality simulations for north-western Europe for the period 2007-2011 were performed with the CTM LOTOS-EUROS (Schaap et al., 2008) at 7x7 km^2 resolution. A simulation using the standard time profiles in LOTOS-EUROS was compared to one in which updated time profiles for ammonia emissions from mineral fertilizer and livestock housing (Skjøth et al, 2011) we implemented, as well as the updated profiles for manure application based on manure transport data. Model performance was evaluated using two-weekly passive sampler data from 20 locations in Flanders.
Model performance for ammonia improved by using meteorologically dependent temporal variability for ammonia, which is reflected in smaller bias and 15-20% higher temporal correlation for all stations (Figure 2). Both improvements in temporal variability (livestock housing/fertilizer, and manure application) are important to increase the agreement between model and measurements. The comparison of modelled and measured (Vercauteren et al., 2011) SIA components did not show a significant difference between the model runs.

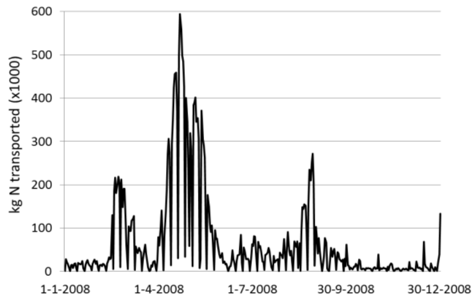

Fig.1 Temporal variability of manure transport in Flanders in 2008

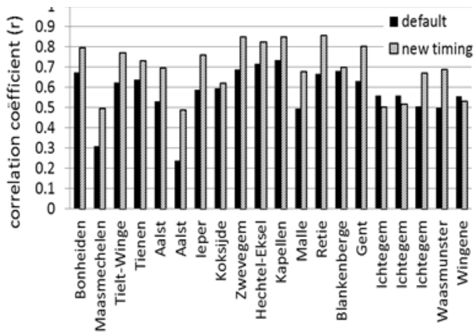

Fig.2 Temporal correlation modelled and measured ammonia concentrations for stations in Flanders

Conclusions
Using meteorological dependent temporal variability of ammonia emissions from agriculture strongly improves ammonia modelling. Although the use of manure transport data as proxy for emissions from manure application comes with quite large uncertainties and simplifications, it is a good starting point to improve representation of temporal variability of this source.

Acknowledgement
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EMISSION FACTORS FROM RESIDENTIAL BIOMASS HEATING SISTEMS

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Summary
The direct measure of the emission factors from different specific sources is of fundamental importance in the field of source apportionment for atmospheric PM and other pollutants, mainly where a large variability is reported in the literature and when the technological evolution rapidly changes these factors.
This study, financed by EU INTERREG ALCOTRA AERA project, provides important emission factors of total PM, Non-methanic volatile organic compounds (NMetVOC), polycyclic aromatic hydrocarbon (PAH) and nitrogen oxides (NOx) generated by three different automatic heating systems (a pellet stove, PS, a 25kW boiler, boiler25 and a 100kW boiler, boiler100) fed with two types of fuels: certified pellet and non certified pellet. All the tests are performed in a laboratory test rig.

Introduction
Biomass combustion, mainly when associated to small scale domestic appliances, is one of the main recognised sources of PM and other pollutants in many areas of Europe including Alpine valleys and the north part of Italy and it is responsible for huge outdoor pollution as pointed out in several publications as the recent document published by WHO on "Residential heating with wood and coal" (2015). In addition wood combustion produces volatile organic compounds (VOC) with a high content of various toxic and carcinogenic compounds such as PAH (Ravindra et al., 2008) and dioxins (Lavric et al., 2004). Many different kinds of heating appliances and many different kind of wood fuels are used; the large variation in the technical characteristics of the former and in the properties of the latter influence vary much the actual emission produced. These pollutants emission factors strictly depend on the fuel quality and the type of appliances. For this reason specific emission factors for the different pollutants released in the different combination of technologies and fuels are very important to predict the impact of biomass heating systems on the local air quality.

Methodology and Results
Appliances at different scale ranging from a pellet stove 9 kW to a 100kW boiler fed with two types of fuels: certified pellet (CP) and non certified pellet (NCP) are tested in a laboratory test rig.
The boilers and the stove have been operated at their maximum output for a time long enough to reach their steady conditions before testing.
The NMetVOC and NOx have been measured in the flue gases by means of continuous automatic analysers based on FID and chemiluminescence detection techniques respectively. PM has been sampled on plane quartz fibre filters and gravimetrically determined. The Benzo(a)Pyrene (B(a)P) has been determined on the PM fraction, in the gas phase using PUF sorbent and in the condensed phase.

	NMetVOC mg/MJ	NOx mg/MJ	PM mg/MJ	B(a)P µg/MJ
Boiler100CP	3.0	54.3	8.5	0.005
Boiler100NCP	2.3	108.5	23.9	0.023
Boiler25CP	4.5	77.7	22.3	0.208
Boiler25NCP	8.5	120.4	28.8	0.218
PS9CP	2.2	43.0	10.4	0.322
PS9NCP	3.7	59.6	56.8	0.113

In the table the emission factors previously described are reported.

Conclusions
Certified pellet has shown better performances in terms of NMetVOC, NOx and PM in most cases, while a clear correlation with the pellet quality for B(a)P is not evident. The largest boiler shows a very good performance in terms of low B(a)P emissions, compared to the others, while for the other pollutants not any evident difference is observed for these automatic appliances. The study highlights the major effect of fuel quality for appliances having a similar technology even if the scale is different

Acknowledgements
The study has been founded in the framework of EU INTERREG ALCOTRA AERA project

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EMISSIONS FROM SHIPS IN PORTS

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Summary

This study aims at quantifying the emissions from ships in ports, in particular for those times when the ships are at berth and use their own auxiliary engines to provide heat and electricity to the ship. These emissions can make up a considerable amount of a city's total emissions, in particular for nitrogen oxides and particulate matter. However, they are rarely considered because they are difficult to quantify. The method presented here is based on a survey on board of 195 ships visited in 5 North Sea ports. It gives size dependent fuel use functions that can be further used to draw spatially resolved emission maps for ports. These maps may serve as input data for city scale air quality model systems.

Introduction

Ships emit considerable amounts of pollutants, not only when sailing, but also during their stay at berth. This is of particular importance for harbour cities because ship emissions can contribute a lot to regional air pollution and to the problem that some of the EU standards (for PM and NO_2) cannot be met there. It is difficult to estimate the emissions from ships in harbours only from the technical specifications of the ships because their activities are not well known. We made a survey on board of almost 200 ships in 5 different harbours in the North Sea region in order to get more information about the fuel use in auxiliary engines and boilers. This approach follows an idea from Hulskotte and Denier van der Gon (2010).

Methodology and Results

The survey that was handed to the captain or chief engineer of the ship contained questions about the ship's specifications, the engines on board, the type and amount of fuel used and the time the engines were run while the ship was at berth. It was also asked if the fuel was burned in boilers to produce steam or in generators to produce electricity. The data was then grouped by ship category and ship size. These parameters are most frequently available from port authorities in their arrival and departure lists and can therefore later be used to estimate the ship emissions in a certain harbour without further knowledge about the individual ship characteristics.

The ships were visited in the harbours of Antwerp, Bergen, Bremerhaven, Hamburg and Rotterdam (Hulskotte et al., 2013). The evaluation of the survey resulted in functional relationships between ship size and fuel use per hour at berth for each ship type. For most ship types the number of ships that were surveyed was still small (around 20 ships), therefore a linear regression was the main method to derive this relationship. Container ships could best be represented by a power law that better represents the small ships. For cruise ships, the data base was too small, therefore typical numbers for the energy demand per passenger and a relation between number of passengers and ship size were used to derive a comparable function.

The results of the survey have been combined with arrival and departure data from different harbours in the North Sea area to calculate the fuel consumption of ships at berth. These values were divided into auxiliary engines and boilers. Combined with emission factors for the most important species NO_x, SO_2, CO, CO_2, hydrocarbons (VOC), and PM, the total emissions of ships at berth were calculated. The emission factors were derived from test bed measurements of about 430 different engines that were evaluated by Germanischer Lloyd within the Clean North Sea Shipping project (CNSS, 2014).

Finally, the emissions from ships entering and leaving the harbour were also taken into account. They were spatially distributed according to the route the ship took inside the harbour area. A software has been developed that displays the annual emissions on a 250 m x 250 m grid. These emissions can serve as input for city scale air quality model systems.

Conclusions

Emissions from ships in ports can be a significant fraction of the total city emissions in some harbour cities. Their estimation is difficult because the activities of ships at berth are not well known. The approach presented here relies on a survey on board of almost 200 ships in 5 North Sea harbours. It gives size dependent relationships of the average fuel use per hour for 9 different ship types. The data was used to calculate annual port emissions in the ports of Antwerp, Rotterdam and Hamburg. For Antwerp and Hamburg, arrival, departure and manoeuvring of the ships inside the harbour were considered in addition to construct spatially highly resolved emission maps for the harbour area.

Acknowledgement

This work was supported by the European Research and Development Fund within the INTERREG IV B North Sea program in the project Clean North Sea Shipping.

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HIGH RESOLUTION EMISSION ESTIMATION IN A HEAVILY TRAFFICKED URBAN AREA IN MADRID (SPAIN)

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Summary
This work aims to obtain high resolution NO_x and PM_{10} emissions related to traffic activity at a hot-spot in Madrid (Spain). For that, twelve representative scenarios for a heavily trafficked roundabout are simulated with the traffic microsimulation model VISSIM. Measured traffic data (fluxes and fleet composition) are used as input for the model to obtain speed-time profiles for each vehicle. These profiles are used to predict representative emission factors for different vehicle classes in the VERSIT+$_{micro}$ model, through the ENVIVER interface. The emission factors are compared with the ones of COPERT IV, a widely used average-speed model, as a preliminary model assessment. The results are strongly influenced by low average speeds due to saturated traffic situations.

Introduction
Since pollution levels exceed the legal limits in specific traffic-related urban locations it is necessary to develop emission reduction measures on hotspots and highly contaminated micro-environments mainly in urban areas where traffic represents one of the major contribution to emissions (Borge et al., 2012). On these specific points finer-scale tools are needed because of the complexity of the processes that determine emissions from mobile sources (Borge et al., 2014). Therefore, there is a need to test microsimulation models that may reproduce with great detail traffic activity in small areas and may provide reliable emission to find out abatement options and to feed CFD microscale air quality models (Santiago et al., 2013).

Methodology and Results
The selected study area is Fernández Ladreda square, a roundabout with complex geometry, high traffic flow and a freeway crossing through a tunnel in Madrid. An intensive field campaign with cameras was carried out to obtain accurate traffic data. Twelve representative 1-hour length scenarios from a weekly pattern are selected and simulated with the VISSIM model. The data for the speed-time profiles are introduced in the emission model VERSIT+$_{micro}$ and the different vehicle classes are assigned, all through ENVIVER interface. The main results are twelve emission distributions with a resolution of 5m x 5m aggregated to 1-hour and also the total emission in the area for the different traffic scenarios. The emission distribution results of NO_x and PM_{10} are influenced by average speeds of the road section which is affected by traffic intensity and congestion. Scenarios with low traffic intensity (Fig. 1) show fluid traffic conditions presenting emissions in specific zones with low speeds. This methodology is validated comparing the emission factors with the ones of the average-speed emission model COPERT IV.

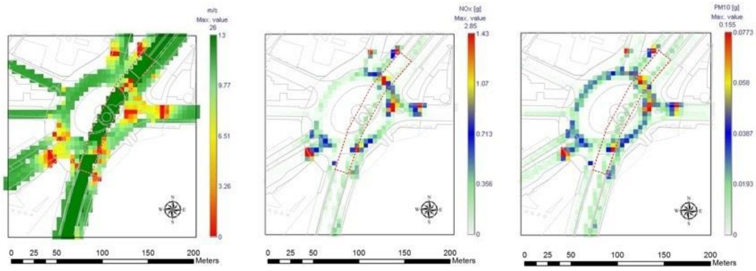

Fig1. *Average speed, NO_x and PM_{10} emission distribution for free flow conditions*

Conclusions
A suitable combination of traffic and emissions micro-simulation models is needed to accurately define the emissions in a specific area. The results obtained from this methodology are in agreement with the ones of COPERT IV and are promising as inputs for CFD models that may be used to design and test microscale air quality abatement measures.

Acknowledgement
This work was funded by the Madrid City Council under the project TECNAIRE (S2013/MAE-2972). The traffic modelling system VISSIM was made available by PTV Planung Transport Verkehr AG and the emission modelling system VERSIT+$_{micro}$/ENVIVER was made available by TNO.

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MAX-DOAS MEASUREMENTS OF SHIPPING EMISSIONS

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Summary

This study aims to analyse the influence of shipping emissions on the coastal air quality by evaluating ground-based remote sensing measurements using the MAX-DOAS (Multi Axis Differential Optical Absorption Spectroscopy) technique. Within the scope of the MeSmarT project (www.mesmart.de), measurements of the atmospheric trace gases nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) have been carried out in the marine troposphere at the measurement sites in Wedel and on Neuwerk and on-board several ship cruises on the North and Baltic Sea. This study shows long term evolutions as well as single ship measurements.

Introduction

Shipping traffic is a sector that faces an enormous growth rate and contributes substantially to the emissions from the transportation sector, but lacks regulations and controls. Shipping is not enclosed in the Kyoto Protocol. However, the International Maritime Organization (IMO) introduced sulfur limits for marine heavy fuels, nitrogen oxide limits for newly-built ship engines and established Emission Control Areas (ECA) in the North and Baltic Sea as well as around North America with the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78 Annex VI). Recently, on the 1st of January 2015, the allowed sulfur content of marine fuels inside Sulfur Emission Control Areas has been significantly decreased from 1.0% to 0.1%. However, measurements of reactive trace gases and the chemical composition of the marine troposphere along shipping routes are sparse and up to now there is no regular monitoring system available.The project MeSmarT (measurements of shipping emissions in the marine troposphere) is a cooperation between the University of Bremen, the German Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH) and the Helmholtz-Zentrum Geesthacht. To estimate the impact of shipping emissions on the atmospheric boundary layer chemistry, elevated signals (ship emission peaks) as well as background concentrations of shipping-related trace gases and particles are monitored with various methods like in-situ measurements (Kattner et al., 2015) and remote sensing.

Methodology and Results

Here we present MAX-DOAS observations of NO_2 and SO_2 carried out from two permanent sites close to the Elbe river (Wedel, Germany) and on the island Neuwerk close to the mouths of Elbe and Weser river and on-board several regular monitoring cruises of the BSH in the North and Baltic Sea since the year 2013. Mixing ratios of both trace gases have been retrieved using different approaches (pure geometric and taking into account the radiative transfer) and compared to in-situ observations, showing the advantages and disadvantages of both methods. Single day measurements show emission peaks which can easily be allocated to the plumes of single ships. The capability of two-channel MAX-DOAS systems to do simultaneous measurements in the UV and visible spectral range has been used to derive spatial distributions of ship emissions and to analyse the movement of the exhausted plumes. Furthermore, simple approaches have been used to calculate emission factors of NO_x and SO_2 for single ships and have been compared to recent studies. Long term time evolutions have been evaluated to show the impact of recent sulfur emission regulations on the measured SO_2 pollution levels. The wind direction dependence of the measured trace gas concentrations has been analysed to quantify the fraction of shipping emissions on the overall emissions and to identify additional sources of background pollution coming from the coast. Moreover, a comparison of the measured concentrations with the model results of the chemistry transport simulations done by the Helmholtz-Zentrum Geesthacht is shown.

Conclusions

MAX-DOAS measurements of the reactive trace gases NO_2 and SO_2 in the marine boundary layer at our MeSmarT measurement sites can be used to evaluate the influence of shipping emissions on the local air quality. Single day measurements can be used to analyse the composition, spatial distribution and movement of emission plumes that can be allocated to single ships. Long term evolutions in the whole time series of measurements since 2013 show the wind direction distribution of the measured pollution levels and the impact of sulfur emission regulations on the measured SO_2 concentrations.

Acknowledgement

The research project which facilitated the reported study was funded in part by the German Federal Maritime and Hydrographic Agency and the University of Bremen. The authors thank the Waterways and Shipping Office Hamburg for their help and support.

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URBAN METEOROLOGY

THE EFFECT OF GEOMETRY MODIFICATION ON THE CONCENTRATION FIELD IN AN URBAN ENVIRONMENT

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Summary
Changes in the city structure have an effect on the transport and dispersion of contaminants in an urban environment. Wind tunnel measurements were carried out to identify the impact caused by the modification of building geometry in the model of Hamburg inner city. Results show that geometry simplification and modification has an effect on the concentration field.

Introduction
Numerical modelling is widely used to predict transport and dispersion in urban areas (Lateb et al., 2015). However, the city geometries considered by the models are simplifications of the full scale building structure. The simplification is due to the low resolution of the input data and the discretization of the modelled fluid volume.
The city structure is never static, it changes constantly due to construction works. Buildings are destroyed or modified and new ones are erected. The changes in the city geometry have an effect on the dispersion characteristics.

Fig.1 Wind tunnel model of Hamburg inner city

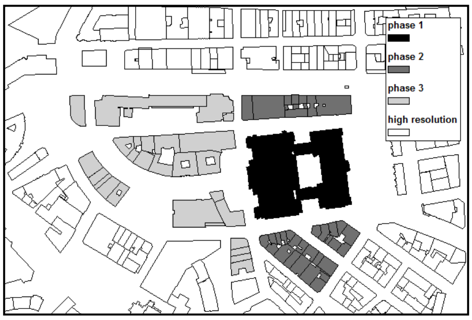

Fig.2 Phases of geometry simplification

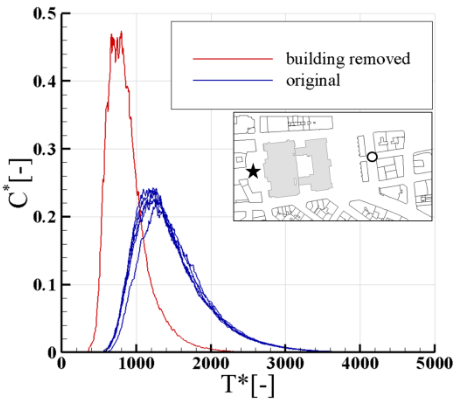

Fig.3 Concentration time series resulting from puff releases. The building removed is indicated with grey. A star represents the source and the measurement point is marked with a circle.

Methodology and Results
Boundary-layer wind tunnel measurements were carried out to quantify the effect of city geometry changes and simplifications on transport and dispersion phenomena (Fig. 1).
Buildings in a 1:350 scale high-resolved model of Hamburg inner city were substituted by Level of Detail 1 (LoD1) geometry. The LoD1 buildings have flat roofs and the outline is defined based on digital field map measured by airborne laser scanning.
The buildings replaced by LoD1 models are highlighted on Fig. 2. With each phase, the number of simplified buildings increases in the model.
A further test case was measured, where one building was entirely removed from the high-resolution geometry.
Measurement gas was emitted from ground-level point sources in and near the investigated area. Concentration resulting from continuous and puff releases was measured with high temporal resolution.
The results show that geometry simplification has an effect, if the source and the measurement point are located near the modified buildings.
When a building is removed from the city structure, significant differences arise in the concentration field. Fig. 3 shows puff results measured in the original city structure and in the model, when one building was eliminated. Not only the peak concentration and the dosage, but the arrival time and the duration of the puff are changing (Berbekar, et al., 2015). The differences are significantly higher, than the repeatability of the results.

Conclusions
Simplified geometry is considered, when modelling the transport and dispersion numerically in an urban area. Geometry simplification has an effect, if the source and the measurement point are located near the modified buildings.
The structure of a city is constantly changing. The elimination of a building has a significant effect on the concentration field, even if the emission is not in the direct vicinity of the removed structure.

Acknowledgement
The financial support of the *Behörde für Inneres und Sport* in Hamburg is gratefully acknowledged. The authors would like to thank Gopal Patnaik from the Naval Research Laboratory for the fruitful discussions.

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ON THE ASSESSEMENT OF THE DRAG FORCE DUE TO CUBE ARRAYS EXPOSED TO DIFFERENT BOUNDARY LAYERS

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Summary
This paper presents an analysis of drag force wind tunnel measurements pressure distribution obtained from CFD simulations over idealized cubical building arrays for two different conditions of boundary layer and three wind velocities. The aim of the research is to study the variation of the drag force within a large range of building packing density (the planar area index λ_p ranges from 0.028 to 1) by using the standard load cell method that is novel for this type of applications.

Introduction
In the urban environment settlements are exposed to different approach flows due to different surroundings. The surroundings may vary from a gradual transition from the rural area to the urban area to an abrupt change from the rural to the urban area. There are various methods for determining the drag force on a settlement. Indirect methods are based on data retrieved from the velocity above the obstacles. These methods require the existence of a constant-stress layer which gives rise to a logarithmic velocity profile which is not always the case (Conceal and Belcher, 2004). One direct method is using a balance (e.g. Zaki et al., 2011), which is considered suitable to provide an accurate measurement of the spatially-averaged drag force for an array.

Methodology and Results
The aim of this study is to present wind tunnel measurements of the total drag force recorded with the standard load cell method (direct method), that is novel for this type of applications (Fig.1), for city-like ideal objects located in an environment with an abrupt change from the rural to the urban environment. The measurements were performed for two types of boundary layers (with and without upstream roughness elements) and three wind velocities (which correspond to different revolutions per minute RPM of the fan that drives the wind tunnel) and for a large range of packing densities, from λ_p = 0.028 representing a rural area to the upper limit where the whole lot is covered by one single building (λ_p = 1). Results are combined with pressure distribution at building height estimated by means of Computational Fluid Dynamics (CFD) simulations.

Results show that at lower packing densities the drag force can be expressed as the sum of the drag force of the individual buildings generating an isolated roughness flow. The force increases with increasing packing density and reaches its maximum value at λ_p = 0.25. From this maximum value and further on there is a slight decrease until it becomes almost constant. The force is no longer proportional to the number of the buildings due to the wake interference or skimming flow occurring at larger packing densities. Instead the array starts to behave as one single unit and the drag distribution results in a higher value recorded at the windward side of the array (see Fig.2 for preliminary results).

Shear stress (total force/total surface area) and the corresponding friction velocity are also estimated and discussed. The drag force due to the cubes is finally parametrized using the canopy-drag length scale and results are discussed.

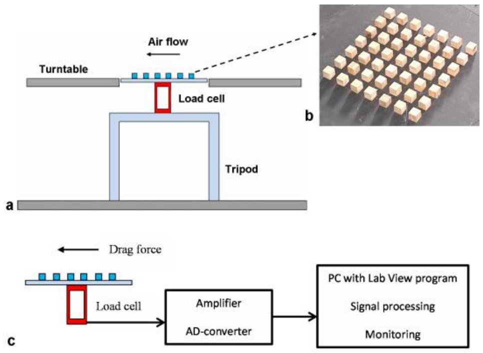

Fig.1 a) Side view of the drag force measuring principle. b) Picture showing an example of the array built in the wind tunnel and attached to the circular disc. c) Block diagram of drag force measurement system

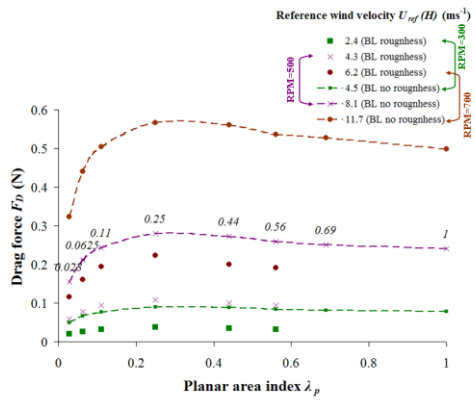

Fig.2 Drag force F_D (N) as function of the planar area index λ_p for the different RPM

Conclusions
An experimental investigation of the drag force acting on surfaces of arrays of cubical buildings characterized by different packing densities is presented. The total drag force acting on the array was measured in wind tunnel. The effect of building packing density on the drag force, estimated shear stress, friction velocity and canopy-drag length scale is analysed.

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WRF PBL MODELS COMPARISON AGAINST DATA MEASURED IN A URBAN ENVIRONMENT

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Summary
We run different PBL models in the Weather Research and Forecasting model (WRF) and perform a validation with measurements of wind profiles, temperature and turbulent kinetic energy . We use the UTP (Urban Turbulence Project, Mortarini et al. 2013) date-set measured in the outskirts of Turin (Italy). It provides measurements performed by sonic anemometers a three different heights (5, 9, 25 m). The data refer to mean wind, temperature and standard deviations of the wind velocity fluctuation collected for more than one year. Results of the comparisons are presented and a model evaluation in term of statistical index is shown and discussed.

Introduction
Air pollution and air quality models make use of numerical weather prediction (NWP) models in order to provide the input to transport and dispersion models. Besides the wind and temperature fields, the diffusion coefficients are important for characterizing the disperion processes . These quantities are estimated by the planetary boundary layer (PBL) scheme in the NWP model. Nowadays the widest used NWP model is WRF which includes several PBL schemes coupled with different surface layer models. For these reasons it is important to evaluate the performance of WRF in simulating not only the mean temperature and wind fields but also the turbulent kinetic energy (TKE) from which the diffusion coefficients are derived.

Metodology and Results
We performed different simulations by changing the PBL models and consequently the surface layer model. We considered the following PBL schemes: Option 2, MYJ, Janjic (1994, MWR); option 5, MYNN2, Nakanishi and Niino (2006, BLM); option 8, BouLac, Bougeault and Lacarrere (1989, MWR). As far as the surface layer model is concerned, we took into account the option 2 Noah Land Surface Model and option 5 CLM4 (Community Land Model Version 4). Furthermore for PBL 2 and 8 we run the model with the urban model Building Energy Model (option 3). The results of the model evaluations are presented in the following tables. In each Table *n* indicates the PBL model, *m* the surface layer model and *p* the urban model. We considered the anemometer data at 25 m and the period from the 1st to the 12th of January 2008.

n=2 m=2 p=0	Mean data	Mean model	FB	NMSE	COR
U (m/s)	1.22	1.63	-0.29	0.45	0.14
T (K)	279	276	0.011	0.00014	0.78
TKE (m^2/s^2)	0.22	0.13	0.56	1.12	0.23

n=2 m=2 p=3	Mean data	Mean model	FB	NMSE	COR
U (m/s)	1.22	1.61	-0.27	0.38	0.27
T (K)	279	277	0.007	0.00008	0.78
TKE (m^2/s^2)	0.22	0.19	0.16	0.51	0.38

n=5 m=5 p=0	Mean data	Mean model	FB	NMSE	COR
U (m/s)	1.22	1.72	-0.34	0.67	0.065
T (K)	279	278	0.014	0.0002	0.67
TKE (m^2/s^2)	0.22	0.36	-0.45	1.05	0.22

Conclusions
The results show that the best performance for TKE is obtained with the option 2 for the PBL (and 2 for the surface layer) in the case in which the urbal model is activated. The urban model is activated also in the PBL model 8 experiments. In this case the agreement between simulated and measured TKE is better than the other except for the simulation performed using the PBL model 2 and the urban model.

n=8 m=2 p=3	Mean data	Mean model	FB	NMSE	COR
U (m/s)	1.22	1.84	-0.41	0.60	0.11
T (K)	279	276	0.008	0.00009	0.76
TKE (m^2/s^2)	0.22	0.32	-0.37	0.77	0.24

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WRF-ARW V3: User's Guide

A CFD STUDY ON THE EFFECTIVENESS OF TREES TO DISPERSE ROAD TRAFFIC EMISSIONS AT A CITY SCALE

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Summary
This paper focuses on the effectiveness of trees at dispersing road traffic emissions on a city scale. CFD simulations of air-pollutant concentrations were performed using the OpenFOAM software platform using the k-ε model. Results were validated against the CODASC wind tunnel database before being applied to a LIDAR database of buildings and trees representing the City of Leicester (UK). Most other CFD models in the literature typically use idealised buildings to model wind flow and pollution dispersion. However, the methodology used in this study uses real buildings and trees data from LIDAR to reconstruct a 3D representation of Leicester City Centre. It focuses on a 2 x 2 km area which is on a scale larger than those usually used in other CFD studies. Furthermore, the primary focus of this study is on the interaction of trees with wind flow dynamics.

Introduction
Road transport is one of the largest contributors of air pollution in urban environments. By 2050, air pollution could account for the largest portion of environmental deaths if no precautions are taken, ahead of unsafe water supply and sanitation (OECD, 2012). Predicting the concentration of air pollutants is essential for monitoring air quality. During the last decade, a number of studies have shown the importance of vegetation in the urban environment. Few of these studies have looked at the dispersive impact of vegetation on the city scale.

Methodology and Results
This paper aims to investigate the effectiveness of trees at dispersing road traffic emissions on a city scale. CFD simulations have been performed with the OpenFOAM software platform using the k-ε model. The CFD results were validated against data from the CODASC wind tunnel study (CODASC, 2014). A 3D database of buildings and trees was derived from airborne LIDAR data, and then integrated into the study on a flat 2 x 2 km area around the City Centre of Leicester. Idealised deciduous trees were modelled as porous bodies using a momentum sink for the velocity. The dispersion of fixed traffic emissions was simulated for a tree-free city (city without trees), and for a city with trees for 12 wind directions. Although the assumption that the volume of urban space occupied by trees in tree-free city is negligible, this is not very close to reality. However, removing the trees in the modelling stage is a useful way of specifically studying their dispersive impact on air pollution.

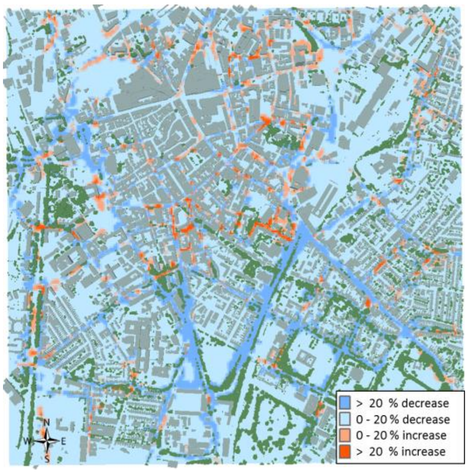

Fig.1 Modelling results of the trees effect on the dispersion of road side traffic emissions in Leicester (UK).

Conclusions
It was found that in effect, trees have a regionally beneficial impact on road traffic emissions by increasing turbulence and reducing ambient concentrations of road traffic emissions by 7% at pedestrian height on average. This was an important result given that previous studies generally concluded that trees trapped pollution by obstructing wind flow in street canyons. Therefore, this study is novel both in its methodology and subsequent results, highlighting the importance of combining local and regional scale models for assessing the impact of trees in urban planning.

Acknowledgement
The authors want to thank Dr C. Gromke for providing key wind tunnel data (CODASC) and to OpenFOAM Ltd for providing the platform software used in this study. This work was supported by the Engineering & Physical Sciences Research Council (EPSRC) and the European Space Agency (ESA) under the uTRAQ project for A. Jeanjean and the NERC knowledge exchange fellowship for R. Leigh under grant NE/L002930/1.

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CFD STUDY OF INDUCED EFFECTS OF TRESS ON AIR QUALITY IN A NEIGHBORHOOD OF PAMPLONA

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Summary

Urban trees affect air quality by modifying pollutant dispersion and by acting as pollutant sink via deposition. Despite the fact that these effects are well known, their exact quantification in an urban environment is still lacking. This study aims at evaluating the effects of trees on dispersion of traffic emissions in a neighbourhood of Pamplona (Spain) for different meteorological conditions. A CFD-RANS model has been used to simulate the air flow and pollutant dispersion in this urban area. The results have been evaluated against the measurements obtained during an experimental campaign. This comparison is used to improve the parametrization of the vegetation effects in the CFD model.

Introduction

Nowadays, urban air quality is one of the most important environmental problems. The interaction between atmosphere and urban surfaces (buildings, trees, etc.) induces complex flow patterns reducing the ventilation in the streets. This fact, linked with the high traffic emissions within urban canopy, generates very heterogeneous pollutant distribution with hot spots of concentrations that make difficult to compute the real population exposure. In this context, one of the focus of the LIFE+ RESPIRA project is to demonstrate that by promoting sustainable mobility and bicycle use, it is possible to improve air quality and reduce exposure to air pollution. To reach this goal, one of the main tasks consists in developing a specific tool able to reproduce the maps of pollutant in Pamplona accurately and with the highest possible resolution, as function of the meteorological conditions. For this purpose, a CFD-RANS model has been used for simulating the urban air pollution. This work is focused on two of the most representative streets of a neighbourhood of Pamplona: San Fermin St. and Tafalla St. (Fig.1), characterized by: a parallel disposition and the same length (approximately 800m), road traffic, and the presence of trees along only one of them. This configuration makes possible to study the effect of trees on pollutant concentration maps, comparing the results on both streets.

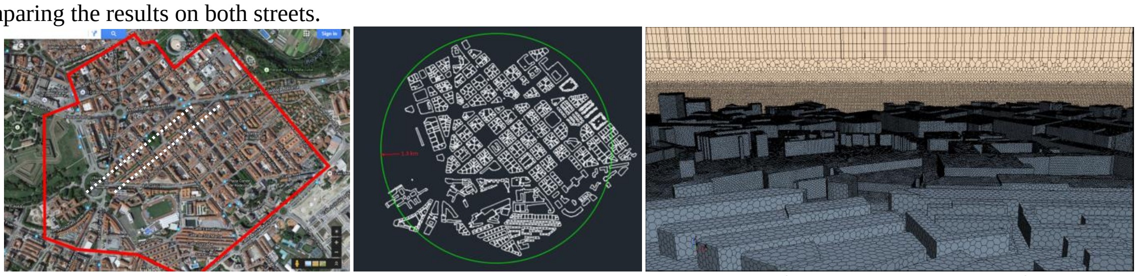

Fig.1 Satellite image (the dashed lines are the study streets), computational domain and mesh of the study neighbourhood of Pamplona. .

Methodology and Results

A 3D full-scale geometrical model including both the buildings and the trees has been built. The spatial domain comprises a circle of about 1.3km (Fig.1). The geometrical model takes into account the height of each building. The mesh resolution is around 2 m in the study area (Fig.1). The main emissions are from road traffic and are modelled in the streets close to the ground. The trees effects are implemented in the CFD model taking into account the aerodynamical effects on wind flow and the deposition of pollutants on the trees. The dynamical effects of the vegetation are modelled considering trees as porous medium. In this way, sources/sinks terms in the momentum, turbulent kinetic energy and turbulent dissipation rate equations were added in the numerical cells with trees (Santiago et al., 2013). The deposition is modelled by a sink term in the transport of pollutant equation (Vos et al., 2012). These two mechanisms (decrease of ventilation and deposition on leaves) compete and determine the air quality at pedestrian level as well as the amount of pollution leaving the urban/vegetation canopy. In this work, we evaluate this issue in a real environment and compare with experimental data obtained in the project.

Conclusions

CFD technique is a powerful tool to provide the pollutant distributions within the streets. This study shows the vegetation effects on air quality in a neighbourhood by using CFD-RANS simulations. As future work, this methodology will be applied to the whole city of Pamplona.

Acknowledgement

The authors would like to acknowledge the E. U. through the LIFE programme for the financial support of this work under the LIFE+ RESPIRA project with contract number: LIFE13 ENV/ES/000417.

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COMPARISON OF TEMPORAL VARIATION OF MODIS DERIVED DUST CONCENTRATION AND SURFACE OBSERVATION OVER AN URBAN AREA

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Abstract

Increasing number of aerosols in the atmosphere has strong impact on human health. Aerosols are caused by natural sources, such as dust, sea-spray and volcanoes and also by anthropogenic sources, such as combustion of fossil fuels and biomass burning activities and from gas-to-particle conversion processes. Remote sensing of aerosols has been recently used to understand the spatial and temporal variation of aerosols. Validating aerosol products obtained from satellite sensors may need ground-based measurements. Satellites are able to yield timely information on the atmospheric conditions at the regional and global scales inexpensively. Many researchers are focused on studying the correlation between satellite based aerosol properties and groud-based mass concentration measurements around the world (Wang and Christopher, 2003; Filip and Stefan, 2011; Barladeanu et al., 2012).

In this paper, dust concentration by the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Aqua and Terra satellites and ground based measurements of PM_{10} concentration, averaged over urban stations, were compared over Tehran urban area in Iran, from 2010 to 2013. The MODIS sensor captures the radiative energy from the target in 36 spectral bands over the visible light, near infrared and infrared spectra. The raw imagery has a spatial resolution ranging from 250 m to 1 km. Ground-based measurements of PM10 were obtained from 13 air quality stations that were used the cyclic measurement of PM_{10} by beta gauge. The dataset consists of daily average of PM_{10}. Quality control tests were applied to all data to assure their accuracy.

The monthly variation of PM_{10} is distinctly different from both satellite and ground-based measurements (see fig. 1). Results indicate that MODIS measurements underestimate the mass concentration in the whole year. Dust concentration from MODIS has a clear maximum in the warm months, from June to August. However, the ground-based concentration shows two maximums; one in cold months and the other in the warm months. The monthly variation in MODIS dust concentration is less marked than that of the ground-based measurements. Consequently, as shown in figure 2, the correlation between four-year time-series of PM_{10} is low (0.24). The correlation is improved when the data is divided by the seasons. The monthly variation of correlation coefficient between MODIS and ground based PM_{10}concetration is likely due to the level that dust particles were loaded. During cold season, dust localized in a confined region near the surface, therefore satellite may not recognize the dust clearly. Another reason is the different character for the aerosol particles in different months.

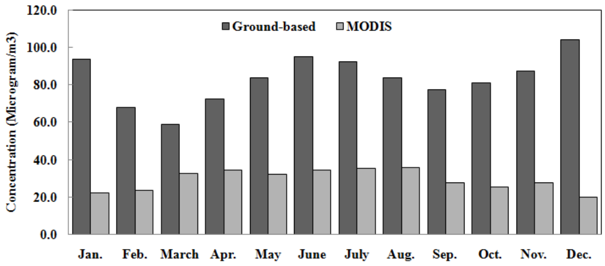

Fig.1 Monthly average variation of dust concentration over Tehran urban area from 2010 to 2014.

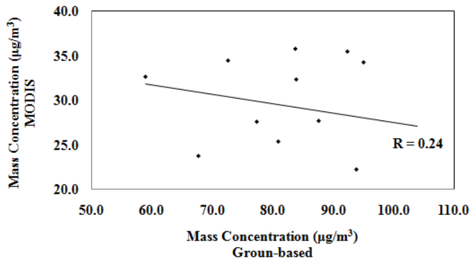

Fig.2 Average correlation of dust concentration between MODIS and ground-based measurements over Tehran urban area from 2010 to 2014.

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MIXING LAYER HEIGHT MEASUREMENTS DETERMINE INFLUENCE OF METEOROLOGY ON AIR POLLUTANT CONCENTRATIONS IN URBAN AREA

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Summary

Local emissions alone cannot explain high air pollution episodes in urban areas. The influences of mixing layer height (MLH) as well as advection and convection must be considered. Results of an air quality campaign with a focus on biogenic emissions, conducted in Berlin during summer 2014 (BÄRLIN), are discussed here. MLH is determined continuously by ceilometers at locations inside and outside of Berlin. Correlations of MLH with air pollutants and particle number concentrations in different size modes indicate a variety of different influences on single air pollutants, also showing the role of particle formation processes and gaseous chemistry. Furthermore, the spatial variation of the MLH is investigated.

Introduction

MLH is a key parameter to determine the influence of meteorological parameters on air pollutants near the surface. However, greater possibilities to apply remote sensing methodologies to estimate MLH have been identified in recent years. Such a method was set up during the BÄRLIN campaign (Bonn et al., 2015).

Methodology and Results

The concentrations of NO, NO_2, O_3, CO and about 70 volatile organic compounds (anthropogenic and biogenic of origin) as well as particle number and particle mass concentrations in different size modes were measured at an urban background station of the Berlin air quality network (BLUME) - Nansenstr./Framstr., Berlin-Neukölln. Ceilometers, which are commercial mini-lidar systems, were applied: A Vaisala CL51 at that site and a Jenoptik CHM 15k at the Meteorological Observatory Lindenberg of the Deutsche Wetterdienst, which is located about 50 km south-east of Berlin. Special software provids estimations of MLH from vertical profiles of laser backscatter data. Correlation analyses were used to investigate the coupling of air pollutants with MLH (see Table 1). Significant influences of MLH on NO, toluene, $PM_{2.5}$ and PM_1 as well as particle number concentrations in the size modes 70 – 100 /, 100 – 200 / 200 – 500 nm were found (negative correlations).

Table 1. Correlation matrix for all correlation coefficients r of air pollutant concentrations with MLH on the basis of averaged diurnal courses in August 2014. Particle number concentrations in the size modes N1=10-20, N2=20-30, N3=30-50, N4=50-70, N5=70-100, N6=100-200, N7=200-500 and N8=500-1100 nm.

August	MLH	PM 10	PM 2,5	PM 1	NO	NO2	CO	Benzene	Toluene
MLH	1	-0.45	-0.85	-0.82	-0.60	-0.47	-0.40	-0.45	-0.65
PM 10	-0.45	1	0.72	0.55	0.85	0.48	0.65	0.36	0.33
PM 2,5	-0.85	0.72	1	0.97	0.72	0.77	0.74	0.62	0.77
PM 1	-0.82	0.55	0.97	1	0.59	0.83	0.73	0.65	0.83
NO	-0.60	0.85	0.72	0.59	1	0.47	0.58	0.33	0.44
NO2	-0.47	0.48	0.77	0.83	0.47	1	0.92	0.80	0.85
CO	-0.40	0.65	0.74	0.73	0.58	0.92	1	0.83	0.76
Benzene	-0.45	0.36	0.62	0.65	0.33	0.80	0.83	1	0.85
Toluene	-0.65	0.33	0.77	0.83	0.44	0.85	0.76	0.85	1

August	MLH	N1	N2	N3	N4	N5	N6	N7	N8
MLH	1	0.46	0.39	0.20	-0.29	-0.49	-0.37	-0.73	0.07
N1	0.46	1	0.92	0.75	0.48	0.25	0.25	-0.12	0.54
N2	0.39	0.92	1	0.93	0.69	0.48	0.51	0.10	0.75
N3	0.20	0.75	0.93	1	0.85	0.69	0.72	0.35	0.76
N4	-0.29	0.48	0.69	0.85	1	0.96	0.93	0.73	0.74
N5	-0.49	0.25	0.48	0.69	0.96	1	0.98	0.88	0.62
N6	-0.37	0.25	0.51	0.72	0.93	0.98	1	0.86	0.62
N7	-0.73	-0.12	0.10	0.35	0.73	0.88	0.86	1	0.32
N8	0.07	0.54	0.75	0.76	0.74	0.62	0.62	0.32	1

Conclusions

Anthropogenic emissions of precursor gases with subsequent particle formation, coagulation and accumulation remarkably influence particle size distribution in the urban atmosphere. This can be concluded from the medium positive correlation coefficients between UFP and MLH declining with increasing particle sizes as particle-particle interactions decrease. The MLH influence is most pronounced for the central accumulation mode size range N7, for which residence time is crucial. Small particles (N2 - N5) are emitted directly by road traffic and combustion processes. Larger particles are influenced by sedimentation, so that there is no influence of MLH on the upper size range N8. Diesel soot emission particles (N5, r= -0.5) and accumulation mode particles (N7, r =-0.7) correlate well with MLH. MLH correlates with smallest particles (N1, N2) probably because of cross-correlation with global radiation and new particle formation. The most appropriate correlation analysis of the concentrations with nearly continuous MLH values is the investigation of averaged diurnal courses of hourly-mean air pollutant concentrations (in our case one month) in comparison to correlation analysis on an hour-by-hour basis.

Acknowledgement

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INFLUENCE OF URBAN HEAT ISLAND ON ATMOSPHERIC COMPOSITION

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Summary

This study aims to reveal interrelations between atmospheric composition over cities and atmospheric boundary layer (ABL) thermal structure. Extensive database of TROICA train measuring campaigns which occurred in 1995-2010 and included both direct in situ atmospheric composition and air temperature profile observations was used for analyses. Average data on temperature, humidity, and on surface concentrations of main trace gases (O_3, CO, NO, NO_2, SO_2) in ambient air over Russian cities of different sizes for different seasons and different times of day were obtained. The most significant effect of temperature increase was observed in the nighttime in the central part of large cities (1.9 ° C), in small towns excess of night temperatures is somewhat higher than the average value in middle cities because of the low-rise buildings that leads to greater warming of the surface air layer under nighttime temperature inversions. Temperature increase over cities central part is well correlated to changes in non-organic atmospheric composition.

Introduction

The link between atmospheric composition and thermal structure is supposed to be significant and is confirmed for some megacities (Elansky et al., 2014). But lack of comprehensive direct measurements makes evidences of this mutual interrelations quite rare. It is clear that ABL thermal structure implies accumulation of atmospheric constituents that in its turn leads to additional heating of air through absorption of radiation. Unique TROICA experiment when about 110 urban settlements of different size have been crossed many times providing continuous accurate measurements gave valuable statistics for quantitative assessment of heat island parameters and its influence on atmospheric composition and air quality.

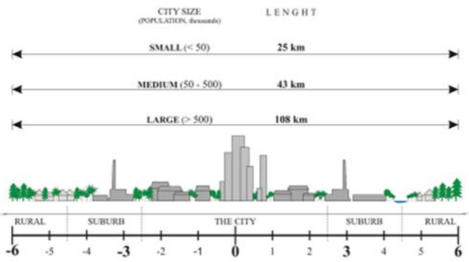

Fig.1 Scheme of relative scaling for study urban air pollution in cities of different size

Methodology and Results

Method of superposed epochs was used to make statistical analyses of TROICA data (see Fig.1). When considering the magnitude of the heat island, depending on the season, it is determined that the greatest increase in temperature in urban areas of all categories is observed at night in the summer, the smallest - in the daytime in the transitional seasons - spring and autumn. In some temperature growth in city comparing to surroundings may reach 3-4ºC, but in average it is within 1.5 ºC for large cities and within 1 ºC for smaller ones. Maximum of air temperature usually corresponds to significant raise of gaseous pollutants (NOx, SO2) and to decrease of ozone (especially in winter when ozone destruction strongly dominates over generation) (see Fig. 2). Carbon dioxide that has both natural and man-made sources revealed some decrease in summer and evident growth by 1.5-2.0% in winter.

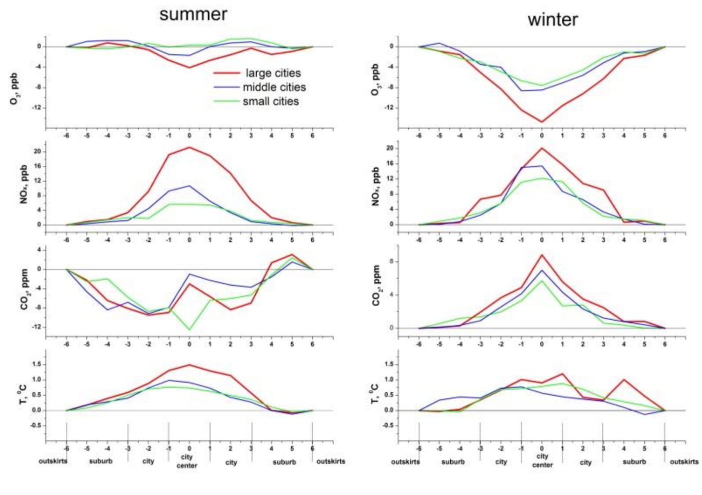

Fig.2 Spatial distribution of O_3, NO_x and CO_2 surface concentrations and surface air temperature T over different groups of cities in summer and winter according to experiment TROICA database

Conclusions

The study shows that existence of heat island over cities may be accompanied by considerable deterioration of air quality. Quantitative relation of air composition and temperature in urban areas that was found could help to simulate contribution of measured thermal structure on air quality. Contribution of air pollution in ABL to the heat island intensity should be estimated in later studies.

Acknowledgement

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SPECIAL SESSION – AIR POLLUTION METEOROLOGY FROM LOCAL TO GLOBAL SCALES

VERTICAL TROPOSPHERIC DISTRIBUTION OF AEROSOL OVER THE PO VALLEY REGION, UNDER DIFFERENT TRANSPORT REGIMES.

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Summary

This work aims to provide a characterization of the vertical aerosol and pollutants variability at tropospheric level over the Po Valley area during summer 2012. The analysis is based on a novel comprehensive database of measures complemented with model analysis from the Lagrangian transport system FLEXPART (coupled with emission databases) and WRF-Chem, the Weather Research and Forecasting (WRF) model coupled with Chemistry. The meteorological analysis showed a succession of different transport regimes during the season, resulting in a large variability of aerosol and pollution at different time and spatial scales. An aerosol classification, based on optical properties from the lidar measurements, and reinforced with aerosol in-situ observations and transport analysis, was adopted to follow the vertical evolution of particles of different nature. The combination of the airborne and in-situ measurements with the output of the transport and chemical models allows to establish and explain the processes responsible for the export of primary pollutants (using CO as a tracer) from the Po valley to the Mediterranean basin. This study allows to individuate and quantify the extent of two dust events, with an intrusion of dust and mixing with local pollution in the Planetary Boundary Layer (PBL), of two events of Po Valley pollution export toward the Mediterranean Basin and to identify recurrent afternoon events of non-spherical aerosol (likely soil dust) uplift.

Introduction

The Po Valley basin, located in Northern Italy, is a region characterized by high concentration of both natural and anthropogenic aerosol and trace gases. The relative proximity to the Sahara desert makes this region often subject to long range dust transport (e.g. Pederzoli et al., 2010). At the same time high anthropogenic emissions, coupled to stagnant atmospheric conditions, lead to unusually high concentrations of atmospheric pollutants. Such pollution, under some particular condition, may flow toward the Mediterranean basin (Finardi et al., 2014). The presented study offer, for the first time, information on the impact of such transport events on the vertical distribution inside the PBL, as well as a characterization and quantification of the export events toward the West-North Mediterranean.

Methodology and Results

Lidar profiles at San Pietro Capofiume (SPC, 44°39'0" N, 11°37'0" E,11m a.s.l) are used to investigate the vertical distribution of aerosol and their optical properties; measurements from Aerodynamical Particle Sizer (APS) at SPC and Optical Particle Counter (OPC) at the Monte Cimone WMO/GAW Global Station (CMN; 44.12N, 10.42E, 2165 m asl) provide information on the size distribution of aerosol at the ground (around 30 m a.s.l.) and at 2100m a.s.l respectively. Particles were mostly individuated below 2000m, with a prevalence of spherical aerosol (50% of measurements). Two events of dust advection from northern Africa were identified (19th-21th June and 29th June–2nd July), with intrusion and mixing with local pollution in the PBL. Dust is found prevalently above 2000m, with a frequency of occurrence of about the 20% during the season with a non-negligible occurrence (~7%) of individuation at the ground. Moreover, events of rapid resuspension of particles likely originated from rural soil sources under conditions of developed PBL, were observed during afternoon-evening hours with frequency of occurrence of around 22%. The combination of CO measurements from the TRAQA flights with the transport and chemical model analysis allowed to individuate two episodes of easterly pollution export from the Po basin (23th -24th June and 26th -27th June), impacting the North-Western Mediterranean with a contribution up to 50 ppbv of CO over the local background value.

Conclusions

Air quality in the Po Valley appears to be largely affected by natural sources. Events of long range transport, as well as the episodes of soil aerosol upflit, may significantly contribute on the PM concentration exceedances. On the other hand, transport events assign to the Po Valley area a relevant role on the pollutant concentration of the surrounding regions.

Acknowledgement

Observations are performed in the framewok of the Supersito project by Regional Agency of Prevention and Environment, from Emilia Romagna region (ARPA-ER, Italy www.supersito-er.it), TRAQA campaign (TRAnsport et Qualité de l'Air au dessus du bassin Méditerranéen) and the european project PEGASOS (Pan-European Gas-AeroSOl-climate interaction Study, pegasos.iceht.forth.gr) and the Project of National Interest NextData.

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NORTH ATLATIC OSCILLATION MODEL PROJECTIONS AND INFLUENCE ON TRACER TRANSPORT.

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Summary
We use a global climate circulation model to investigate the temporal variability of the North Atlantic Oscillation (NAO) pattern, including multi-year to decadal trends from the recent past to the end of the century, and its relation to the spatial variability of atmospheric pollutants. We analyze the NAO signal, the influence of the NAO on the pollutant transport over the North Atlantic sector and scan for significant trends in the future projections. In our analysis, we consider the carbon monoxide CO pollutant tracer, which is directly emitted by combustion sources.

Introduction
The NAO plays an important role in the climate variability of the Northern Hemisphere (Hurrell, Kushnir and Visbeck, 2001) with significant consequences on pollutant transport (Christoudias, Pozzer and Lelieveld, 2012). We study the influence of the NAO on the atmospheric dispersion of pollutants in the near past and in the future by considering simulations performed by the ECHAM/MESSy Atmospheric Chemistry (EMAC) general circulation model.

Methodology and Results
We analyze two model runs: a simulation with circulation dynamics nudged towards ERA-Interim reanalysis data over a period of 35 years (1979-2013) and a simulation with prescribed Sea Surface Temperature (SST) boundary conditions over 150 years (1950-2099). The model is shown to reproduce the NAO spatial and temporal variability and to be comparable with observations (Fig.1). We find that the decadal variability in the NAO, which has been pronounced since 1950s until 1990, will continue to dominate in the future considering decadal periods, although no significant trends are present in the long term projection (100-150 years horizon). We do not find in the model projections any significant temporal trend of the NAO for the future, meaning that neither positive nor negative phases will dominate. Tracers with idealised decay and emissions are considered to investigate the NAO effects on transport; it is shown that during the positive phase of the NAO, the transport from North America towards northern Europe is stronger and pollutants are shifted northwards over the Arctic and southwards over the Mediterranean and North Africa, with two distinct areas of removal and stagnation of pollutants.

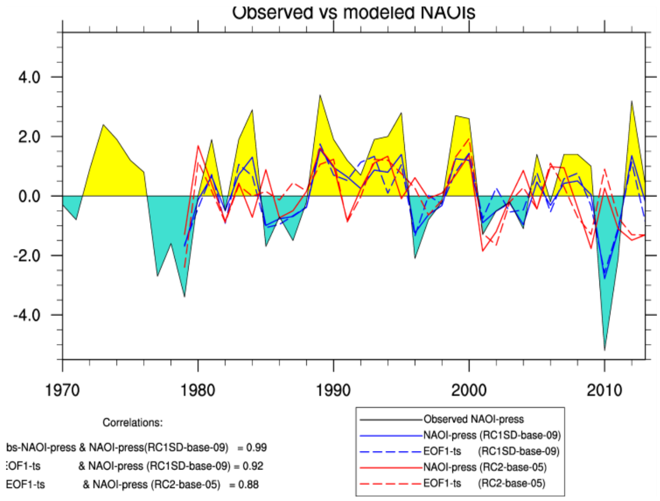

Fig.1: Observed and Modelled NAO index values

Conclusions
Our results indicate that the NAO is influenced by natural climate variability rather than external factors. We find confirmation that SSTs influence the NAO evolution. Since the NAO is strongly correlated with pollutant transport, the NAO Indices may be used as indicators of (future) pollutant transport over Europe.

Acknowledgements
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SIMULATING AEROSOL-CLOUD INTERACTIONS OVER SOUTHERN WEST AFRICA WITH COSMO-ART IN THE FRAMEWORK OF DACCIWA

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Summary
For a case study in June 2014, the atmospheric composition and the feedback between aerosols and clouds over Southern West Africa (SWA) have been simulated with the integrated modelling system COSMO-ART (Vogel et al., 2009, Bangert et al., 2012). The application of an interaction between aerosols and clouds leads to a significant increase in the extension of the simulated low-level stratus and a reduction of their cloud base height over Togo and Benin.

Introduction
SWA is linked to rapid socio-economical changes including a strong population increase, enhanced urbanization, landuse changes and increased anthropogenic emissions. Within the EU project DACCIWA (Dynamics-aerosol-chemistry-cloud interactions in West Africa) we contribute with COSMO-ART to the understanding of the impact of the atmospheric composition on the cloud microphysical and dynamical behavior across SWA.

Methodology and Results
COSMO-ART was used in the weather forecast mode with a grid mesh size of 3km, based on a double-nesting with 28km and 5km grid mesh size. The model describes online the emission and the temporal development of aerosols and their feedback on radiation and cloud formation. Furthermore the two-moment scheme of Seifert and Beheng (2006) was activated instead of the standard bulk scheme which is usually used in COSMO for the operational weather forecast. The model includes the variety of emission sources relevant for the research domain (e.g. sea salt, mineral dust, biogenic volatile organic compounds, vegetation fire emissions, anthropogenic emissions). Additionally a parameterization of the gas flaring emissions, which are emitted especially at the Niger Delta and the Nigerian coastal area, has been developed and applied. With this model setup it was possible to simulate the air pollution contribution from the several sources and the interaction especially with the so-called Nocturnal low-level stratus (NLLS) which frequently occurs in extended areas across SWA during the West African Monsoon. As a case study we have selected a two day period from 7th to 8th of June 2014 which was linked to a distinct NLLS layer. In comparison to a reference simulation without aerosol-cloud interactions a significant increase in the extension of the NLLS and a reduction of the cloud base height over Togo and Benin can be seen.

Conclusions
By conducting a COSMO-ART aerosol-cloud interaction case study simulation, which considers the natural and anthropogenic emissions in SWA, it can be shown that the aerosol has a strong influence on the SWA cloud characteristics. However an analysis of further case studies is necessary for a better understanding of the underlying local processes.

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IMPACT OF REGIONAL CIRCULATION ON METEOROLOGY AND EXTREME EVENTS OVER ASIA FOR PRESENT AND FUTURE CLIMATE

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Summary
A numerical simulation of climate over the Asian region using WRF at a spatial resolution of 54 km, was performed for 3 representative years of present and future climate under the RCP 8.5 scenario using the HADGEM2-ES as the forcing global model. The aim was to study the potential relationship between large and regional scale circulation and their influence on regional meteorology and events of extreme weather over Asia. Extreme weather events are usually linked with persistent synoptic anomalous circulation patterns over a region. Several of these events are also related with stable atmospheric conditions that are known to be precursors of high pollutants concentration events. This study focusing on characterising the Asian meteorology shows that the variation of persistent circulation patterns appear to influence regional events of extreme weather such as heat waves, consecutive dry days, consecutive wet days and strong breeze days. Moreover, the variation of the regional anomalous circulation could be linked with variations on the large scale circulation features.

Introduction
The link between circulation and regional weather has been well documented, especially over Europe (e.g. Cassou et al., 2005). These studies highlighted the important role of some climate features such as the North Atlantic Oscillation (NAO), atmospheric blocking, and extra tropical cyclones (ETC’s) and their influence on colder and wetter winters and hotter and dryer summers. While much of the research has focussed on the European region, there are relatively less research investigations for the Asian continent. Along with the previous climate features, the intertropical Convergence Zone (ITCZ), Monsoonal Circulations, and the El-Niño Southern Oscillation (ENSO) play a role in the anomalous atmospheric circulation patterns that influence the onset of severe weather episodes affecting several Asian regions (e.g. Park et al., 2013; Chen, 2013). This study focusses on the analysis of the temporal and spatial evolution of weather extremes as well as anomalous circulation patterns and regional meteorology over the Asian region.

Methodology and Results
The general analysis of circulation patterns and meteorological events over Asia relied on the combined use of a global climate model HadGEM2-ES and WRF modelling systems. For the definition of extreme weather events and meteorological analysis, daily precipitation (Pr), 2-m mean, minimum and maximum temperature (Tmean, Tmin and Tmax), 10-m wind and horizontal components (W10, U10 and V10) and mean sea level pressure (MSLP) were applied. Empirical Orthogonal Functions (EOFs) were used to detect circulation patterns, and, climate indices defined by the European Climate Assessment & Dataset (ECA) project, were computed regarding extreme events. The ERA-Interim (ERA-I) reanalysis was used for model evaluation regarding the present climate. Increase of consecutive dry days and heat waves over Central, Southern and Eastern Asia from 2000 to 2050 (Fig.1) appear to be in line with the increase of anticyclonic activity over the region during summer. Also during summer periods, consecutive wet days are shown to decrease in South Asia and increase over the Tibetan Plateau. The analysis also shows that the duration of the South Asian Monsoon decreases from May to September in 2000 to July to August in 2050. There is some evidence that this could be due to the decrease of the temporal predominance of the cyclonic circulation during summer period over the years.

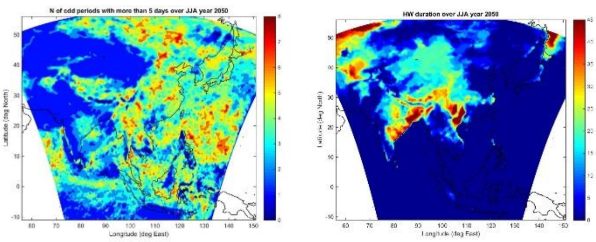

Fig1. Consecutive 5 day periods and heat wave duration during the summer months (JJA) of the year of 2050.

Conclusions
This modelling study reports the impact of regional circulation on meteorology and on events of extreme weather over Asia. Variations in temperature and precipitation, persistent anomalous circulation patterns and regional features are shown to influence the evolution of extreme weather events. Future changes in the large-scale circulation, regional circulation patterns and meteorology, appear to influence the evolution of the extreme events over several Asian regions.

Acknowledgement
This work was possible due to the global model HADGEM2-ES meteorological data provided by UKMO centre. Part of the research involving climate and meteorology approach was developed as part of FP7 TRANSPHORM project.

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COASTAL OZONE IN NAPLES: EPISODE ANALYSIS BY MEANS OF AIRCRAFT MEASUREMENTS AND MESOSCALE MODELLING

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Summary

Persistent high pressure ridges of African origin affecting the Mediterranean basin and continental Europe cause heat waves in different areas of the continent and favour the occurrence of ozone episodes, as happened in July 2015. Airborne observations have been performed on 15-16 July over the coastal region near Naples. Aircraft measurements have been compared with high resolution meteorological and air quality model simulations to verify their reliability and to investigate local circulation and pollutants dynamics. Sea breeze and local emissions gave rise to production of ozone inland of Naples conurbation, causing high concentrations over the region located between the coast and the Apennine chain. Ozone was then injected in the upper boundary layer and transported towards the sea by the wind rotation occurring above 500 m a.s.l. causing a complex vertical layering of concentration over the coast, with maximum values between 500 and 800 m.

Introduction

Naples is one of the largest conurbations in the Mediterranean basin. Road traffic, harbour activities and winter residential heating are the main air pollutants sources. High ozone concentrations episodes affect the inland region downwind of the densely inhabited coastal area. The project AriaSaNa (http://www.ariasana.org/) has the objective to improve the knowledge of air quality processes integrating innovative ground based and airborne measurements with state-of-the–art meteorological and air quality modelling. A forecast system based on the chemical transport model FARM (Mircea et al., 2014) coupled with the meteorological model WRF (http://www.wrf-model.org/) runs operationally since July 2014 with a horizontal grid spacing of 1 km. Besides that, 2015 summer campaigns investigated air pollution through measurements performed by the SkyArrow/ERA aircraft.

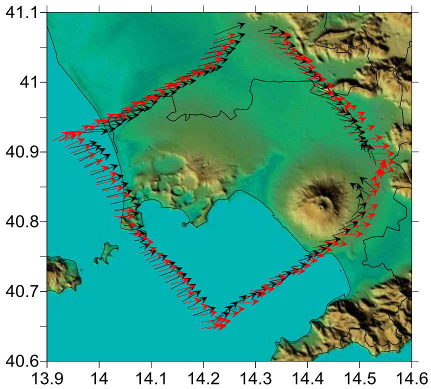

Fig.1 Measured wind (black) and WRF forecast (red) along flight track

Methodology and Results

Airborne measurements were performed at an average height of 150 m a.g.l. along a square track with side length of about 30 km enclosing Naples, its gulf, and the Vesuvius. The airplane executed vertical profiles at the square track vertexes up to a height of about 1500 a.s.l. The main atmospheric flow features detected on July 15th are correctly reproduced by WRF (Fig.1). Differences between modelled and measured wind are observed in the wake of Vesuvius, where unsteady flow can occur. Observed and modelled ozone concentrations show a general coherence, with higher spatial detail provided by airborne measurements. The occurrence of elevated concentrations over the inland plains is confirmed. The model predicts high concentrations over the sea due to the advection from the ozone layer over the Tyrrhenian sea foreseen by continental scale models into which the local simulation is nested. The aircraft detects reduced O_3 concentration over the gulf of Naples, that can be explained by titration effect of NO_X emissions due to the intense marine traffic during the touristic season, and can be underestimated by modelled emissions. The comparison of ozone vertical profiles shows coherence of measured and modelled concentrations near the surface and in the upper layers, while the model apparently does not foresee the ozone rich layer visible between 500 and 1000 in the western (Fig 2) and northern profiles. A deeper exploration of model results (relaxing the comparison pairing in space and time) allowed to confirm and interpret the observations. The ozone produced inland is transported vertically in the upper boundary layer, where wind direction then turns counter clockwise, carrying pollutants towards the sea and causing complex vertical layering of concentration over the coastal area.

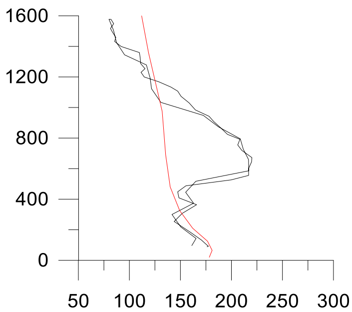

Fig.2 Measured (ascending and descending leg; black) and predicted (red) ozone ($\mu g/m^3$) vertical profiles.

Conclusions

Airborne measurement together with high resolution mesoscale model simulation allowed to analyse and explain the complex atmospheric pollutants dynamic and its short term variability over the gulf of Naples. The analysis results can help to improve the quantification of the population and agricultural areas exposure to high ozone concentrations.

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THE INFLUENCE OF MID-LATITUDE CYCLONE TRACKS ON SURFACE OZONE AT REMOTE EUROPEAN COASTAL MONITORING SITES

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Summary
The role of the passage of mid-latitude cyclones on surface O_3 in springtime was investigated by linking O_3 measurements from the EMEP database for ~20 years from two remote stations (far from major emission sources) on the west coast of Europe – Mace Head, Ireland and Monte Velho, Portugal – to cyclone tracks that passed the surrounding region. O_3 measurements at Mace Head and Monte Velho are influenced by cyclone tracks passing in different regions in the vicinity of the observation sites, demonstrating the importance of the associated fronts and conveyor belts. Case studies examined in detail the spatio-temporal influence at each location of strong cyclones on surface O_3 as the cyclones evolved. Different synoptic situations led to high and low O_3 at the two surface stations.

Introduction
The spatiotemporal variability in meteorological factors -- wind speed and direction, humidity and temperature -- impacts the temporal variability of pollutant concentrations. These meteorological factors are influenced by the large-scale atmospheric pressure centers nearby. For Western Europe, this is mainly the location of the semi-permanent Icelandic Low, a climatological feature due in part to the cumulative effect of many cyclones passing through the region between Iceland and southern Greenland, and the semi-permanent Azores High. The seasonal variability in the frequency of cyclones can impact surface O_3 observations, whereby the frequent cyclones associated with the Icelandic Low can entrain air from different source regions, primarily, Europe and North America. North American emissions are able to reach Europe both in the low-level winds as well as lofted by frontal lifting to upper-levels, along the North Atlantic storm track region, where air can be rapidly transported downwind.

Methodology and Results
Spring was chosen as it is typically the season of maximum intercontinental transport and stratosphere-to-troposphere transport (STT) of O_3 at these locations. Cyclones were identified in the ERA-Interim reanalysis and the MACC reanalysis using the cyclone tracking algorithm, TRACK (Hodges, 1995, 1999). The two stations were chosen due to their location within and slightly south of the major North Atlantic storm track, respectively. The causes of high and low O_3 values measured at each station in relation to the frequency and passage of mid-latitude cyclones was quantified. For Mace Head, when cyclones tracked north of the station or the region was centered over Mace Head, there was a significant likelihood that surface O_3 measurements would be high (> the 75th percentile value). Conversely, more cyclones were associated with low O_3 measurements (< the 25th percentile) when they passed to the south of Mace Head. At the more southerly station, Monte Velho, the relationship between the location of storm tracks and surface O_3 is weaker and generally opposite to that at Mace Head, whereby slightly more cyclones passing to the north (on the edge of the storm track) are associated with low surface O_3 and slightly more cyclones to the south of the observation site (far from the storm track region) associated with high O_3.

The MACC reanalysis was utilised to select the strongest cyclones passing to the north and south of each station that were associated with high O_3 and where measured surface O_3 and MACC simulated O_3 values were within 20% agreement. For the two cyclones that passed to the north of Mace Head (N1; Fig. 1) and Monte Velho (not shown), O_3-poor subtropical air arrived from the southwest, ahead of the associated cold fronts. In all four case studies, following the passage of the cold front, high surface O_3 was associated with air that originated in the stratosphere being brought down to the mid and lower troposphere within the dry intrusion airstream. However, a direct connection with the stratosphere was not required as aged, stratospheric O_3-rich air from previous cyclones in the region could become entrained and subsequently descend within the strong cyclones (to the south of Mace Head and north of Monte Velho) and large-scale descent and accumulation of O_3-rich air could occur within a neighboring anticyclone (south of Monte Velho).

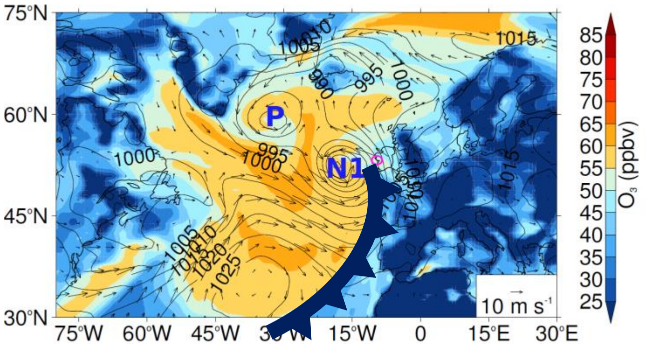

Fig. 1 MACC reanalysis O_3 (color), MSLP (contours) and horizontal winds at 1000 hPa on 4March 2007 00UTC. Approximate cold front indicated by blue line with triangles.Fig 1.

Conclusions
The temporal variability of O_3 measurements are influenced by passing cyclones. The case studies highlight the importance of the passage of a cyclone's cold front to influence surface O_3 measurements, the ability of cyclones to bring down O_3 from the stratosphere, and that nearby surface high pressure systems also play an important role in the variability of surface O_3.

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THE IMPACT OF LONG RANG AIR TRANSPORT ON THE SURFACE NH_3 LEVELS AT A RURAL SITE IN THE NORTH CHINA PLAIN IN SUMMER 2013

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Summary

In-situ measurement of ambient ammonia (NH_3), trace gases and the water-soluble ions in $PM_{2.5}$ was conducted at Gucheng (39°08′N, 115°40′E, 15.2 m a.s.l.), a rural site in the NCP in summer 2013. The mean hourly concentrations of NH_3, SO_2 and NO_x were 43.9, 4.3 and 13.2 ppb, respectively, and 19.77, 19.77 and 11.34 μg/m^3 for NH_4^+, SO_4^{2-} and NO_3^- in $PM_{2.5}$, at Gucheng in summer 2013. The air masses from the North China Plain region contain the highest concentration of ammonia, suggesting a potential contribution of air transport to our measurements. The result reveals that the NH_3 concentrations are influenced by meteorological conditions, atmospheric mixing, local and regional sources during summer 2013 in Gucheng.

Introduction

Ammonia is the primary alkaline trace gas in the atmosphere. Ammonia has both direct and indirect impacts on important environmental issues including regional fine particles, acid rain and eutrophication (e.g. Meng et al., 2011). Ammonia and other trace gases are observed by DLT-100 Ammonia Analyzer and a set of commercial instruments from TE during summer 2013. The hourly concentrations of the water-soluble inorganic ions in $PM_{2.5}$ are also measured with the Ambient Ion Monitor (URG 9000 Series, USA) in summer 2013.

Methodology and Results

The concentrations of NH_3 at Gucheng site range from 0.9 to 862.9 ppb, with the average of 43.9±65.9 ppb. To identify the impact of long-range air transport on the surface air pollutants levels, the 72-h backward trajectories were calculated using the HYSPLIT 4.9 model. The trajectory calculations were done for four times of each day in summer 2013, with the four time points of 00, 06, 12, and 18 UTC, respectively. The various back trajectories were grouped into 5 clusters. As can be seen in Fig. 1, Clusters 1, 2 and 3 represent relatively low and slow moving air parcels, with cluster 2 coming from northwest areas at the lowest transport height among the 5 clusters. The other two clusters represent air parcels mainly from the northwest. These clusters of trajectories originated from clean regions and travelled quickly from higher atmosphere to Gucheng site in the North China Plain, which is expected to bring cleaner air masses into surface. The cluster 2 from the North China Plain region was most important for the rural site, contributing 56% of air masses. The occurrence frequencies of each type of air masses arriving at Gucheng in different months were calculated. The corresponding mean concentrations of NH_3 in different clusters of backward trajectories are also analyzed in order to characterize the dependences of the pollutants concentrations on air masses. Large differences in the concentrations of NH_3 exist among the different clusters, with cluster 2 corresponding to the highest NH_3 level (48.9 ppb), and cluster 3 corresponding to the second highest NH_3 level (32.8 ppb). These two types of trajectories have the shortest transport distances and lowest transport heights, which help the accumulation of NH_3. The high NH_4^+ level (45.9 μg/m^3) in cluster 4 might be subject to the long rang transport from northwest sector.

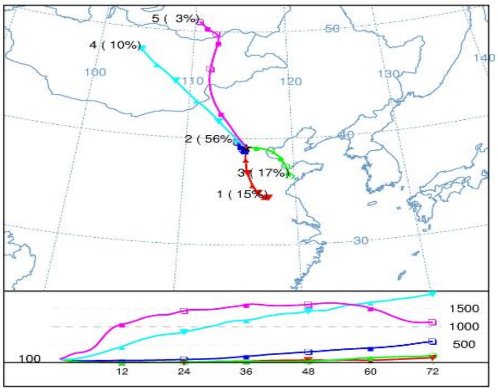

Fig.1 72-h backward trajectories for 100 m above ground level at Gucheng in summer 2013

Conclusions

The results indicate that transport of air masses from the North China Plain region might contributed to the atmospheric ammonia variations in Gucheng, , a rural site in the NCP, while the NH_4^+ was contributed by both long-range transport and local formation.

Acknowledgement

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SOURCE-RECEPTOR RELATIONSHIPS OF INTERCONINENTAL TRANSPORT USING THE UKCA CHEMISTRY-CLIMATE MODEL FOR THE TF-HTAP PHASE 2 PROJECT.

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Summary

This study presents results from source-receptor simulations performed with the United Kingdom Chemistry Aerosol (UKCA) model as part of the Task Force on Hemispheric Transport of Air Pollution (TF-HTAP) phase 2 model intercomparison. These simulations examined the effects of: a) a 20% emission reduction from a number of source regions on their downwind continents; b) global perturbations to different emission sectors and c) global perturbations to different pollutants. UKCA results from these different simulation sets are compared to further understand the impact of potential control strategies in different world regions.

Introduction

Currently, there are no international agreements that address the intercontinental transport of tropospheric ozone and its precursors. However the contribution of upwind pollution to free tropospheric levels as well as to exceedances of surface air quality standards over downwind regions have been reported e.g. from East Asia to the western United States (Lin et al. 2012). In TF-HTAP phase 1, an ensemble of 21 global and hemispheric chemistry transport models was applied to estimate the spatially average surface ozone response over east Asia, Europe, North America, and south Asia to 20% decreases in anthropogenic emissions of the ozone precursors: Nitrogen Oxides (NOx), Non-Methane Volatile Organic Compounds (NMVOCs), and Carbon Monoxide (CO) (individually and combined), from each of these regions (Fiore et al. 2009). The ensemble mean annual-mean surface ozone response to foreign emissions was largest in spring and late autumn (~1 ppbv) when intercontinental transport tends to be strongest. In TF-HTAP phase 2 a larger number of source/receptor regions are considered. Additionally, sector based emission perturbations as well as those of individual pollutants are evaluated.

Methodology and Results

A large set of perturbation simulations were performed for the period 2008-2010 using the UKCA chemistry-climate model. A base simulation was first undertaken and the results evaluated against observations. The main focus of these simulations was to examine the effects of 20% emissions reductions globally and over 13 world regions (see Fig. 1) on pollutant concentrations downwind. Further perturbation simulations were performed to assess the effects of global emission reductions from (i) anthropogenic sectors of transportation, power and industry and residential and (ii) natural sources of fires and dust. A final set of simulations examined the effects of reducing global NOx, CO and CH_4 levels. The results from these simulation will be presented to further understand the intercontinental transport within similar latitude bands e.g. across mid-latitude regions, from the mid-latitudes to the tropics and across hemispheres. Furthermore, the global effects of emission reductions to various sectors/sources will be outlined.

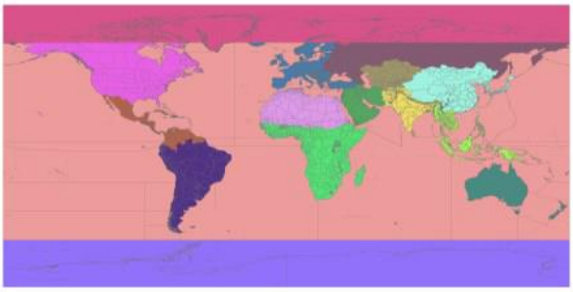

Fig.1 World regions defined for the HTAP 2 intercomparison

Conclusions

A large number of model perturbation experiments have been performed to quantify the role of intercontinental transport from a diverse range of major emission source regions on their downwind receptor regions, and in particular to examine transport within and across hemispheres. Source-receptor relationships for various sectors and sources are also quantified.

Acknowledgement

This work was supported by the UK Met Office and the Task Force on Hemispheric Transport of Air Pollution

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FORECASTING LONG-RANGE AIR QUALITY IMPACTS OF WILDFIRE EMISSIONS

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Summary
We present an overview of the Copernicus Atmosphere Monitoring Service (CAMS) and its application to monitor and evaluate the long-range impact of North American wildfire emissions on European air quality in the summer of 2015.

Introduction

The Copernicus Atmosphere Monitoring Service (http://atmosphere.copernicus.eu/), implemented by ECMWF on behalf of the European Commission, provides a unique perspective on global atmospheric composition and the transport and impact of atmospheric pollution associated with wildfire emissions. CAMS utilises near real-time satellite observations of wildfire locations and emissions of aerosols and trace gases. Five-day forecasts of global smoke aerosol and trace gases, produced on a daily basis with the ECMWF Integrated Forecasting System (IFS), allow pollution plumes to be predicted to several days ahead. European regional air quality forecasts are performed using a suite of state-of-the-art air quality models to calculate multi-model ensemble products with boundary conditions from the global system.

Monitoring fire emissions and pollution transport

Wildfires are a significant component of the Earth system, emitting large quantities of trace gases and aerosols which perturb the chemical composition of the atmosphere and can have impacts on surface air quality far from the emission source. The 2015 wildfire season in boreal North America was particularly strong, exacerbated by persistent dry conditions in the west. More than 5 million acres in Alaska and 9.7 million acres in Canada were burnt, making 2015 the second most devastating fire year on record for Alaska after 2004, with the most intensive three-week period of burning on record. We evaluate the long-range transport of emissions from these wildfires on European air quality, analysing CAMS forecasts of trace gases and aerosols associated with forest fires (e.g., carbon monoxide, PAN, and organic and black carbon aerosol) in comparison against satellite and aircraft observations.

The most intensive wildfires in boreal North America started in Alaska and Canada in the second half of June, lasting into the first half of July. The total amount of carbon monoxide emitted by these fires over this period was estimated, using satellite measurements of fire radiative power, to be 13 Tg(CO). Smoke plumes were monitored during their transit to Europe via the North Atlantic Ocean (as shown in Fig 1) and in one case via the eastern Arctic Ocean. The CAMS global forecasts generally performs well, correctly estimating the time of arrival of the smoke plumes into the Europe domain. However, Fig 2 shows that the CAMS global system can underestimate or cannot fully resolve fine-scale vertical structures in the observations related to the relatively coarse horizontal resolution of the IFS.

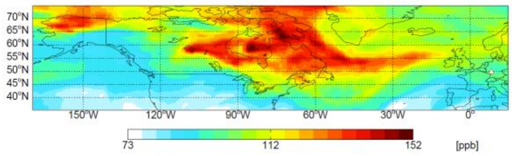

Fig 1 CAMS forecast CO (ppb) at 500 hPa averaged between 1 and 15 July 2015. The white triangle indicates the location of Frankfurt, Germany where the smoke plume was observed in the free troposphere.

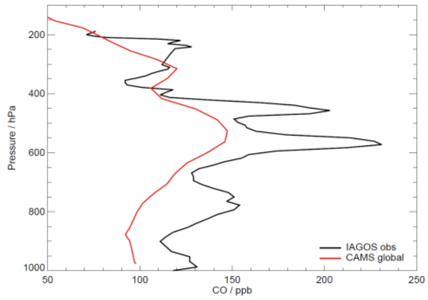

Fig 2 CO profile over Frankfurt, Germany on 8 July 2015 observed in situ by IAGOS (black line) and forecast by the CAMS global system (red line).

Conclusions

CAMS operationally produces a wide-range of products related to atmospheric composition including reactive gases, greenhouse gases, and aerosols. These products are provided via a free and open data access policy for anyone to download.

THE INFLUENCE OF SYNOPTIC WEATHER REGIMES ON UK AIR QUALITY: REGIONAL MODEL STUDIES OF TROPOSPHERIC COLUMN NO_2

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Summary
Previous studies have shown a relationship between observed satellite tropospheric column NO_2 and synoptic meteorology. In this study, we show that the UK Met Office Air Quality in the Unified Model (AQUM) can simulate tropospheric column NO_2 fields under cyclonic and anticyclonic conditions, as seen from space. The model is used to investigate the importance of different controlling factors (e.g. chemistry and transport) to UK air quality. By using a range of idealised NO_x-like tracers with different e-folding lifetimes, we show that under different synoptic regimes the NO_2 lifetime in AQUM is approximately 6 hours in summer and 12 hours in winter. Within a season (summer or winter) under different synoptic regimes, a large proportion of the spatial pattern in the UK column NO_2 fields can be explained by transport processes.

Introduction
Synoptic weather can significantly influence UK air quality through the transport and accumulation of atmospheric pollutants over source regions and urbanised areas. Pope et al., (2014) was one of the first studies to use satellite data (NO_2) to detect enhanced air pollutant concentrations under stable conditions. Here, we see if the UK Met Office's air quality model can simulate these relationships and aim to better understand the factors governing UK air quality.

Methodology and Results
The Lamb Weather Types (LWT) are an objective midday classification of UK circulation patterns. Daily UK circulation is categorised under a specific vorticity type (e.g. cyclonic) and flow (e.g. northerly). Pope et al., (2014) used the LWT to composite tropospheric column NO_2 data from the Ozone Monitoring Instrument (OMI - 13:00 LT overpass) under winter and summer cyclonic and anticyclonic conditions. Under anticyclonic conditions, tropospheric column NO_2 is larger over the UK source regions when compared with the seasonal average (positive anomalies in Figures 1b & d). Cyclonic conditions reduced tropospheric column NO_2 over the UK as the unstable weather transports it out over the North Sea. This is seen in Figures 1a & c, from the negative (positive) anomalies over the UK (North Sea).

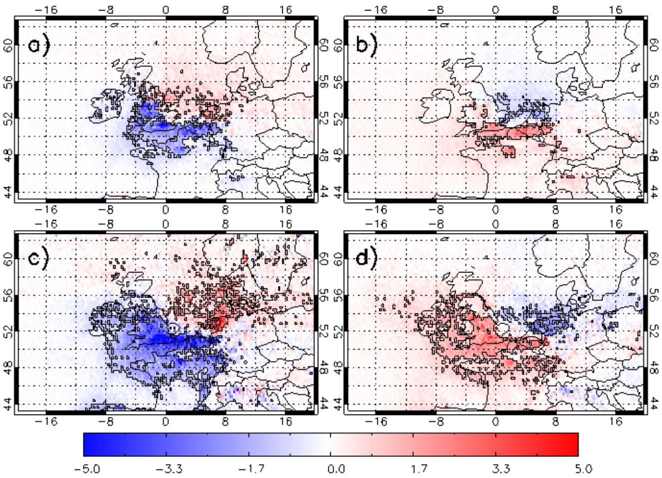

Fig.1 OMI tropospheric column NO_2 ($x10^{15}$ molecules/cm^2) anomalies from the seasonal average for a) summer cyclonic, b) summer anticyclonic, c) winter cyclonic and d) winter anticyclonic conditions. Black polygonned regions show statistically significant anomalies at the 95% confidence level.

We composite AQUM tropospheric column NO_2 fields directly under the LWTs and show that AQUM can successful simulate the LWT-NO_2 relationships seen from space. NO_x-like tracers with fixed life-times were used to determine an approximate life-time of tropospheric NO_2 under the seasonal synoptic regimes. Depending on which tracer life-time anomaly field (similar to Figure 1) matched the AQUM NO_2 anomaly field indicated the approximate NO_2 life-time. Overall, summer (winter) NO_2 has approximate lifetimes of 6 (12) hours.

Conclusions
This study shows that to a first-order approximation atmospheric chemistry is, as expected, more influential in summer than in winter. By using NO_x-like idealised tracers with fixed life times, we show that within seasonal synoptic regimes, transport processes explain a large proportion of the spatial variability in UK tropospheric column NO_2. This work also shows that the Met Office AQUM can reproduce the large-scale accumulation of air pollution over the UK under anticyclonic conditions.

Acknowledgement
We acknowledge the use of the TEMIS (http://www.temis.nl/index.php) OMI dataset and the LWT data from the Climatic Research Unit, University of East Anglia. This work was supported by the UK NERC National Centre for Earth Observation.

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A MULTI-SCALE MODELLING SYSTEM FOR STUDYING URBAN CHEMISTRY AND TRANSPORT

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Summary
This paper presents preliminary results from a coupled air quality modelling system comprising a Gaussian-type local air quality model with a regional photochemistry transport model. Predicted modelled concentrations are compared to measurements recorded in London, for a range of sites. This work forms part of the NERC project CureAir (Coupling Urban and Regional processes: Effects on Air Quality) and an overview of the aims of this project will also presented.

Introduction
Despite substantial emission controls, the health burdens of the EU urban population attributable to exposure to air pollution are substantial with fine particle matter ($PM_{2.5}$) responsible for ~458 000 premature deaths in Europe in 2011 (EEA, 2014). Hence, the capability to simulate the complex urban chemical environment is imperative for the development of policies aiming towards improving poor air quality and human health. The chemical composition of the urban atmosphere is driven by: pollutant emissions; transport and mixing; and deposition and chemical reactions acting on relatively short timescales and influenced by regional background concentrations with driving processes occurring over longer timescales. These processes can be investigated by coupling a regional chemical-transport model to a local urban Gaussian dispersion model which can explicitly represent the near-field dispersion and chemical processes associated with sources such as road traffic and industry.

Methodology and Results
Stocker *et al.* (2012) describes the concept of coupling a Gaussian-type local air quality model with a detailed regional photochemistry transport model, while avoiding the 'double counting' of emissions when simulating the reducing influence of local emissions with distance from source but the increasing influence of the regional background. This method, which exploits the advantages of both models, has been developed into a user-friendly and flexible interface for coupling the local dispersion model ADMS-Urban (CERC, 2015), which includes local chemistry and can represent the impacts of urban morphology including street canyons and urban heat island effects, with EMEP4UK (Vieno *et al.*, 2014) or other regional chemistry transport models, using meso-scale meteorology from WRF. This multi-scale system is being used to model pollutant concentrations in the UK and London, at resolutions of 5 km and tens of metres respectively, for the 2002-2013 decade.

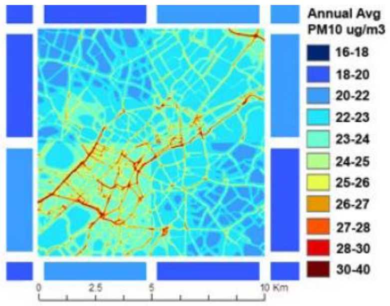

Fig.1 Annual average PM_{10} concentrations from the coupled EMEP4UK and ADMS-Urban modelling system

Validation of the system has been undertaken by comparing modelled NO_x, NO_2, O_3, PM_{10} and $PM_{2.5}$ concentrations at kerbside, roadside and urban background sites with measurements from the London Air Quality Network. Further, an analysis of how the dispersion and chemical processes are accounted for at varying spatial and temporal scales in the different system components has been performed.

Conclusions
The preliminary results from this coupled air quality modelling system demonstrate that the chemical processes occurring in the urban atmosphere are well represented. Further, the analysis of particulate concentration data demonstrates the importance of modelling long-range transport in addition to local emissions when modelling urban air quality. The impact of the Urban Heat Island on air quality at the regional and local scales is of relevance to the future projections that are being performed for this study.

Acknowledgement
This work was supported by NERC (NE/M003906/1).

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METEOROLOGICAL CONDITIONS ASSOCIATED WITH EXTREME POLLUTION EVENTS OVER THE NORDIC COUNTRIES

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Summary and background
Improving our understanding of couplings of meteorology (including circulation patterns) and pollutant variability is critical to eventually understand transport patterns and surface distribution of harmful pollutants. It further helps to carry out process-oriented evaluation of CTMs and to realistically simulate these couplings in CTMs. From purely an observational perspective, both top-down and bottom-up approaches can be employed to understand statistical linkages between meteorology and pollutant distribution. For example, in a top-down approach, the focus could lie on a particular weather state and how it impacts the pollutant distribution (e.g. as in Thomas and Devasthale, 2014). While in a bottom-up approach, the focus directly lies on identifying extreme pollution events first and then investigating typical meteorological conditions associated with those events. Both of these approaches have their advantages and limitations, esp w.r.t. the verticality of atmosphere in question. Here, we present preliminary results from the second (i.e. bottom-up) approach to understand possible linkages between extreme pollution events and weather states over the Nordic countries in general and over Sweden in particular using satellite sensor data.

Methodology and preliminary results
Data used: Carbon monoxide (CO) from AIRS-Aqua and MOPITT (2003-2014, 11-year), Ozone (O3) from OMI (2004-2014), NO2 from OMI (2004-2014). CO and O3 are analyzed with focus on the free troposphere, while NO2 is analyzed with focus on the near-surface.
Identification of extreme events: All pollution events exceeding 90 percentile values are investigated for each season and trace gas species in question from 2003 to 2014.

Below, the figures 1-3 show an example of analysis to be presented in the conference. Fig. 1 shows histograms of CO over southern Sweden at 500 hPa and 90 percentiles thresholds for different seasons with vertical lines. Fig. 2 further shows back trajectories from FLEXTRA for events exceeding 90 percentile values during winter to understand dominant direction of pollutant transport, which is confirmed by Fig. 3 to be from northwest based on ERA-Interim wind data. This analysis highlights the importance of one pollution pathway originating from North America carrying CO over northern Europe.

Fig. 1

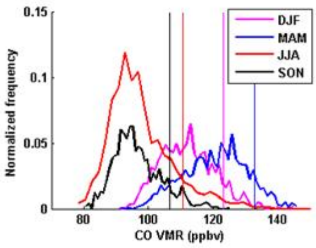


Fig. 2

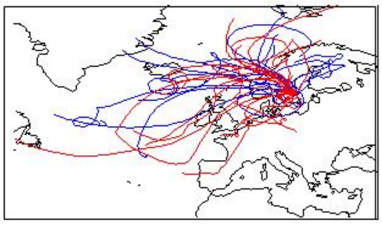
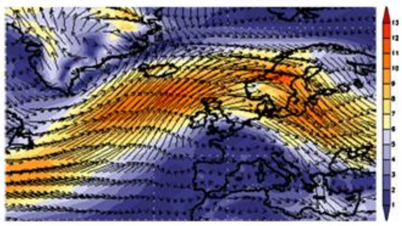


Fig. 3



Conclusion
Identifying the dominant weather patterns during extreme pollution events helps in better understanding of the role of local meteorology in governing the transport and distribution of pollutants in the atmosphere; the knowledge of which would help to better constrain CTMs. Detailed investigations of the statistical linkages between meteorology and pollutant distribution would be carried out and presented in the conference.

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SOURCE APPORTIONMENT MODELLING OF OC AND NMVOCS IN THE BERLIN URBAN AREA

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Summary

A 3-month measurement campaign (BAERLIN-2014) was carried out during the summer of 2014 in the Berlin/Potsdam region of Germany. A variety of gas-phase, particle, and meteorology parameters were measured. Source apportionment methods were applied to the PM10, specifically organic carbon, and higher time-resolution data collected, focusing on the NMVOCs, to investigate source contributions, including the role of anthropogenic vs biogenic influence in the urban area. Initial results indicate a significant influence of vegetation as well as traffic, but the largest contribution to OC from SOA. The source apportionment analyses were complemented with air mass back trajectory data, and compared to the existing understanding of sources based on local emission inventories. Inorganic contributions to PM10 mass were from sulfate, nitrate, and ammonia.

Introduction

Urban areas typically have high population density and significant emissions, and therefore often struggle with air quality exceedances. In Europe more than 90% of the urban population are exposed to levels of ozone and PM exceeding WHO air quality guidelines (EEA 2014). Addressing this air pollution effectively requires sufficient knowledge of the sources and origin of the pollutant emissions. To characterize air pollution in the Berlin/Potsdam region, a 3-month measurement campaign was carried out from June-August 2014. As a large metropolitan area, traffic was expected to be a significant source of emissions. Less typical and a specific aspect of the BAERLIN-2014 campaign, was the investigation of the role of vegetation on air quality, as for Berlin/Potsdam specifically, some 40% of the area in the greater Berlin area is either green space or water (BSV 2010).

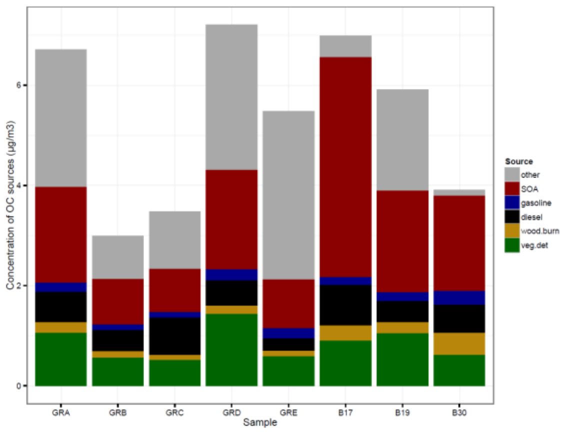

Figure 1. PM10 OC chemical mass balance source attribution.

Methodology and Results

In BAERLIN-2014, a variety of measurements were added to an urban background monitoring station that is part of the Berlin air quality monitoring network, in Berlin Neukölln (station ID MC042), augmenting the existing measurement capacity. High time resolution data was collected for a range of air pollution parameters, including NO, NO_2, O_3, CO, ca. 70 NMVOC masses via PTR-MS, as well as particle number, mass, and size distribution. In addition, PM10 filter samples were collected. The PM10 filters were analysed for organic carbon (including the water soluble fraction), elemental carbon, ions, and organic tracer compounds. Chemical mass balance (CMB) source apportionment was conducted for the organic carbon composition of the PM10 samples, grouped based on HYSPLIT back-trajectory analysis, and an evaluation of the bulk chemical composition. For example, samples GRB and GRC (Figure 1) were characterized by lower PM mass and OC, and a higher ratio of ions to OC. The GRB group was characterized by air masses passing over northern France and central Germany before arriving in Berlin, while the air masses from the GRC sample passed over the North Sea and northern Germany. In comparison, sample GRD air masses came from the northeast, passing over the coastal regions of Poland, and the Baltic countries, and the ratio of ions to OC was much lower. The OC CMB solution was characterized by contributions from vegetative detritus, diesel emissions, gasoline vehicles, and wood burning, in addition to a significant contribution from SOA (Figure 1). In addition, PMF analysis was carried out with a focus on the NMVOCs.

Conclusions

Results from the CMB analysis indicate that of the organic carbon fraction of PM10, a significant fraction was secondary organic aerosol. Vegetative detritus and diesel emissions both contributed significantly to OC. Diesel emissions are also a much more dominant contributor to OC than emissions from gasoline vehicles. Further details of the CMB results in the context of secondary inorganics and results from the in-progress NMVOC-focused PMF analysis will also be discussed.

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BLACK CARBON AMBIENT CONCENTRATIONS AND SOURCES IN BANGKOK

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Summary
The objective of this study is to determine black carbon (BC) aerosol concentrations in Bangkok's urban atmosphere. Results showed diurnal variation of 1-hr BC concentrations with peaks in the morning and night related to traffic. Monthly 24-hour BC concentrations during November 2013 to January 2015 had average values around 1.55 to 5.78 ug/m^3 with maximum concentration in January each year. BC concentrations in the dry season were higher than wet season when the wind direction came from north to east of Bangkok. The ratio of char-EC to soot-EC for each particle size in January ranges from 0.4-3.1 showing the signature of traffic sources as well as biomass burning.

Introduction
Black carbon aerosol or elemental carbon in the atmosphere is formed by the incomplete combustion of fossil fuels, biofuels, and biomass. It plays an important role as the solar absorber. It has the potential to cause global warming second to only carbon dioxide. In addition, black carbon aerosol also affects human health. It is considered a carcinogen. Identification of sources of black carbon aerosol in the atmosphere is important for air quality management.
The objective of this study is to determine black carbon aerosol concentrations in Bangkok's urban atmosphere. Monitoring location was on the roof-top of the 10th floor building occupied by the Faculty of Applied Science, KMUTNB. To determine the BC ambient concentrations representative of urban air-shed, the sampling location was located away from specific sources of air pollution including traffic and industrial emissions.

Methodology and Results
The air samples were collected continuously for 24 hours every 6 days from November 2013 to January 2015. BC concentrations were measured by an aethalometer. A cascade impactor was used for collection of various sizes of particulate matter including PM<0.1, PM0.5-1.0, PM1-2.5, PM2.5-10 and PM>10. The carbon compositions in particulate matter were analyzed for organic carbon (OC), elemental carbon (EC) separated to char-EC and soot-EC. Meteorological data: wind speed, wind direction, rainfall were recorded at this site. Results showed diurnal variation of 1-hr BC concentrations with peaks in the morning and night related to traffic (Fig.1). Monthly 24-hour BC concentrations have average values around 1.55 to 5.78 ug/m^3 (Fig. 2). BC concentrations in the dry season were higher than the concentrations in the wet season, especially in January each year when the wind direction came from north to east of Bangkok. The analysis results of carbonaceous components in January 2015 showed that 20-50% of carbon in particulate matter is organic carbon. The ratio of char-EC to soot-EC for each particle size ranges from 0.7-4.1 with particle size 1.0-2.5 microns having the maximum ratio.

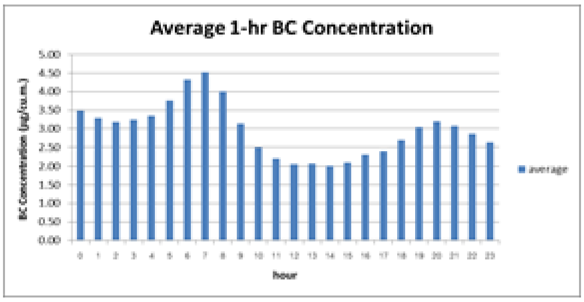

Fig.1 Diurnal BC Concentration

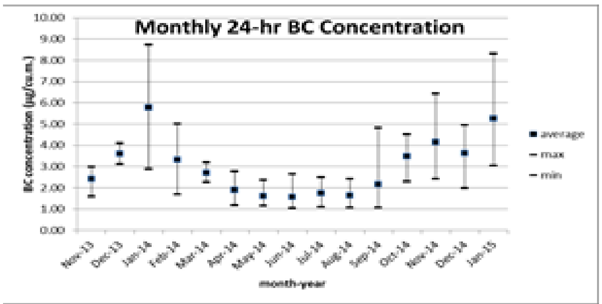

Fig.2 Monthly 24-hr BC Concentration

Conclusions
BC concentrations in Bangkok's urban atmosphere were high in the dry season especially in January. Ratio of char-EC/soot-EC in particles in January showed signature of vehicle exhaust and biomass burning (Han et al., 2010). The January wind direction showed that BC concentrations in Bangkok ambient air was affected by biomass burning from neighbouring provinces and other countries to the north of Bangkok.

Acknowledgement
The Nano sampler and chemical analysis was supported by Prof. Dr. Masami Furuuchi and his colleagues from Kanazawa University.

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IDENTIFYING THE MOST HAZARDOUS SYNOPTIC CONDITIONS FOR WINTER UK PM10 EXCEEDENCES

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Summary

We investigate the relationship between synoptic scale meteorological variability and local scale pollution concentrations within the UK. Synoptic conditions representative of atmospheric blocking highlighted significant increases in UK PM10 concentration ([PM10]), with the probability of exceeding harmful [PM10] limits also increased. Once relationships had been diagnosed, The Met Office Unified Model (UM) was used to replicate these relationships, using idealised source regions of PM10. This helped to determine the PM10 source regions most influential throughout UK PM10 exceedance events and to test whether the model was capable of capturing the relationships between UK PM10 and atmospheric blocking. Finally, a time slice simulation for 2050-2060 helped to answer the question whether PM10 exceedance events are more likely to occur within a changing climate.

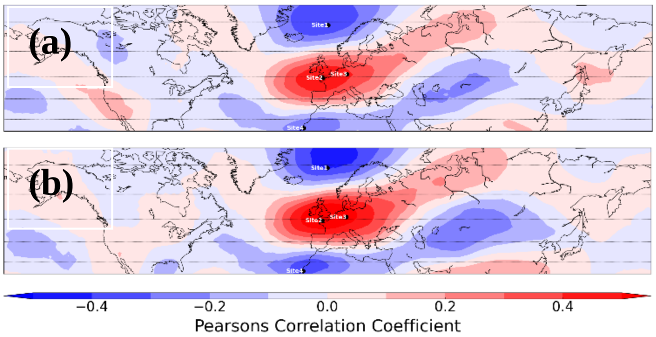

Fig. 1, Correlation between a Rossby Wave Breaking metric and (a) observed UK [PM10] and (b) modelled PM10 using the Met Office UM. PM10 in both cases is lagged by 2 days following the occurrence of Rossby Wave Breaking.

Introduction

Atmospheric blocking events are well understood to lead to conditions, conducive to pollution events within the UK. Literature shows that synoptic conditions with the ability to deflect the Northwest Atlantic storm track from the UK, often lead to the highest UK pollution concentrations. Rossby wave breaking (RWB) has been identified as a mechanism, which results in atmospheric blocking and its relationship with UK [PM10] is explored using metrics designed in Masato, et al., 2013. Climate simulations facilitated by the Met Office UM, enable these relationships between RWB and PM10 to be found within the model. Subsequently the frequency of events that lead to hazardous PM10 concentrations ([PM10]) in a future climate, can be determined, within a climate simulation. An understanding of the impact, meteorology has on UK [PM10] within a changing climate, will help inform policy makers, regarding the importance of limiting PM10 emissions, ensuring safe air quality in the future.

Methodology and Results

Three Blocking metrics were used to subset RWB into four categories. These RWB categories were all shown to increase UK [PM10] and to increase the probability of exceeding a UK [PM10] threshold, when they occurred within constrained regions. Further analysis highlighted that Omega Block events lead to the greatest probability of exceeding hazardous UK [PM10] limits. These events facilitated the advection of European PM10, while also providing stagnant conditions over the UK, facilitating PM10 accumulation. The Met Office UM was used and nudged to ERA-Interim Reanalysis wind and temperature fields, to replicate the relationships found using observed UK [PM10]. Inert tracers were implemented into the model to replicate UK PM10 source regions throughout Europe. The modelled tracers were seen to correlate well with observed [PM10] and Figure 1 highlights the correlations between a RWB metric and observed (a) and modelled (b) [PM10]. A further free running model simulation highlighted the deficiency of the Met Office UM in capturing RWB frequency, with a reduction over the Northwest Atlantic/ European region. A final time slice simulation was undertaken for the period 2050-2060, using Representative Concentration Pathway 8.5, which attempted to determine the change in frequency of UK PM10 exceedance events, due to changing meteorology, in a future climate.

Conclusions

RWB has been shown to increase UK [PM10] and to lead to greater probabilities of exceeding a harmful [PM10] threshold. Omega block events have been determined the most hazardous RWB subset and this is due to a combination of European advection and UK stagnation. Simulations within the Met Office UM were undertaken and the relationships seen between observed UK [PM10] and RWB were replicated within the model, using inert tracers. Finally, time slice simulations were undertaken, determining the change in frequency of UK [PM10] exceedance events within a changing climate.

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SPECIAL SESSION - AIR QUALITY IMPACTS OF THE INCREASING USE OF BIOMASS FUELS

RESIDENTIAL WOOD COMBUSTION IN ATHENS SINCE 2010: IMPACTS ON AIR QUALITY AND ATMOSPHERIC VARIABLES

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Summary
This study aims to quantify atmospheric aerosol emitted from residential wood burning ($PM_{10\text{-rwb}}$) in Athens and their impact on the state of the atmosphere by online-coupled photochemistry and meteorology modelling. The unique combination of a 7wl aethalometer (AE33) and an Aerosol Chemical Speciation Monitor (ACSM) was further deployed to record the temporal variation and chemical composition of $PM_{10\text{-rwb}}$ emissions. Improved correlation was observed between COSMO-ART outputs and measurements after the incorporation of the revised $PM_{10\text{-rwb}}$ emissions to the original TNO-MACCII database. The concentration of total PM_{10} mass in the city center during a cold (<7°C), weekend exceeded 90 μg m^{-3}, i.e. well above the EU daily limit. Around 75% of this mass was organic (50%) and elemental carbon. The $PM_{10\text{-rwb}}$ fraction (above 60%) is predicted to have caused a radiative cooling up to -0.7 W m^{-2}. The health and climate related impacts of $PM_{10\text{-rwb}}$ sources call for a revision of the current tax legislation for domestic heating oil prices.

Introduction
For the past 5 years, Greece has been experiencing a major financial crisis which, led to a shift in the fuel used for residential heating towards bio-fuels (primarily wood). As a consequence, severe winter smog episodes became more frequent and initiated large experiments for measuring mass concentrations, chemical composition and physicochemical properties of aerosols in big cities of Greece (e.g. Paraskevopoulou et al., 2015). This is the first aerosol modelling study of a winter smog event over Athens, quantifying the $PM_{10\text{-rwb}}$ and its feedback on radiation.

Methodology and Results
A high resolution (<3 km) COSMO-ART simulation was performed over Greece during winter 2014 using TNO-MACCII anthropogenic emissions. Two months of hourly black carbon (BC_{wb}) measurements (decomposed time series from the AE33) were processed to revise the temporal cycles of rwb emissions. The original chemical profile of aerosol emissions from rwb was modified based on the chemical composition of aerosol spikes measured during night time of the winters 2012-2015 with the ACSM measurements. The applied changes resulted in significant improvements to the temporal evolution of aerosol pollution, especially for days with minimum temperatures below 7°C. In particular, hourly PM_{10} spikes exceeded 150 μg m^{-3} (as observed) and the mean correlation between measurements and model outputs for BC and organics (OA) improved significantly (r^2 from 0.43 to 0.54 and from 0.03 to 0.62, respectively). The 2-day average concentration of total PM_{10} mass in the city center was higher than 90 μg m^{-3} (see Fig.1), i.e. well above the EU daily limit. Around 50% of this mass was OA, while BC accounted for 25%. The mean $PM_{10\text{-rwb}}$ was above 60% and is predicted to have caused a radiative cooling up to -0.7 W m^{-2} (see Fig.1), leading to a reduction of 2-m temperatures by 0.2 K. These results demonstrate the need to mitigate rwb emissions as an important source of PM_{10}.

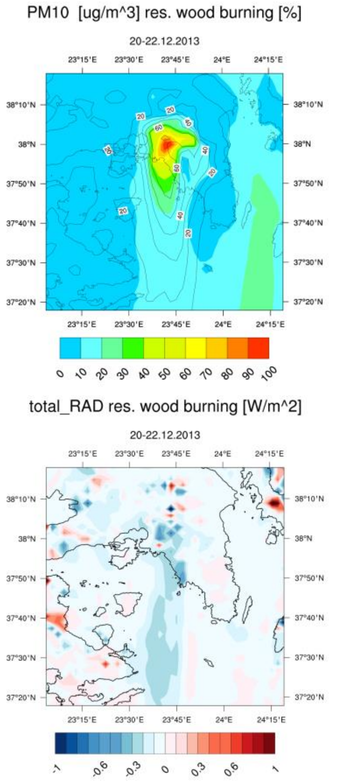

Fig.1 Spatial distribution of total PM_{10} (top, contours), PM_{10}rwb (top, iso-lines) and ΔRad_s (bottom) over Athens.

Conclusions
As the economic crisis continues in Europe, rwb will remain a significant source of aerosol pollution during wintertime over the densely populated areas. Furthermore, these particles include significant fractions of absorbers (e.g. BC) and refractors (e.g. OA) of solar radiation, i.e. interfere with climate forcing from anthropogenic activities. Hence, there is a need to introduce suitable legislation to regulate the prices of oil for domestic heating.

Acknowledgement
The work is co-funded by the "Programme Agreements between Research Centers" GSRT 2015-2017. Part of the current work was performed in the frame of the project THESPIA- of the action KRIPIS, of GSRT, financed by Greece and the European Regional Development Fund of the EU in the frame of NSRF and the O.P. Competitiveness and Entrepreneurship and the Regional Operational Program of Attica. We acknowledge NOA colleagues responsible for the operation of the aerosol site.

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THE USE OF 14C MEASUREMENTS ON OC AND EC FOR WOOD BURNING SOURCE APPORTIONMENT AT AN URBAN SITE IN NORTHERN ITALY.

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Summary

This work aims to present the results of a carbonaceous fraction source apportionment carried out starting from ^{14}C measurements on the organic (OC) and elemental (EC) carbon fractions to distinguish the contributions of fossil fuels and modern sources (wood burning, biogenic). A suitable thermal treatment was developed to perform the analysis.

Introduction

The carbonaceous aerosol is a main constituent of atmospheric aerosol and has adverse effects on health, air quality, visibility, and Earth's radiation balance. In this context, the development of analytical and modelling techniques aiming at the identification of natural and anthropogenic contributions gains great importance.

^{14}C measurements on organic and elemental carbon (OC and EC, respectively) allow a distinction between the wood/biomass burning and the biogenic source, provided that the OC/EC emission ratio for wood/biomass burning is known. Drawbacks of the approach are the need to isolate OC and EC for the ^{14}C analysis and the difficulty in the assessment of the secondary contribution from wood/biomass burning (Szidat et al., 2009).

Methodology and Results

The samples were prepared for the ^{14}C analysis using a devoted sample preparation line (Calzolai et al., 2011) following the methodology developed in Bernardoni et al., 2013.

The samples were collected in a heavily polluted area (Milan, Italy) during wintertime. The fraction of modern carbon values for OC, EC and TC were used to attempt a source apportionment in the area (see figure 1). The wood burning primary contribution to OC was evaluated from both ^{14}C and levoglucosan measurements using tailored emission factors (Piazzalunga et al., 2011). A good agreement between the approaches was found and wood burning primary contribution accounted for about 18 % of OC in Milan during wintertime. Secondary OC from wood burning and the contribution from other urban sources were tentatively identified following literature approaches, with the aim of evaluating the biogenic contribution to OC in the area, which was estimated to be about 18%.

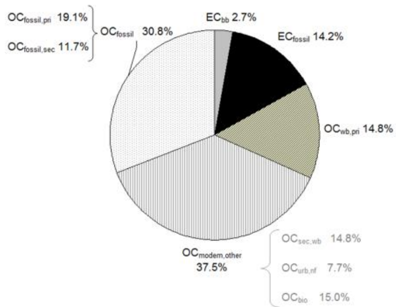

Fig.1 TC source apportionment in the PM10 using ^{14}C measurements

Conclusions

^{14}C measurements on OC and EC are a powerful tool for the source apportionment of the carbonaceous fraction of the atmospheric aerosol.

Acknowledgement

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RESULTS FROM A PILOT STUDY ON THE COMPOSITION AND TOXICITY OF ULTRAFINE PARTICLES DUE TO WOOD BURNING

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Introduction

The intensive use of wood and biomass combustion for domestic heating raises issues on negative health effects that particulate matter emitted by this source can have.

The inhalation of wood smoke effluents can alter the pulmonary immune defence mechanisms, with main damages to macrophages and lung epithelial cells.

It is expected that ultrafine particles (UFP, d<100 nm) can be the major responsible for adverse health effects due to their ability to penetrate deeply into the respiratory system, potentially having access to the central nervous system (Oberdörster et al., 2005).

The TOBICUP (TOxicity of BIomass Combustion generated Ultrafine Particles) project aims at collecting and characterising the UFP generated by wood/biomass combustion from domestic pellet and wood stove emissions and in ambient air in order to assess the most relevant physical-chemical parameters influencing their toxicity. In this work only data from the ambient air field campaign will be presented.

Methodology and Results

The TOBICUP project joined chemical and physical information (metals, ions, elemental/organic carbon, PAH content and number concentration and size distribution – see Fig. 1) about emissions from wood/pellets stoves and in ambient air. Metals, ions, and carbonaceous component were detected through ICP-AES, IC and TOT respectively.

UFP sampling was carried out using multistage cascade impactors, considering only particles collected on stages with nominal cut-off <100 nm.

The collection of data was carried out during winter and summer 2015. The sampling took place in Morbegno (SO) – a town in the low Valtellina Valley, an alpine valley in Northern Italy heavily impacted by the use of wood/pellets stoves for domestic heating. The choice of the two seasons is aimed at comparing ambient UFP effects during periods when wood/biomass burning is an important source (Jan-Feb) and other periods, when conversely it is very limited and almost negligible (Jun-Jul).

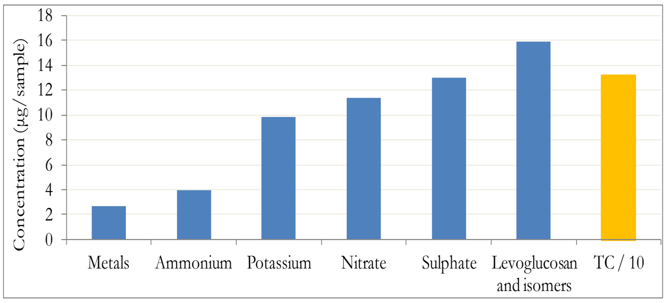

Fig. 1: Average composition in the winter samples (d < 100 nm)

A toxicological analysis was then carried out to characte models, using both laboratory-sampled UFP and ambient UFP.

In this presentation we will show results of the physical-chemical characterisation of particles collected during the winter and summer field campaigns and the preliminary data on toxicological effects of such particles.

Acknowledgement

This work was supported by CARIPLO foundation (Grant 2013-1040). We acknowledge Comune di Morbegno for providing the winter and summer sampling sites.

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BIOMASS BURNING CONTRIBUTION TO PAHS CONCENTRATION IN THE URBAN AREA OF ROME. MAIN FINDINGS FROM THE LIFE+ EXPAH PROJECT AND FURTHER OBSERVATIONS.

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Summary

The main findings of EU LIFE+ EXPAH project, aimed to assess PAHs exposure and their health effects on the population living in urban areas, are presented. Domestic heating and biomass burning were found to be the main contribution to PAH levels observed in Rome urban area.

Introduction

Polycyclic Aromatic Hydrocarbons (PAHs) are a class of complex organic chemicals of increasing concern due to their occurrence in the environment. They are ubiquitous in ambient air and some of them have been identified as carcinogens or suspected carcinogens for human. Domestic heating, mobile sources and vehicles, are the largest contributors of PAHs in highly urbanized areas. Therefore, population living in cities are particularly exposed to these pollutants. The EXPAH project, funded by the EU LIFE+ program, aims to assess the population exposure to PAHs in the city of Rome and the consequent health effects on the inhabitants by means of an integrated approach including measurements, modeling techniques and epidemiologic investigations.

Methodology and Results

Several experimental field campaigns were carried out, during different seasons, to investigate the ability of PAHs to penetrate living environments (homes, schools, offices, cars and bus). Experimental results evidenced that indoor PAHs levels were about one order of magnitude higher in winter than in spring/summer due to domestic heating. Benzo(a)pyrene (B[a]P), the most toxic PAH, was usually well below the European guideline value in the warm season whilst it exceeded this value during winter. The PAHs emission inventory, built for the Lazio Region (Gariazzo et al., 2015), indicates that the domestic heating is responsible for 28% and 96% respectively for PM_{10} and PAHs emissions in the city of Rome (figure 1). Biomass burning systems are estimated to be responsible for 99% and 90% of PAHs and PM_{10} emissions from residential heating, even if the contribution of biomass burning to the overall heat production is small. Environmental and health impacts were estimated based on one year of PAHs simulated concentrations at urban level. Daily average concentrations indicated that Rome urban area is exposed to high levels of PAHs during the winter with B[a]P exceeding limit value. A 3.1% of increased in mortality was estimated for 1 ng/m^3 variation in PAHs exposure occurring 2 to 5 days before deaths. To evaluate the impacts of future emissions on PAH levels, the Current Legislation (CLE) scenario for year 2020, based on the GAINS-Italy project, has been simulated. A general reduction of 2020 emissions with respect to 2009 reference values was obtained for all pollutants except for PAHs, as they show an increase of 38% (figure 2). The increase of PAHs emission is influenced by domestic heating and mainly due to the predicted increase of wood combustion contribution. An Additional Measures (AME) scenario, forcing the substitution of biomass with natural gas for domestic heating, has been considered as a possible effective action leading to a potential PAHs emissions of more than 90%.

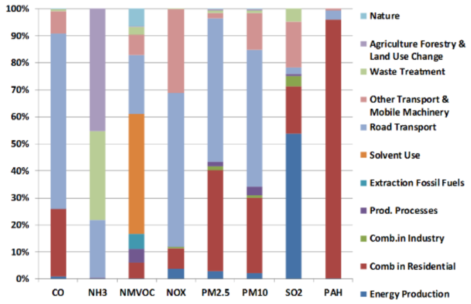

Fig.1 Contribution of the different source to the emission of pollutants in Rome

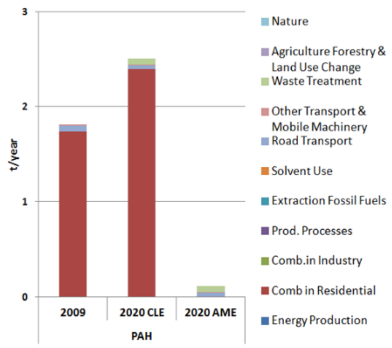

Fig.2 Emission Scenarios: reference (2009); current legislations (2020 CLE); additional measures (2020 AME)

Conclusions

EXPAH LIFE+ project has highlighted the relevance of domestic heating and biomass burning on the environmental and health impacts of PAHs at urban level. The analysis of future emission scenarios indicates that PAHs emissions are estimated to increase during the next years claiming for the adoption of mitigation measures.

Acknowledgement

The LIFE+ EU financial program is acknowledged for the provision of funding for EXPAH project (LIFE09 ENV/IT/082).

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INTEGRATED METHODOLOGY FOR ASSESSING DOMESTIC WOOD BURNER MUNICIPAL SHARE

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Summary
This paper presents the experience of ARPA Lombardia in improving emission estimates from small domestic wood burners. The uncertainty level of the share of biomass municipal consumption among different technologies strongly affects total emissions. Starting from the huge amount of data available for Lombardy, this work presents the development of a procedure for combining information from different sources. Local energy balance, CATI (Computer Aided Telephonic Interviews) surveys, time series of the share of residential wood heaters effectively used and purchased in the region are processed for the update of the local indicators. CATI surveys define for each sampling cell (identified by province, altitude and density of inhabitants) percentage of frequently users and average amount of biomass burned. The propagation of these data to each municipality is performed by the amount of inhabitants and data from regional energy balance. The update of the share of burning technologies starts from the indicators of previous inventory editions and the declared production amount of the technologies by the reconstruction of the time series of technology share. The resulting indicators seem to best fit and harmonize all the possible data available for the emission inventory development.

Introduction
The heating sector, mainly due to fuelwood is the main emission source of PM, CO, BaP and is also relevant in the emissions of Zn and Cd in Lombardy for 2012 as reported by the regional emission inventory (ARPA Lombardia, 2015). As shown in figure 1, the contribution to heating sector emissions for PM10 and BaP varies between fuel type, fossils and wood, and between wood burner's technologies. Many factors not only average temperatures can affect seasonal biomass consumption and the technology share strongly affects pollutant emission from domestic wood burning. The improving of definition of activity indicators for the main appliances is relevant for increasing quality emission estimate as documented by many international experiences during TFEIP periodic meetings (http://www.tfeip-secretariat.org/) with particular attention to data provided by stakeholders (eg.: producers, sellers, chimney sweepers). These latter are considered as relevant sources in monitoring technology evolution of the devices. At the regional Italian level, many experiences in detecting quantity of wood burned detailed for technology types are also reported by application of CATI.

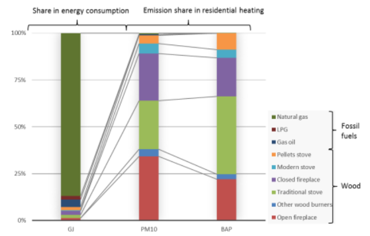

Fig.1 Energy consumption and PM10, Bap emissions in domestic heating, Lombardy 2012.

Methodology and Results
Staring from a detailed analysis obtained for 2008 by CATI on diffusion in Lombardy of different domestic wood technologies detailed for sampling cells defined on provinces, altitude and pop. density it is possible to obtain historical trend of the indicators up to 2012 by mean of selling data as reported by ANFUS and CECED. Substitution rate of each technology is estimated according to device average age and a substitution scheme defined on selling data. Technology distribution can be defined as the number of appliances N:

$$N_{i,m,k} = D_{i,m} \times U_j \times F_i \times \frac{1}{\sigma_m\sqrt{2\pi}} \times e^{-\frac{(k-\mu_m)^2}{2\sigma_m{}^2}} \qquad R_{i,m,y} \cong \sum_k \frac{1}{100} \times (k-1) \times N_{i,m,k,y}$$

with i=municipality, m=technology type (eg.: stoves, fireplaces, …); k=device age; D=percentage diffusion of device type m stated by CATI; U=percentage of frequent users by CATI; F=number of families in municipality; σ_m=standard deviation of average age, η_m=average age of device (eg.: according EC DG TREN, 2009). The number of appliances can vary during the years because: obsolete systems are renovated, appliances are installed or substituted. As a matter of facts the potential number of obsolete devices for a year k can be defined as $R_{i,m,y}$. In Lombardy for 2008 can be calculated that 8-9% of the number of appliances could be potential substituted, this value is in good agreement with other references (EC DG TREN, 2009) were the renewal rate was in the range of 7-8%.

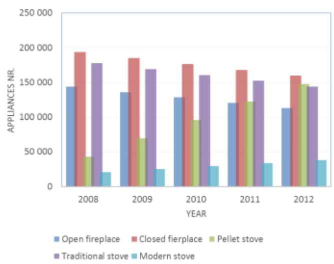

Fig.2 Appliances number trend evolution for Lombardy.

Conclusions
Figure 2, depicts the trend of technology distribution for domestic wood burners from 2008 to 2012. According to CATI for 2008 (JRC, 2010) in Lombardy the total number of appliances was in the range of 500 000 – 600 000 units. The simulated increasing of pellets stoves is in good agreement with new national statistics (ISTAT, 2015) and with data from producers (http://www.federforeste.it/)

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REACTIVE OXYGEN SPECIES FOUND IN URBAN $PM_{2.5}$ AND PM_{10}: CHEMICAL ANALYSIS AND SOURCE APPORTIONMENT

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Summary

Ambient air particulate matter contains redox reactive constituents (organic substances, metals) that contribute to the production of Reactive Oxygen Species (ROS). Linear regression between a marker of ROS (DTT activity) and aerosol chemical components revealed strong associations between ROS-generation potential and biomass burning markers. ROS activity was found to be associated with high concentrations of BC, metals, PAHs and K found in $PM_{2.5}$ in urban settings.

Introduction

The concentrations of PM_{10} at urban sites increase during the winter due to the combination of strictly anthropogenic urban emissions such as traffic and domestic heating, and meteorological conditions such as the prevalence of anticyclonic scenarios. Over the last three years, biomass was used as heating source in the large metropolitan areas of Thessaloniki affecting a large amount of the city population. At the same time the use of light heating diesel was heavily taxed (Sarigiannis et al., 2014). In the same period Greece faces a financial crisis with significant repercussions on the average household income. This combination resulted in reduced traffic loads but excessive biomass use for domestic heating during wintertime.

Methodology and Results

An extensive campaign was carried out over the last three winters from January to April 2013, from December 2013 to the end of March 2014 and from December 2014 to March 2015, at two locations in the urban area of Thessaloniki. Two sampling sites were used. The urban background site is located in the Ilioupoli district of western Thessaloniki, a densely populated area where road construction and elevated buildings do not foster pollutants dispersion. PM samplers were placed on the roof of a building at a height of approximately 9 m above the ground. No significant traffic sources were in close proximity to the site. The traffic site is located at the campus area of Aristotle University of Thessaloniki, at six meters from the ground, about 50 meters from the main highway of downtown Thessaloniki, Egnatia Street. For the collection of aerosols, low volume samplers were used (TCR-Tecora). $PM_{2.5}$ and PM_{10} samples were collected on PTFE filters (Pall Corporation, 47 mm diameter) for 24 h. Samples were analysed for black carbon, ionic species, metals, PAHs, levoglucosan and ROS generation. Dithiothreitol (DTT)-based chemical reactivity is considered a quantitative method for the assessment of the capacity of PM to catalyse ROS generation. The redox activity of a sample is based on the ability of the PM to catalyse electron transfers between DTT and oxygen in simple chemical systems (Li et al 2008). $PM_{2.5}$ and PM_{10} samples were stored at -20 °C in the dark prior to use. For sample measurement, a cycle filter punch with a known mass of $PM_{2.5}$ and PM_{10} was added to the DTT vial and the rate of DTT loss was monitored over time. Ambient air data showed a high concentration of PM_{10} (73.1 μg/m3) and $PM_{2.5}$ (62.7 μg/m3) during the sampling period. While the contribution of traffic to ambient air PM is reduced, during the sampling period the contribution of biomass heating increases up to 34%. At the traffic site Fe, Cu and Zn had higher concentrations than at the urban background site. K, a key biomass tracer, had higher concentrations at the background site indicating the presence of another strong combustion source beyond traffic. This was found to be the use of biomass burning for space heating. The oxidative potential of $PM_{2.5}$ was the highest, while the one of PM_{10} follows. The same tendency was observed at both sampling sites. On mass basis, fine particles had higher oxidative potential than coarse particles due to their higher active surface and, consequently, specific absorption capacity. $PM_{2.5}$ has a higher surface area to volume ratio than PM_{10}. A simple linear regression was conducted between the measured concentrations of various chemical components and volume based DTT activity. DTT activity was best correlated with BC and K.

Conclusions

Chemical analysis proved that the oxidative potential of PM is not correlated to its mass. On the contrary, a strong correlation between chemical composition and oxidative capacity of PM exists. Thus the potential of chemical compounds of urban atmospheric aerosols to generate reactive oxygen species (ROS) and identify major ROS-associated emission sources was assessed. ROS activity was found to be associated with high concentrations of metals, PAHs and levoglucosan found in $PM_{2.5}$. $PM_{2.5}$ is generated by combustion, such as diesel exhaust and biomass burning for domestic heating. Furthermore, PM_{10} constituents comprise ground particles, such as dust and pollen. In addition, although at lower amounts than $PM_{2.5}$, PM_{10} may be derived from biomass combustion processes, too. Positive matrix factorization (PMF) was applied to apportion the relative contribution of various sources to the ROS-generation potential of chemical species of $PM_{2.5}$ and PM_{10}.

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OUTDOOR AND INDOOR MEASUREMENTS OF BIOMASS COMBUSTION INDUCED BLACK CARBON, CO AND PAH IN A RESIDENTIAL AREA

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Summary
Caused by complaints on bad air in the residential area of Dettenhausen in Southern Germany, this study aimed to investigate to which extent the local air quality is affected by wood combustion smoke from domestic heating during the winter period. Based on former studies (Bari et al. 2011) the air quality measurement campaign was carried out covering a winter period from December 2014 to March 2015 in order to characterize worse air quality which might occur during inversion situations. Besides meteorological parameters, the following air pollutants were measured: Black Carbon (BC), portion of Biomass Burning BC (BB%)(with Magee AE33), CO, PM10 and particle-bound PAHs. Concentration profiles of the pollutants are illustrated. The wood burning tracer levoglucosan was also determined and its correlations with the above mentioned pollutants especially with BC and BB% are determined and discussed. During one "inversion week" in February 2015 the influence of the outdoor smog on indoor air was investigated. The windows could not held open over night because of the strong odour from wood combustion. The message is: Keep the windows closed under such conditions!

Introduction
Wood burning for room heating is one of the main sources of particulate matters in residential areas, which deteriorates the local ambient air quality through the emission of incomplete combustion products, primary particulate matter and gas pollutants like VOC, PAHs and CO. Studies aiming at the estimation of the wood burning contribution to PM, organic carbon (OC), Black Carbon (BC) and toxic PAHs in ambient air are of worldwide interest.

Methodology and Results
Air quality measurement campaign: Particulate matters (PM10) were sampled from ambient air and subsequently chemical analyses of the samples for the characterization of particle-bound PAHs and wood burning tracer levoglucosan were carried out in lab. Meanwhile BC, CO and meteorological parameter were continuously measured. Indoor air quality measurement in a residential apartment: PM10 was both sampled for periods from 24 hours to 48 hours using low volume samplers and continuously measured with a laser aerosol spectrometer. Other pollutants BC, CO and temperature were continuously monitored when the wood was burning in the stove in the living room.

The results show that ambient PM10 concentration presented fluctuations. During two periods one in Feb. und the other in Mar., which are identified as inversion periods, PM10 was observed to be over 30 µg/m³. The 24 filters chosen for PAH analysis were however not from inversion periods but certain amount of PAHs were still detected with some daily average BaP over 1 ng/m³. Wood burning tracer levoglucosan was found in the PM10 samples and the portion to PM ranged from 0.08% to 12.7%. The ambient BC concentrations showed a fluctuated profile with an average of 1.5µg/m³, and a daily average biomass burning contribution of 33%.

As to indoor measurement during the February inversion period, from the comparison of both integrated samples and online measurements, the indoor daily average PM10 was significant lower than outdoor, with an average indoor/outdoor ratio: I/O=0,35. Black carbon profiles agreed well with that of PM10, while the BB% showed relatively high portions revealing BC mainly originated from wood burning. During this event Co showed outdoor higher concentrations than indoor.

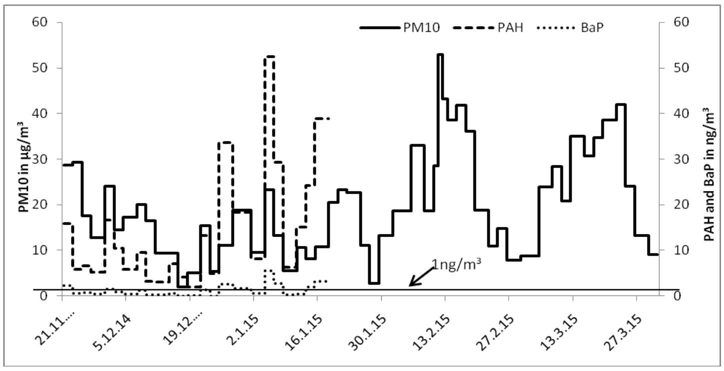

Fig.1: PM10, PAH and BaP profiles

Conclusions
In the studied area, PM10 appeared relative high values during inversion periods and the share of levoglucosan found in PM10 indicated that the contribution of wood burning is significant. Meanwhile, BC measurement also showed over 30% contributions from biomass burning to BC. Indoor air quality measurement showed however lower pollutant concentrations when the windows kept closed during night.

Acknowledgement
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THE IMPACT OF WOOD BURNING FOR RESIDENTIAL HEATING ON AIR QUALITY IN MILAN AND THE PO VALLEY: ANALYSIS AND PERSPECTIVES

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Summary

Despite the common perception of people, wood burning in small domestic appliances has an important impact on air quality in Milan and the Po Valley. The fraction of heat from residential heating using wood is increasing, due to the lower price of this fuel compared to that of other ones and to the policies in favour of renewable sources. Emission inventory data show that wood burning for residential heating is the first source of primary PM10 and B(a)P in Lombardia region and one of the prevalent sources in Milan agglomeration, too. The higher values of B(a)P are not found in the city downtowns but in the suburbs and in the valleys, where the use of wood is more widespread. All the source apportionment studies realized confirm the importance of this source, both on the PM10 and B(a)P concentrations.

To implement effective actions to limit the impact of this source and to make compatible air quality and climate change mitigation policies it is essential to consider all the aspects that can influence emissions from this source, starting from the awareness and education of people, to the good installation and maintenance of the stoves and fireplaces, to the improvement of the quality of the appliances and of the fuels (with particular reference to pellets constituents). Although the modern stoves are much more performant compared to the old ones, further technological developments should be required.

Introduction

The Po Valley is surrounded on three sides by mountains exceeding 2500 m above sea level and it experiences meteorological conditions that are often adverse to air pollution dispersion. More than 20 millions of people live in the basin, whose 10 million in Lombardia, the largest region of the valley, with a population density of more than 3000 inhab/km2 in Milan, in the centre of the area. The Po Basin represents an important area also in terms of produced wealth (more than 50% of the Italian GDP). These features make it particularly difficult to achieve levels of air quality compatible with European limits, in particular for particulate matter. B(a)P exceedances to EU standards are registered, too, above all in the areas where the use of wood is more widespread, on the bottom of alpine and pre-alpine valleys.

Methodology and Results

In Lombardia, emission inventory data show that wood burning from residential heating is the first source of primary PM10, accounting almost 40% of the regional PM10 yearly emissions, despite to the fact that the 87% of the energy required to heat buildings is obtained from natural gas, and only 7% from wood. In the downtowns of the biggest cities the contribution of wood combustion on PM10 total emissions decreases remaining anyway one of the main ones (22% in Milan municipality). All these percentages increase during the cold season, when the higher PM concentration are registered. With 70% of the regional emissions, wood burning in stoves and fireplaces is the principle source of B(a)P, too.

Different source apportionment studies were conducted based on the analysis of specific tracers like levoglucosan over the collected gravimetric PM samples from the air. The results confirmed emission inventories data: in the Po Valley the contribution of wood burning to PM10 mass varies from year and season, arriving to 24% in urban stations (i.e. Milan), to 47% in rural plain stations (i.e. Parona), and to 59% in alpine and pre-alpine stations (i.e. Darfo).

In the framework of the scenario studies supporting Regione Lombardia Air Quality plan, different hypothesis have been investigated, showing that the complete substitution of the obsolete stoves by stoves equipped with the Best Available Techniques (BAT) could reduce the PM emission factors from this source by one order of magnitude, still remaining two orders of magnitude higher than those of natural gas, and one order than those of gasoil for domestic heating. The introduction of regular good maintenance practices could contribute to reduce emissions, too.

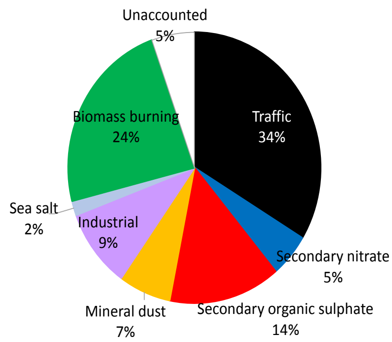

Fig.1 PM10 source apportion result in Milan urban background station (from AIRUSE LIFE+ project)

Conclusions

Wood burning is one of the most important sources of PM and one of the toxicologically relevant compounds, such as B(a)P. Different actions are possible to reduce the impact of this fuel, going from the improvement in the maintenance operations to a replacement of oldest stoves with BAT models. To really make air quality compatible with climate change mitigation policies, it is necessary to continue on the path of technological development in order to arrive to appliances with emission factors comparable with those of other fuels normally used in modern cities together with a reduction of energy needs.

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ENVIRONMENTAL IMPACT OF BIOMASS BURNING FOR CIVIL USES ONTO A MOUNTAIN AREA

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Summary

The impact of biofuel combustion for civil uses onto the environment was investigated through determining a list of air toxicants at Leonessa, a town lying in Apennines mountain region, Central Italy, and in its surroundings (Terzone). Attention was focussed on suspended particulate matter (PM_{10}), polycyclic aromatic hydrocarbons (PAHs) and regulated pollutants (nitrogen dioxide, ozone and benzene).

Methodology and Results

Two in-field campaigns, each lasting two weeks, were carried out in summer 2012 and winter 2013. Contemporarily, air was monitored in downtown Rome and in other localities of the province. In the summer all pollutants were more abundant in Rome (e.g., PAHs, 0.93 ng/m^3, vs. 0.37 ng/m^3 at Leonessa and 0.14 ng/m^3 at Terzone; benzene, 0.9 µg/m^3 in Rome vs. 0.2 µg/m^3 at Leonessa), apart from ozone (73 µg/m^3 in Rome and >100 µg/m^3 at Leonessa). By contrast, in the winter PAHs were more at Leonessa (15.8 ng/m^3) than in the capital city (7.0 ng/m^3), and benzene was similar (2.3 µg/m^3), despite suspended particulates were less (22 vs. 34 µg/m^3). Due to lack of other important sources and the scarce impact of transport at mid (inter-regional) scale, biomass burning was identified as the major emitter of PAHs at Leonessa during the winter. Its importance was confirmed by the molecular signatures, pictured by PAH concentration ratios distinct from those of Rome. Other towns too experienced PM levels similar to capital city but higher PAH loads (~9.6 ng/m^3), suggesting that uncontrolled biomass burning contributed to pollution across the Rome province. Important differences among PAH diagnostic ratios were observed at the sites also in the summer; nevertheless, in this case the ageing of air masses could play a role.

Conclusion

PAH and PM10 were monitored in two in-field compaigns,. Biomass burning was identified as the major emitter of PAHs at Leonessa during the winter. In summer period important differences among PAH diagnostic ratios were observed. Despite, the suspended particulates were less than in Rome suggesting the lack of other important sources and the scarce impact of transport at mid scale.

Acknowledgement

This work was supported by the Italian Ministry of Education, University and Research.

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A CROWSOURCING TOOL TO IMPROVE THE ESTIMATE OF WOOD-BURNING EMISSIONS FROM DOMESTIC HEATING

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Summary
Our study will present a new method to improve estimation of wood – burning emissions from domestic heating in Norway. The method is being developed within the iResponse project that aims at improving and assessing information using communication technologies (ICT)-based crowdsourcing tools for environmental research and decision making. The project follows the principles of Responsible Research and Innovation (RRI), a concept gaining popularity among European policy makers for emerging technologies like nanotechnology and ICT (e.g. EC, 2013). We will develop a crowdsourcing tool to collect personal data about wood consumption for domestic heating, and we will use these data for estimating emissions. The purpose of the crowdsourcing method is to obtain high space and temporal emission inventory of wood burning for domestic heating. We will present the preliminary functionalities of the crowdsourcing tool and the methods to estimate wood burning emissions.

Introduction
More than half of the global population currently live in cities and by 2050 around 70% will do it so. This puts pressure on the urban environment and calls for smart urban development. ICT - enabled crowdsourcing has the potential to support urban environmental research and enable citizen participation. However, societal concerns exist about crowdsourcing, and especially regarding data protection, open access information and transparency in research results. As stated in the Science Special Issue "The end of privacy" (Enserink & Chin, 2015) "there are ways to protect the private information hidden in big data files, but they limit what scientists can learn; a balance must be struck". Our study focusses on the development and evaluation of ICT tools for citizen to be engaged in environmental research and decision making related to the urban environment through a transparent process, and that respects data privacy and social concerns.

Wood burning is one of the main contributors to particulate matter (PM) in Norway. Addressing this problem requires better knowledge of emissions and their contribution to pollution levels. Wood burning emissions in Norwegian urban environments are currently estimated based on information regarding annual wood consumption at regional level, stove technology, dwelling density and the corresponding emission factors. With data obtained through citizen participation and crowdsourcing, we aim at improving the emission estimates for high spatial and temporal resolution. Hence, a tool will be developed for gathering the needed input data from citizen participation. In addition, the potential social concerns from crowdsourcing tools will be mapped in a process based on collaboration with stakeholders, citizens and, social and natural scientist.

Methodology and Results
A tool and method for collecting data on wood consumption for house heating will be developed and, later, to be used for emission estimates. The application will gather high-resolution wood consumption data based on citizen's participation. The development of the tool is carried out based on a co-designing process involving ICT designers, social and natural scientists, and contributions from citizens and stakeholders. We will test the tool in urban areas during winter months when wood burning occurs. Data analysis will focus on the geographical distribution of participating citizens, amount of wood consumed and type of stove (open fireplace, new/old oven). Wood consumption data in Norway is available at relatively low spatiotemporal resolution (yearly values, regional levels). The crowdsourced data will allow production of wood burning emission maps at a hitherto unavailable high spatiotemporal resolution. The outcome of this application will improve the input for air quality models, supporting regulatory process to reduce the exposure of people to harmful pollutant levels more effectively. In our study, stakeholders were involved at the early stage of the development process. The results from stakeholder workshops aiming at mapping of the key challenges and opportunities related to the crowdsourcing tool will also be presented as an important output of the project.

Conclusions
Our study opens and promotes new ways of research, based on co-design and integration, and with possibilities to address a wide range of societal challenges. Crowdsourcing is a powerful tool to obtain high space and temporal emission inventory of wood burning emission from domestic heating. However, challenges and social concerns (data protection, transparency, open access) need to be taken into account in the design of the method.

Acknowledgement
This work is supported by the Research Council of Norway (247884/O70).

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AIR QUALITY IMPACT OF THE DIFFUSION OF HIGH EFFICIENCY PELLET BOILERS AT EU LEVEL

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Summary

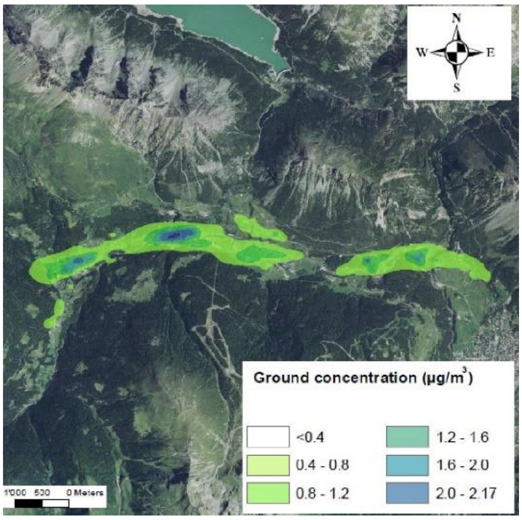
This research has been carried on in the framework of the EU FP7 Research Project "BioMaxEff" (Cost efficient biomass boiler systems with maximum annual efficiency and lowest emissions, 2011-2014 - www.biomaxeff.eu) aiming at the demonstration of ultra-low emissions and high efficiency small-scale pellet boilers. The work focuses on the environmental impact assessment (through national emission scenarios, air quality modelling on local scale, LCA and LCC analysis) of future market penetration scenarios of high efficiency pellet boilers [1].

Introduction

Due to biomass reduced costs and to Directive 2009/28/EU of 23/4/2009 on the promotion of the use of energy from renewable sources, biomass consumption for residential heating is growing at EU level. Nonetheless, the environmental impact due wood biomass combustion lead to higher emissions of particulate matter if compared to natural gas boiler, not only due to the wood biomass combustion phase but even to other processes, as pellet production. In this research the environmental impact of innovative pellet boilers is studied in terms of air emission, air quality and along the whole life cycle, for substitutions of old biomass boilers.

Methodology and Results

CO, PM_{10}, NO_X, SO_2 emission scenarios for 2 different EU case studies representative of an alpine (Valdidentro, IT) and rural (Lunz am See, AT) areas were developed. A spatial and temporal emissions disaggregation have led to high resolution pollutant-specific emission maps developed for the 2 case studies for the base case (2010) and for two future scenarios: the *Replacement scenario* (2020), assuming a "businesss as usual" substitution of old biomass boilers by innovative pellet boilers tested, and the *Market scenario* (2030), assuming a complete substitution of all biomass, coal and oil boilers by the innovative ones.



Air quality impact assessment analysis of this local emission scenario was performed using the dispersion model CALPUFF. In Figure 1 the Replacement scenario (2020) for PM_{10} in Valdidentro is shown. In the Italian case study, the substitution of half of the already installed wood biomass boilers with the new models would lead to reductions of NO_2 atmospheric concentrations in the range 0.3 -2.0 $\mu g/m^3$ over the urbanized area. With reference to primary PM_{10} concentrations, relevant reductions are evidenced with contributions to air quality in the range 0.4-2.2 $\mu g/m^3$. In the Austrian case study the same substitution would lead to a reduction of NO_2 concentrations up to 7%. With reference to primary PM_{10} concentrations, reductions are in the range of 0.1-0.4 $\mu g/m^3$.

In terms of emission impact assessment, different market penetration scenarios have been applied in the different EU27 States to estimate the emission reduction effect focusing on residential combustion. Energy efficiency scenarios for the EU Countries (2020-2030) have been also considered. The *Replacement scenario* always leads to a reduction of EU emissions (for all Countries and pollutants), while biomass *Market Penetration* reduces the impact only for some pollutants and some EU Member States depending on current residential emission factors.

Finally, LCA and LCC were performed using the SimaPro (v.8.015.13), adopting the ReCiPe Midpoint Method (European Hierarchist version) applied on three different high efficiency pellet boilers compared to traditional boilers (oil and gas).

Conclusions

Air quality could be improved in the short term (horizon: 2020) with the substitution of obsolete and end of life biomass boilers with high efficiency pellet boilers in EU areas where biomass represents the main primary source for residential heating. The results achieved in Valdidentro and Lunz am See have shown that a technology replacement for biomass residential boilers could significantly improve air quality in terms of primary pollutants concentration reduction from 5% up to 25% depending on the site and on the pollutant considered.

Acknowledgements

The research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under Grant Agreement n. 268217.

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USING A DISPERSION MODEL-BASED APPROACH FOR THE SPATIAL AND TEMPORAL DISAGGREGATION OF PM EMISSIONS FROM BIOMASS COMBUSTION IN HEATING SYSTEMS IN THESSALONIKI, GREECE

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Summary

Emissions from wood-burning devices used for heating have been recognised as one of the most significant sources of ambient $PM_{2.5}$ in several urban areas throughout Europe, particularly under unfavourable wintertime conditions. In this study, a combined receptor modelling and dispersion modelling approach is introduced, with the aim of taking advantage of the spatiotemporal information provided by an emissions database combined with the dispersion patterns as calculated by a chemical dispersion model. The methodology is applied with the aim to obtain spatially and temporally disaggregated source apportionment of PM in Thessaloniki, Greece. Results indicate a significant impact of wood smoke on $PM_{2.5}$ ambient levels, particularly in residential receptors around the city centre and most pronounced during the evening and early morning hours.

Introduction

Domestic wood-burning devices represent one of the dominant sources of $PM_{2.5}$ emissions in residential areas. During the last few years, a widespread substitution of domestic oil-burning heating systems with low-quality wood-burning units was observed in the Greater Area of Thessaloniki, Greece. Combined with the typically unfavourable wintertime meteorological conditions, this increase of $PM_{2.5}$ emissions is considered to be largely responsible for an overall increase of up to 30% over the 5-year average in the wintertime $PM_{2.5}$ mass concentrations, observed at a residential measurement site in 2013, while an increase of 20% was observed at the traffic-dominated centre of the city. At the same time, a distinct diurnal variation was registered for wood smoke tracers throughout the urban area, with significantly higher concentrations in the evening hours of the day compared to the morning. This work aims to quantify and spatiotemporally disaggregate the contribution of the domestic heating emissions on the total observed PM, through a combined receptor-dispersion modelling approach.

Methodology and Results

A receptor-based source apportionment of ambient $PM_{2.5}$ for the Thessaloniki Greater Area has been previously performed based on wintertime measurements at two urban sites and using the Robotic Chemical Mass Balance (RCMB) receptor model (Argyropoulos and Samara, 2011). In the present work, results of the RCMB model are incorporated in a dispersion calculation with the aim of taking advantage of the spatiotemporal information provided by the emissions database (see Fig. 1) combined with the detailed dispersion patterns as calculated by the chemical dispersion model MARS-aero. Based on source composition information from the RCMB source database, the chemical profile of individual source categories is introduced in MARS-aero and a series of simulations is performed using the zero-out method, revealing a refined temporal and spatial allocation of source contributions for each receptor. Mass closure of the time-resolved contributions is then obtained by normalizing the calculated concentraion profiles at receptor points on the basis of monitoring data. Calculated concentrations reproduce the observed increase of wintertime maxima of over 60%, or 120mg/m^3, compared to previous years. Furthermore, the calculated diurnal concentration pattern implies a strong impact of emitted wood smoke on the ambient $PM_{2.5}$ levels, especially in residential receptors peripheral to the city centre.. Dyring both typical weekdays and weekends the most significant impact of the heating sector occurs during the evening and early morning hours.

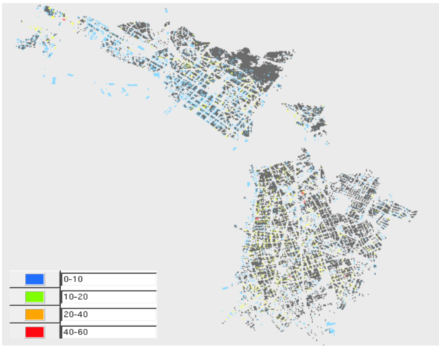

Fig. 1 Spatial distribution and density (units per building block) of domestic wood-burning installations in Thessaloniki

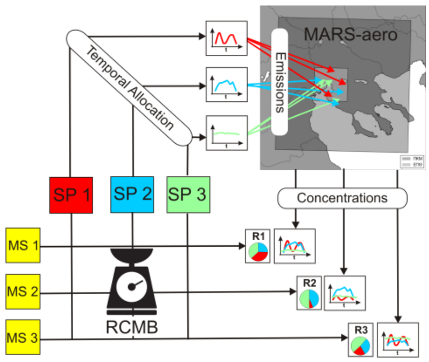

Fig.2 Schematic illustration of the combined use of the RCMB and the MARS-aero models for the apportionment of PM

Conclusions

A combined receptor modelling and dispersion modelling approach is developed for obtaining spatially and temporally disaggregated source apportionment of ambient PM. Results obtained for the Thessaloniki area reveal a dominant impact of domestic heating emissions on the wintertime $PM_{2.5}$ concentrations, especially in residential areas, with significant contributions occurring during the evening and early morning hours.

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HEALTH AND MONETARY COST ATTRIBUTED TO AEROSOL AND GASEOUS EMISSIONS FROM BIOMASS USE FOR SPACE HEATING

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Summary

Over the last years in Greece, the intense use of biomass for space heating resulted in increased ambient and indoor air pollution and enhanced population exposure to particulate matter and genotoxicants in particle and gaseous form such as polyaromatic hydrocarbons (PAHs). This study deals with the precise assessment of exposure to these pollutants and the related health and monetary impact. To these goals, measured and modelled data of outdoor and indoor PM10 and PM2.5 were fed into an integrated exposure assessment framework that takes into account indoor air quality, time-activity patterns of the exposed population and activity-based inhalation rates. Chemical analysis on the sampled PM allowed us to estimate the contribution of biomass burning to PM mass concentration and the associated increase in genotoxicity (expressed in terms of PAHs content and the respective toxicity equivalent quotient of the particle-adsorbed PAH mixture). Health impacts were assessed adapting well-established exposure-response functions as well as mechanistic exposure models; monetary cost of these impacts was calculated based on the valuation of the willingness-to-pay/accept to avoid/compensate for the loss of welfare associated with these health impacts. Overall, exposure to PM and PAHs due to biomass use was significantly increased and the estimated health burden was increased by more than 40%; the associated monetary cost rises to ca. €200m. PM from biomass burning is finer and more genotoxic than PM from traffic or other urban sources.

Introduction

Specific human activities result in significantly increased PM levels in the ambient and in indoor air. A typical example is the irrational use of biomass burning for space heating in Greece. Although the use of biomass for space heating was introduced as a CO_2-neutral means to foster global warming mitigation, a series of austerity measures combined with changes in the taxation of light heating diesel, resulted in irrational use of biomass for residential heating in the winter of 2012-2013.

Methodology and Results

A composite methodology was developed, that included (a) measurements of different size fractioned PM at multiple sites of the urban agglomeration, (b) chemical analysis of the respective particles for identification of sources contribution (levoglucosan, manosan and galactosan), (c) indoor air, exposure and lung deposition modelling for identifying actual uptake of PM across the different regions of the human respiratory tract and (d) health and monetary impact assessment. The estimated mortality is shown in Fig. 1. Almost 170 additional deaths are attributed to PM during the cold period compared to the cold period, although this refers to a period half of duration (4 months compared to 8 months). Similarly, an additional number of 100 respiratory and cardiovascular hospital admissions is expected during the cold period. Among the health endpoints of interest, the highest increase is related to the lung cancer estimated risk; although the overall incidence rate remains low (lifetime individual risk c.a. 10^{-6}), this was actually increased up to almost 6 times compared to the warm period. The associated monetary costs of the observed health effects are dominated by mortality costs, resulting in an increase of c.a. €200m (potentially up to a billion) in the cold period of the year compared to the warm period. Morbidity costs increase due to cardiovascular and respiratory hospital admissions are in the range of €250,000, while lung cancer risks costs (associated with exposure to PAHs in both the particle and the gaseous phases) are lower, mainly due to the low incidence rate.

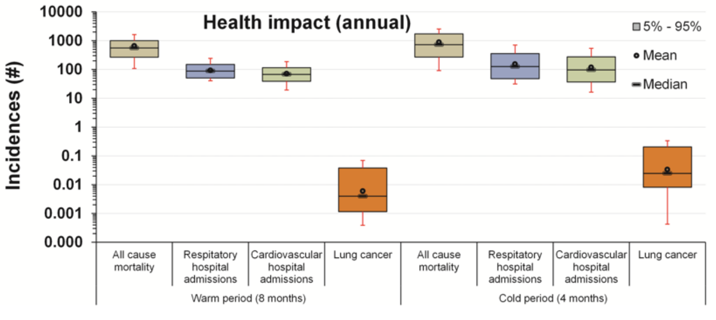

Fig.1 Health impact assessment of the associated health endpoints

Conclusions

Generally, the transition to the cold period (mid-November to mid-March) is accompanied by increased mortality accounting for ca. 200 deaths attributable to airborne particles (expressed on an annual basis) for a population of almost 900.000, reflecting a marginal cost of almost 250 million euro. A very important conclusion of the current study is that biomass emitted particles are i) more toxic in terms of PAH content compared to the ones related to other sources and ii) of lower aerodynamic diameter; as a result, more refined exposure and risk characterization methods are needed so as to properly account for their potential health effects.

Acknowledgement

The development of the risk assessment methodology was done in the frame of the LIFE+ ENV/GR/001040 project CROME (Cross-Mediterranean Environment and Health Network).

SPECIAL SESSION - AIR QUALITY MANAGEMENT FOR POLICY SUPPORT AND DECISIONS

INFLUENCE OF AMMONIA EMISSIONS ON PARTICLE FORMATION IN EUROPE

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Summary

In this study the influence of ammonia emissions on inorganic aerosol concentration in central Europe is investigated. Individual temporal profiles for fertilizer and manure application are calculated based on meteorological, livestock, and land use data for each model grid cell. Comparisons to EMEP observations indicate that the new ammonia emission module leads to a better agreement of modelled and observed concentrations of gaseous ammonia and particulate ammonium. In a scenario analysis it has been found that the planned European emission ceilings have only a minor impact on the formation of secondary particles. However, a reduction of NH_3 emissions from animal husbandry through behavioural change leads to a 24% reduction of total $PM_{2.5}$ concentrations in the model domain during winter, mainly driven by reduced formation of NO_3^-.

Introduction

The emission of reactive nitrogen into the atmosphere causes numerous problems ranging from eutrification to the formation of secondary inorganic particles. The NH_3 emissions in European are constantly increasing, as there has been little progress in controlling agricultural ammonia emissions. The influence of different ammonia abatement strategies on the formation of particles has been investigated through a scenario analysis where scenarios varying in intensity, release time, and temporal variability of NH_3 have been compared.

Fig.1: Annual variation of the daily NH_3 emission. The Standard and Dynamical Temporal Profile (STP) (Schaap et al., 2005) and (DTP) (daily mean, all grid cells)

Methodology and Results

The emissions were processed by the SMOKE-EU model suitable for the CTM CMAQ. The annual NH_3 emissions have been temporally distributed across the year on the basis of the meteorological variables wind speed and surface temperature, resulting in individual ammonia emission data for every grid cell and every hour (Skjøth et al., (2004) and Gyldenkærne et al., (2005). The evaluation with EMEP measurement stations indicated that the model is suitable for a scenario study where NH_3 is distributed differently in amount and time of the year. A political scenario (NEC 2020), a scenario representing the maximum technical feasible reduction (MTFR) (Amann et al., 2011) and a behavioural scenario (RCAP) based on a reduced consumption of animal products have been compared (Willett and Skerrett, 2005). The RCAP scenario shows a severe decrease in the $PM_{2.5}$ concentrations, mainly noticeable in winter (-24%). The reduction of the NO_3^- concentration found for the RCAP scenario in winter is -48%.

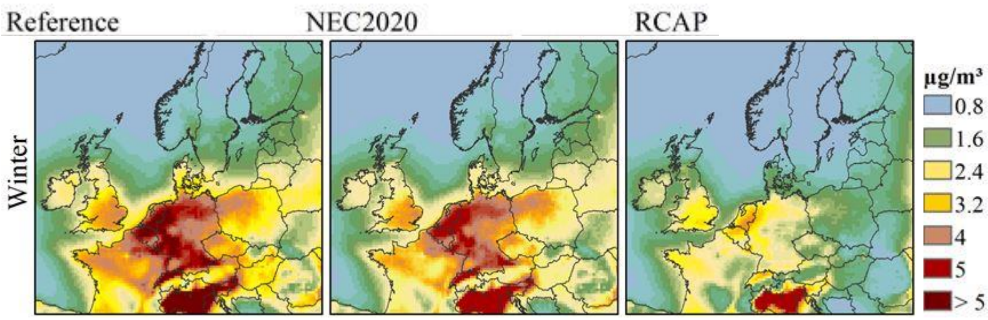

Fig. 2: NO_3^- reduction in winter in the Reference scenario, the political NEC2020 and the behavioral RCAP scenario in µg/m³

Conclusions

Through the implementation of dynamical time profiles the correlation between modelled and observed NH_3 concentrations has improved statistically significant at 14 out of 16 EMEP stations. It has furthermore led to an improvement of the NME and NMB of NH_3, NH_4^+ and NO_3. The main conclusion of this study, however, is the remarkable potential for air quality that a reduction of NH_3 emission in the cold season bears during which the potential of reduction within the animal husbandry is highest.

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MICRO-SCALE MODELLING OF URBAN AIR QUALITY TO FORECAST NO_2 CRITICAL LEVELS IN TRAFFIC HOT-SPOTS

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Summary
In this work we present a forecast modelling system implemented in the city of Torino to provide up-to-date hourly NO_2 concentrations at vey high horizontal resolution (6 m) on a 6 x 7.2 km^2 domain. Each day meteorological fields and background regional concentrations are provided by the forecasting system "QualeAria" (Kukkonen, 2012) while bottom-up traffic emissions are directly simulated with the three-dimensional parallel Lagrangian model PMSS, taking into account the presence of obstacles (buildings), on a 16 core (dual) workstation (64 GB total memory). Comparison of so far simulated values (about 3000 hours in the period April - September 2015) with measures in three monitoring sites (one urban background, one roadside in LEZ and one roadside) shows good agreement in reproducing peaks, daily behaviour and long term averages.

Introduction
NO_2 concentrations in the urban environment have shown little improvements in past years: monitoring stations, especially in road/kerbside sites, indicate that large urban areas are not in compliance with the legal limits, based on WHO guidelines. While atmospheric modelling systems are now routinely used both for assessment and informative purposes on regional and local scales, modelling pollution at street level on a city domain is still a challenging task, often demanded to gaussian-like models. On the other hand, not-stationary three-dimensional models need to be employed if we want to capture inhomogeneities in the ground level concentrations, forecast critical levels and successfully plan effective actions for reducing air pollution in cities.

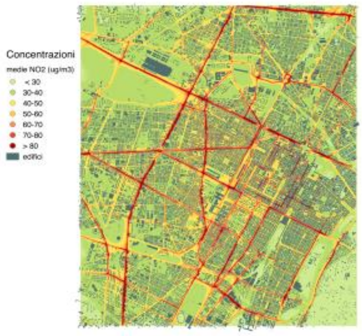

Fig.1 Monthly averaged NO_2 concentrations.

Methodology and Results
Micro-scale simulations are conducted on a 3d grid with 26 vertical levels, up to 1250 m. A parallelized 3d mass-consistent wind field model (Pswift) performs the downscaling of meteorological forecasts down to 6 m, taking into account buildings (filled grid cells). Bottom-up NOx traffic emissions on the main roads (Pallavidino, 2014) are complemented with diffuse emissions assigned to secondary streets, for a total of 13060 linear sources. NO_2 ground concentrations are computed hourly by using a parametrised box model (Kiesewetter, 2014), employing modelled O3 and NOx on a regional scale as a background, coherent with the meteorological forecast. Average values in the first month of simulation (see Fig. 1) reproduce in a realistic way observed differences between background and traffic sites. Compared with the regional model, the micro-scale forecast system is able to improve the modelling of peak events in traffic hot-spots as shown by the quantile-quantile plots in Fig. 2. In the considered period (April - September 2015) the absolute bias was -5 µg/m3 (28 µg/m3 average value) in the background station, 6.3 µg/m3 (36 µg/m3 average value) in the LEZ traffic station, -4.2 µg/m3 (53 µg/m3 average value) in the traffic station.

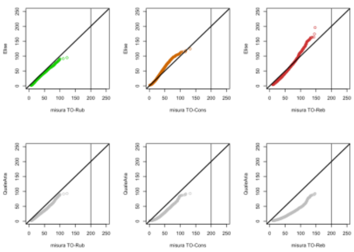

Fig.2 qqplot of microscale (above) and regional scale (below) model results in three monitoring sites (from the left: background, traffic in LEZ, traffic).

Conclusions
The forecast modelling system implemented for the city of Torino has so far proven to be in good agreement with measures and provides a solid framework to the Elise Project, focused on participatory sensing. Simulation of winter months, usually characterized by higher NO_2 concentrations and few exceedances of the hour limit value, will supply a more complete set of data for quality assessment in order to evaluate its suitability as informative tool and decision support system.

Acknowledgement
This work is part of the ELISE (Environmental LIve SEnsing) Project, partially supported by Regione Piemonte under POR/FESR 2007-2013 programme. Helpful discussions were held with G. Tinarelli (Arianet Srl) and A. Bertello (Città Metropolitana di Torino); Regione Piemonte and Città di Torino are kindly acknowledged for providing emission and cartographic data.

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HIGH RESOLUTION FORECASTING OF AIR QUALITY AND EXPOSURE FOR HEALTHIER CITIES (HIRAE)

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Summary

The HiRAE project is a collaboration between UK city authorities and researchers to make and exploit new high resolution air quality forecast and exposure data. The project has be co-designed by researchers and practitioners so that it can develop and implement new technologies that will directly aid progress towards compliance with EU air quality directives and reduce the health impact of air pollution. The two complimentary aims of the project are; 1) To establish a robust engagement plan with the Manchester and Bristol city authorities determining the best ways for the research and statutory communities to work together, and 2) To develop and operate a High Resolution forecasting system that is designed to fully integrate with local authority systems and requirements. The University of Hertfordshire-NCAS Air Quality forecast has been developed and extended to produce high resolution air quality data and exposure forecasts of NO_2, PM_{10} and $PM_{2.5}$, mapped according to street geometries and reflecting traffic and meteorological conditions. The output data has been designed to have maximum impact for Air Quality authorities.

Introduction

In the UK Local Authorities have devolved responsibilities to manage and control air pollution in towns and cities to ensure compliance with EU Air Quality Directive Limit Values. Despite implementing air quality action plans, many cities across the UK are experiencing exceedances and do not comply with EU limit values especially for nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$) (HoC EAC 2014). A major factor that hinders progress on Air Quality is the lack of scientific expertise and the financial resources to develop air pollution modelling, exposure prediction or forecasting capabilities. In this work we address this problem by working directly with local authorities to develop Air Quality modelling tools that are directly applicable to their needs.

Through early and close engagement with city authorities this project provides insight into best practise for outreach work, whilst also contributing novel Air Quality forecasting technologies that are fully integrated with local authority systems and requirements.

Methods

The Forecast System is driven by WRF-CMAQ. Simulations are performed for Europe at 50km resolution with a nested 10km domain for the UK. Meteorological boundary conditions are derived from NCEP FNL and chemical boundary conditions are from MACC II. The TNO emission inventory is processed using SMOKE adapted for the UK and Europe domains. Biogenic emissions are generated with MEGAN and the CB05 chemical mechanism is used with tri-modal to aerosol size distributions. Once the UK simulation is complete a city scale simulation is performed using the UH-OSCAR model and bespoke emissions inventories for Bristol and Manchester. Model interfaces have been developed to link CMAQ to the urban scale model and a suite of online data distribution tools including Web Data Dashboard and API provide access to the forecast and archive of data.

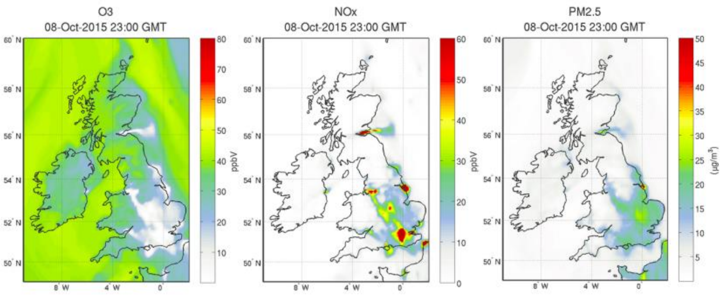

Fig.1 Ozone, NOx and PM2.5 forecasts for the UK domain

Discussion

By engaging with the local authorities in Bristol and Manchester from the outset of the project and maintaining a close relationship with them we have been able to determine precisely how to proceed, whilst maximising mutual benefits. This has been achieved through regular reporting of progress and frequent two-way discussion between all parties. The commitment to engagement has delivered dividends by sharing resources and ideas. New concepts such as integration of forecast data with city journey planners and traffic management systems are key examples of how the city authorities have been able to steer the project goals to focus on their interests.

Acknowledgement

This work is supported by the UK Natural Environmental Research Council (NERC), the National Centre for Atmospheric Science (NCAS), the Department for Environment, Food and Rural Affairs (DEFRA), Bristol City Council, Transport for Greater Manchester, Salford City Council and Oldham Council.

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THE ROLE OF AIR QUALITY MODELLING WHEN MAKING MAJOR POLICY DECISIONS IN THE UK

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Summary

A critique of modelling methods used to determine recent, major planning and infrastructure decisions in the UK is presented.

Introduction

The role of air quality management within a number of topical, high profile decisions in the UK is discussed. The decisions discussed encompass (1) the site of the next airport runway in southern England, (2) regional plans to comply with the European Directive NO2 limit values, (3) the introduction of an Ultra Low Emission Zone in London, and (4) the implementation of the Large Combustion Plant Directive in the UK. Each of these projects involves to a greater or lesser extent an air quality assessment describing the air quality effects of different management options. As one is looking to the future, this mainly requires modelling, with its inherent uncertainty, using the best scientific evidence available. The modelling approaches leading to recommendations will be reviewed, and judged against what might be considered the current, best available practice.

The air pollution effects are not fully understood and can occur over different scales. Future concentrations depend on interactions between different kinds of sources and different pollutants, adding to the complexity of the decision making process. In addition uncertainty regarding future weather, future emission totals, because of technical, economic and social factors, and uncertainty with regard to future emission factors, such as those for diesel cars, suggest that a range of estimates should be made but this is seldom done. These projects also involve an impact assessment which compares the health benefits with costs to ensure that the decision avoids disproportionate social costs.

Conclusions

For the practical reasons these uncertainties have been ignored, or have been left to be implied, in the decision making process. With these factors in mind the approaches used in each of the schemes is judged on practical and scientific grounds. There is shown to be a considerable difference between what would be regarded as leading science and the methods adopted for these major decisions. This gap is shown to be more acceptable if the nature of the uncertainties are made more explicit. Whether the introduction of uniformly applied, recommended methods would help to close the gap is also discussed.

IDENTIFYING AIR QUALITY EPISODIC EVENTS AND SEASONAL CHANGES OVER THE UK USING SATELLITE OBSERVATIONS OF TROPOSPHERIC NITROGEN DIOXIDE

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Summary
This study presents the spatio-temporal patterns of tropospheric NO_2 columnar density, derived from the Ozone Monitoring Instrument (OMI) aboard AURA satellite, over UK from 2005 to 2014. The patterns have been used to identify the annual trends, the NO_2 episodic events and seasonal cycles. Temporal trends indicate that tropospheric density for the period 2005 to 2014 is within 1 to 3 x10^{15} molecules/cm^2. During winter and spring of 2012 and 2013, exceptionally high densities (~10^{16} molecules/cm^2) were observed, which will be investigated further using meteorological and inventory/ground measurement datasets available from the UK automated urban and rural network (AURN).

Introduction
Air quality regulations require routine monitoring of surface concentrations of several species including NO_2, and monitoring networks have been established for the same (URL01). Measurements from ground-based monitoring networks represent only relatively small areas in the vicinity of the stations, and are limited in coverage at regional to global scales. The purpose of this study was to understand the usefulness of the data from a space-borne platform such as Ozone Monitoring Instrument (OMI) located on on the Earth Observing System (EOS) AURA satellite, which provides a one hour near-daily global pollutant measurement at a spatial resolution of 24×13 km^2 at the same time each day.

Methodology and Results
The spatial and temporal patterns of tropospheric NO_2 columnar density, given by OMI sensor aboard AURA, were analysed (Boersma et al., 2011), over UK (grid: 49 to 61° N, -9 to 2° E) for the period 2005-2014. The OMNO2 Level 2 (version 3) data product (pixel size 24×13 km^2) (Krotkov and Veefkind, 2012) was accessed and processed using DataFed (Husar et al., 2008). The spatial patterns (annual, seasonal and monthly) were generated by temporal aggregation over the given time period for each pixel in the grid. Annual patterns indicated high columnar loading (~5-7x10^{15} molecules/cm^2) over south-east UK, with major "hotspots" over the region around London, Sheffield and Liverpool. Though the tropospheric density does not vary much from 2005-2014 (1 to 6 x10^{15} molecules/cm^2); high columnar loading (~7-8x10^{15} molecules/cm^2) was observed for the years 2012 and 2013. Higher densities (1.5 to 3 x10^{15} molecules/cm^2) were observed during spring and autumn, as compared to winter and summer (1 to 1.5 x10^{15} molecules/cm^2). Seasonal patterns for 2012 and 2013 show that the winter and spring of 2012 and 2013 exhibit very high tropospheric densities (~8-9x10^{15} molecules/cm^2) with levels greater than 1x10^{16} molecules/cm^2 being observed during Winter 2013. Further analysis of these initial observations in conjunction with the UK emission inventory and meteorology datasets will provide a better understanding the winter/spring episodes of 2012 and 2013.

Conclusions
This study shows much promise in the use of satellite data for air quality management and has delivered a first step in both spatial and temporal domains. Seasonal episodic events of 2012 and 2013 provide an opportunity for further investigation using ground measurements and meteorological datasets.

Acknowledgements
We acknowledge Professor Rudolf B. Husar and his team, Washington University in St. Louis, for access to DataFed; and the free use of tropospheric NO_2 column data from the Ozone Monitoring Instrument (OMI) sensor aboard AURA satellite, from www.temis.nl. Funding from British Council through UKIERI project 'NAMPSER' between Newcastle University, UK and IIT Bombay, Mumbai is acknowledged with gratitude.

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FAIRMODE'S EU COMPOSITE MAPPING EXERCISE

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Summary
This study presents the first results of a new FAIRMODE capacity building initiative. National, regional or local air quality assessment maps are collected in a "composite mapping exercise" with the objective to trigger discussions on the specific choices in the modelling setup (selection of emission inventory, data assimilation scheme…) and to improve the overall European modelling capabilities in support of the Air Quality Directive.

Introduction
FAIRMODE (Forum for AIR quality MODElling) has the aim to bring together air quality modellers and users in order to promote and support the harmonised use of modelling practices in the framework of the Air Quality Directive. The forum is a response action of the European Commission Joint Research Centre towards the new Air Quality Directive with support of the Environmental European Agency and DG Environment. A recent survey completed by the National Contact Points pointed out that modelling activities have a clear added value to the policy making process but there is still a lack of clarity in legislation and a lack of common guidance on how to apply models in support of the implementation of the Air Quality Directive. Over the last couple of years FAIRMODE-WG1 has focused on a QA/QC methodology (e.g. Model Quality Objectives) and a Benchmarking process for air quality assessment. At present there is more and more consensus within the community on the proposed methodologies and first steps towards a CEN standardization process have been made. Although tackling the QA/QC problem is for sure a big step in the right direction to provide common guidance, it is not sufficient. Remaining open questions within the modelling community are for example: when is a model fit for purpose (adequate resolution, adequate assumptions…)? how best to combine modelling results with monitoring data…? Providing answers to those questions is seen as the next challenge for WG1 and FAIRMODE in general.

Methodology and Results
In order to open the discussion on the questions mentioned above, FAIRMODE initiated an activity aiming at collecting and assembling modelled air quality maps, following the work initiated in the ETC/ACM pilot study (De Smet et al, 2013). The objective is to create a bottom-up composition map of air quality over Europe. National/regional agencies or modelling teams are encouraged to provide their best available air quality map for their particular region and those maps are being compiled into an (hopefully) EU-wide bottom-up composite map. This mapping exercise is used as common platform within FAIRMODE and as a catalyst to trigger discussions on:

- Border effects becoming visible between neighbouring regions/countries
- Use of data assimilation or data fusion techniques to produce air quality maps
- Quality and consistency of underlying emission inventories
- Choice of an adequate spatial resolution for a particular application
- …

Furthermore, the exercise is also used to convince countries or regions that are not yet using models on a regular basis to participate in the process.

So the objective of this exercise is in the first place capacity building. The platform improves comparability of assessment methodologies and makes it easier to learn from each other. A long term objective of the initiative is also to contribute to the formal e-Reporting process. Some Member States are already reporting modelling data in the official data flows and more Member States are expected to do so in the future. However, also here is a clear lack of guidelines on the use of models and reporting formats. It is not the objective of this initiative to deliver model data for the e-Reporting process but it is obvious that FAIRMODE can prepare the ground for a possible harmonized approach and contribute to reporting guidelines.

Conclusions
More than 25 modelling teams from 17 European countries have provided national, regional or local air quality maps so far. At present we only work with annual averages, but this could be extended in the future. All maps are collected in a FAIRMODE platform which offers the opportunity to visualise and analyse the composite air pollution map. The platform is used as a tool to discuss anomalies, choices for model resolution, explore the consequences of specific choices with respect to data assimilation/data fusion schemes, use of underlying emission inventories… The exercise is open for any modelling team in Europe using air quality models in support of the Air Quality Directive.

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CHANGES IN AIR POLLUTION EXPOSURE CAUSED BY REDUCED EMISSIONS VERSUS CLIMATE CHANGE IN STOCKHOLM, SWEDEN

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Objectives
The main objective of this work is to investigate the impact on future population exposure of climate change versus emission changes.

Introduction
Future climate change and control policies will alter the urban air quality [2]. For NOx and PM-exhaust we compare health benefits of three mitigation strategies - a motorway bypass outside Stockholm [1], no exhaust emissions (electric fleet), and a fossil free vehicle fleet - with climate change effects on the exposure. For O_3 we compare changes in exposure due to European and local emissions. We take into account effects of large-scale global climate change to fine-scale local emission change.

Methodology
The effects on NOx and PM exposure are investigated using a Gaussian dispersion model at 100m resolution. For surface ozone, we used nested model calculations from global (50 km) to local scale (1 km over Stockholm). An Eulerian chemistry-transport model (MATCH) was used to analyse impacts on the air quality 2050 of climate change compared with changing European and local emissions. MATCH includes ozone- and aerosol-forming photochemistry with 60 species.

Results
Figure 1 shows the potential reduction in NOx and PM-exhaust exposure of introducing a fossil fuel free (FFF) vehicle fleet compared to removing all exhaust emissions. In the FFF fleet we assume that all diesel and gasoline vehicles would be electric and the remaining emissions (difference between no exhaust and fossil free) are due to existing ethanol, biogas and biodiesel vehicle emissions.

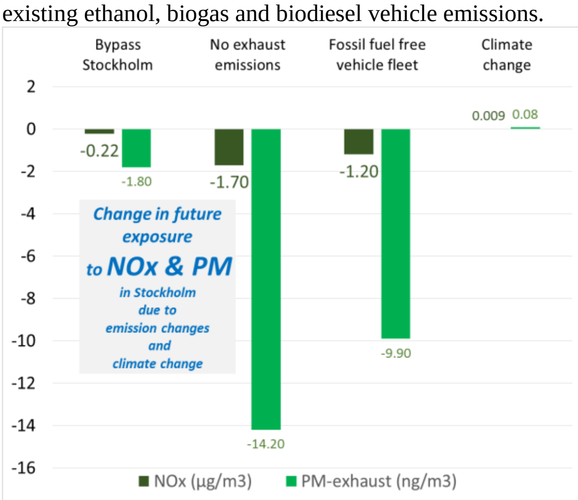

Figure 1. Change in population weighted exposure concentrations for the three emission scenarios and one climate change scenario for the Greater Stockholm area (ca 1.6 million inhabitants).

It is seen that the planned bypass will be much less beneficial for reduced population exposure compared to the FFF scenario and that climate change alone has negligible effect on the exposure.

Future O_3 exposure in Stockholm will decrease due to projected lower European precursor emissions (Figure 2). If the emissions would be the same climate change alone is predicted to cause lower ozone exposure, but the effect is very small compared to lower European emissions. Exchanging all vehicles to electric will cause increasing ozone exposure in Stockholm (due to less NOx), but this is a very small effect compared to the decrease of ozone exposure in Stockholm due to climate change alone.

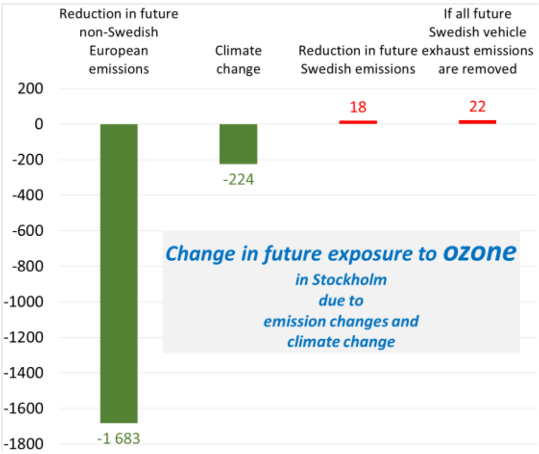

Figure 2. Change in population weighted exposure ozone concentrations due to changes in precursor emissions in Europe and Stockholm, climate change, and if all exhaust emissions in Stockholm would be removed.

Conclusions
The European-wide emission change from present to mid-century causes a strong decrease in particle and ozone concentration, far exceeding the impacts of climate change or local mitigation on the urban background scale in Stockholm.

Acknowledgement
This project was funded by the Swedish Environmental Protection Agency as part of the ERA-ENVHEALTH action plan.

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FUSION OF AIR QUALITY INFORMATION BASED ON THE COMBINATION OF STATISTICAL AND DISPERSION MODELLING APPROACHES

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Summary
A FMI-ENFUSER modelling system is presented, an application which utilizes both Land Use Regression and dispersion modelling. With this combination of techniques the hourly concentration of particle matter ($PM_{2.5}$ and PM_{10}) and NO_2 was accurately predicted in several selected urban test sites in Finland. FMI-ENFUSER can be used also in other regions, provided that an extensive training dataset and GIS-based information is available for the selected region. In the fusion of information modelled background concentration data can be used simultaneously with a heterogeneous set of sensor measurements that can be of variable quality. The system has been implemented in the city of Langfang, China, utilizing as input data $PM_{2.5}$ measurements from 5 sensors and online weather data for the area.

Introduction
The amount of environmental information that can be used for the assessment of air quality in urban areas has increased substantially during the recent years. Low-cost sensors, disposable and wearable, are on their way to consumer markets and regional air quality forecasts are freely available online. It therefore makes sense to fuse the available information. However, the fusion of measured air quality data is especially demanding, since each data point is representative of the surrounding environment, meteorological conditions, human activities and background concentrations. Furthermore, the individual sensor quality must be considered.

Methodology and Results
In the assessment of expected hourly pollutant concentrations, the model combines Land Use Regression (LUR) and dispersion modelling techniques; we call this approach 'dynamic land use regression'. We treat land use data (e.g., CORINE, satellite images, OpenStreetMap) as proxies for emissions and weight the contributions of the sources based on the Gaussian Plume solution. The statistical model estimates are substantially affected by meteorology and the model operates three-dimensionally (also accounting for the influences of topography). As the approach is based on land Use Regression, the model does not require an emission inventory; instead, the training of the model requires a large calibration dataset for each pollutant. For instance, we have used more than 300 000 hourly measurements of NO_2 in Finland for the calibration of the model.
The fusion of information has been described in detail in (Johansson et al, 2015). The fusion can also include modelled and forecasted regional air quality data, for which we have used the FMI-SILAM model. This facilitates the possibility to produce forecasts for urban air quality for the next couple of days. Additionally, emission inventories, if available, can be added as additional layers of 'land use' data acting as area sources for emissions. In the particular case of shipping emissions, we use data provided by FMI-STEAM emission model. The resolution of the FMI-ENFUSER output can be as low as 10 x 10m^2 and the model can detect individual buildings and street canyons.

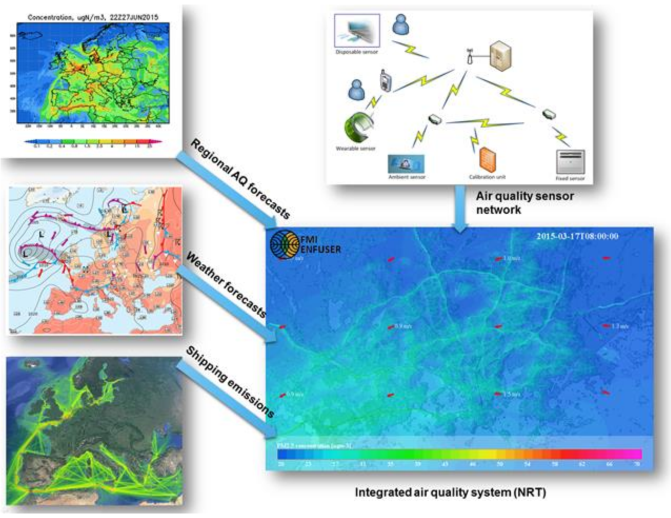

Fig.1 A schematic figure of an air quality estimation and forecasting system, utilizing a sensor network, regional air quality forecasts, weather data and shipping emissions. The example output describes a selected hourly $PM_{2.5}$ concentration in Helsinki, based also on local sensor measurements.

Conclusions
The presented dynamic LUR-modelling can be used for the assessment of urban air quality on a high spatial resolution, when local sensor measurements are available. The system has already been set up and evaluated for Finland, and implemented for a Chinese city of Langfang, for predicting the $PM_{2.5}$ concentrations. In cross validation studies conducted in Helsinki in 2011 it was shown that the model can outperform multi-source urban Gaussian dispersion modelling systems.

Acknowledgement
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MONITORING SHIPPING EMISSION REGULATIONS WITH IN-SITU MEASUREMENTS

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Summary

With in-situ measurements of carbon dioxide (CO_2) and sulphur dioxide (SO_2) within plumes emitted from ships, it is possible to calculate the sulphur content of the fuel the ships are using. Since January 1st, 2015, the regulations according to MARPOL VI have limited the sulphur content within Emission control areas such as North and Baltic Sea from 1 % to 0.1 %. This change has been observed from a measurement station at the Elbe River near Hamburg harbour (Kattner et al. 2015). Since then, a test station at this location for regular monitoring of compliance has been set up and further results from additional measurement locations will be presented.

Introduction

In order to reduce air pollution from shipping, the International Maritime Organisation (IMO) adopted MARPOL Annex VI. Since January 1st 2015, the allowed amount of sulphur in shipping fuel, which is responsible for SO_2 emissions, has dropped from 1% to 0.1% in Emission Control areas (ECA) such as the North Sea and Baltic Sea. This effectively excludes the use of heavy fuel oils by ships in this area. However, there is no continuous monitoring system available to verify that ships are complying with these new regulations. The project MeSMarT (Measurements of Shipping Emissions in the Marine Troposphere) has been established as a cooperation between the University of Bremen and the German Federal Maritime and Hydrographic Agency to estimate the influence of shipping emissions on the chemistry of the atmospheric boundary layer and to establish a monitoring system for main shipping routes.

Methodology and Results

Within the project, thousands of ships have been monitored with focus on their sulphur fuel content, which is estimated by the ratio of SO_2 and CO_2, both measured with in-situ instruments from a measurement station at the Elbe River near Hamburg harbour. It could be shown that almost all ships have been complying with the sulphur fuel content regulation before the change in January 2015 and despite the large change in sulphur fuel content, still 97 % are complying (see Fig.1). Furthermore, this method can be used to identify non-compliant ships and help authorities to target those ships for investigation. Additional measurements on the island Neuwerk near the coast and on the open sea from a research vessel are compared to show if the distance to the coast has an effect on the fuel regulation compliance as well as to extend the methodology to more complicated measurement situations. First results from Nitrogen oxide measurements are shown which are measured simultaneously with SO_2 and CO_2 for each ship plume and which will be subject to future regulation objectives within the Emission control areas according to MARPOL.

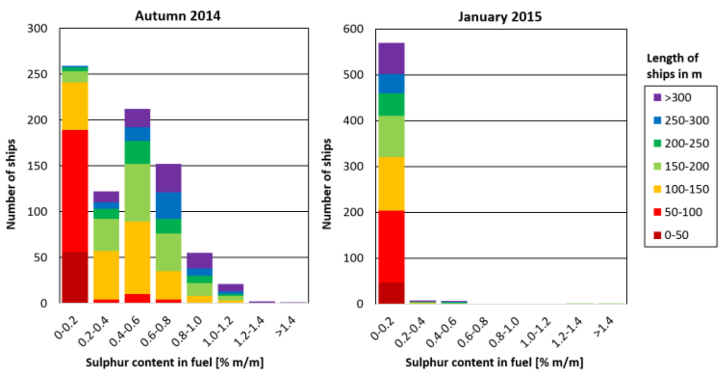

Figure 5: Sulphur fuel content of ships before and after the regulation change. (Kattner et al., 2015)

Conclusion

In-situ measurements of shipping emissions can effectively support the monitoring of compliance to the sulphur fuel regulations within MARPOL IV Emission control areas. It could be shown that 97 % of all measured ships comply with the new regulations and those that do not can be identified.

Acknowledgement

The research project which facilitated the reported study was funded in part by the German Federal Maritime and Hydrographic Agency and the University of Bremen. The authors thank the Waterways and Shipping Office Hamburg and the Institute for Hygiene and Environment, Hamburg, for their help and support.

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RIAT+, AN INTEGRATED ASSESSMENT TOOL TO EVALUATE EFFECTIVE AIR QUALITY MEASURES AT REGIONAL SCALE

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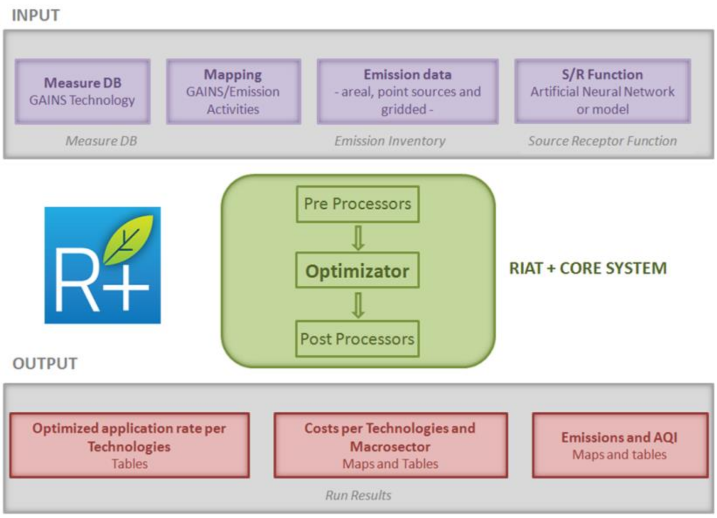
Summary
RIAT+ (the Regional Integrated Assessment Tool, www.operatool.eu) has been developed in the last 5 years to support regional/local authorities in the definition, application and evaluation of air quality plans, with the aim of reducing population exposure to PM, NO_x and O_3, and to reach compliance with EU Air Quality Directive. Its main features and applications are presented in this paper.

Introduction
Air quality in Europe is still facing continued and widespread exceedances, particularly regarding PM, NO_x and O_3. The EU Air Quality Directive (2008/50) requests Member States (MS) to design local and regional plans and assess their impacts on air quality and human health, in case of non-compliance. Managing environmental quality it is always a difficult task since it is the result of human actions on one side and of the natural, unmanageable context, on the other side. The complexity of the problem further increases when dealing with tropospheric pollutants, originated in the atmosphere from non-linear chemical reactions and physical processes involving precursor emissions (VOC, NO_x, NH_3, primary PM and SO_2). So, in recent years, integrated assessment models (IAM) to deal with these problems have been developed at continental scale and then adapted to the national scale.

Methodology and Results
RIAT+ system [1], partly developed during the OPERA project (LIFE09 ENV/IT/092), is an IAM tool designed to help regional decision makers to select effective air pollution reduction policies that improve the air quality, minimizing the costs related to the application of emission reduction technologies. It estimates:

- health impacts and costs related to mortality and morbidity due to population exposure to PM_{10}
- CO_2 emissions related to a set of policies.

Main input and output of the system are described in the Figure.



RIAT+ has been already applied in different EU Regions with various aims:

- in Emilia-Romagna Region (IT) in the optimization approach, to estimate the effectiveness of measures (both technical and efficiency) to be included in the Air Quality Plan (AQP)
- in Alsace Region (FR) in the optimization approach, to support the implementation of an action plan like SRCAE (Regional Scheme on Climate, Air and Energy) identifying the most effective technical and efficiency measures
- in Lombardy Region (IT) in the scenario approach, to estimate the costs and the benefits of both technical and efficiency measures contained in the AQP (i.e. VALUTA project)
- in Brussels Capital Region (BE) in the scenario approach to evaluate a reduced set of traffic and domestic heating measures
- in Porto Region (PT) in the optimization approach applied in Great Porto Area to focus the AQP on RIAT+ selected measures.

RIAT+ can be downloaded (free license) from the OPERA web-site (www.operatool.eu/download/). Finally SHERPA project (Screening for High Emission Reduction Potential on Air currently) currently developed at JRC, is going to enable RIAT+ tool to be used in a first guess approach, using input defined at EU level (both emissions and S/R receptor functions).

Acknowledgement
Thanks to Arpa Emilia Romagna (IT) ARPA Lombardia (IT), CNRS - Centre National de la Recherche Scientifique (FR), Université de Strasbourg (FR), ASPA in Alsace - Association pour la Surveillance et l'étude de la Pollution atmosphérique (FR), VITO - Flemish Institute for Technological Research (BE) and Aveiro University (PT) for their valuable contribution and applications.

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SUPPORTING DECISION-MAKING PROCESSES THROUGH POLICY ACCEPTABILITY ANALYSIS: THE CASE OF AIR QUALITY POLICIES

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Summary
While there is a broad consensus that public acceptability affects both the effectiveness and success of environmental policies, still it has not been fully internalized in the econometric models used to support environmental policies' adoption. Special attention is devoted to air quality policies that imply a behavioural change of individuals. Exploring different quality and quantitative approaches, we found that discrete choice analysis might offer a comparative advantage in supporting the decision-making process in particular when the implementation process regards a behavioural policy.

Introduction
The SEFIRA (Socio Economic Implications For Individual Responses to Air Pollution Policies in EU27) EU FP7 project has been conceived in order to support the review and implementation of the air quality legislation, improving its effectiveness and acceptability. This task has to be achieved through the coordination of trans-disciplinary scientific and socio-economic resources at the European scale. Air quality policies are not implemented in a social vacuum, they require a continuous interaction with individuals, often implying significant changes in their lifestyles. Thus, the extent to which people endorse a policy and find it acceptable is crucial in determining its effectiveness and success both at national and regional scales. However, while there is a broad consensus that public acceptability affects both the effectiveness and success of environmental policies, acceptability has not been fully studied and internalised in the models used to support the policies' adoption.

Methodology and Results
In recent years, individual preferences have been increasingly used to analyse environmental aspects and, in particular, Discrete Choice Experiments (DCEs) have become a popular stated preference method for environmental valuation since their first application in the context of environmental resources. In the literature on DCEs, acceptability is synonymous with preference. Accordingly, the most accepted solution is referred to as the most preferred policy alternative included in the choice experiments. In fact, DCMs (Discrete Choice Models) investigate people's preferences and their potential behaviour, identifying variables affecting individual choices between two or more "choice alternatives" (M. Ben-Akiva and Lerman, 1985). They help in analysing and predicting how people's choices are influenced by their personal characteristics and by the available alternatives. Each alternative is described by a set of specific features, called attributes, which in turn are described by attribute-levels. Making trade-offs between the various attributes-levels, the individual chooses the preferred alternative that yields greatest satisfaction or 'utility'. Within SEFIRA a choice experiment has been conceived made up by two unlabelled policies (choice alternatives), described by selected attributes. In the DCE the social aspects related to individual choices are taken into considerations and socio-economic data of respondents are used allowing to perform a segmentation analysis and highlighting socio-economic differences in the air quality acceptability across the seven European countries.

Conclusions
A lack of decision-makers' knowledge and awareness about how citizens would respond to a proposed policy can lead to ineffective efforts and unplanned effects. Often, policy interventions are adopted without reliable forecasts of the effects of the corresponding policy stimulus on the stakeholders. The results of our analysis are relevant in choosing measures according to their acceptability ranking.

Acknowledgement
This project is funded by the European Union under the 7th Framework Programme; Theme: ENV 2013.6.5-2 ENV.2013.6.5-2 Mobilising environmental knowledge for policy and society Grant agreement: 603941

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THE FRENCH EXAMPLE OF TACKLING AIR POLLUTION FROM BIOMASS FUELS: AN ESSENTIAL TIGHT RELATIONSHIP BETWEEN SCIENTIFIC RESEARCH AND PUBLIC POLICIES

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Summary
While the European PM_{10} limit values are not complied with in 10 areas in France, studies on annual emissions show that domestic wood-heating is the first emitting sector at a national scale. Therefore, acting on air pollutants emitted by biomass fuels has to be a priority in order to improve air quality in our country. In order to efficiently tackle this issue, the French Environment and Energy Management Agency (ADEME) works on strengthening the links between decision-makers, scientists and professionals of the wood-heating industry.

Background
In France, as in many industrialized countries, increase in wood burning for domestic heating has been part of climate change mitigation strategies. In addition to emitting very few CO_2, biomass is locally abundant in many French territories, is a cheap energy for households and represents 60 000 jobs in France. However, in the early 2000s, first scientists alerted ADEME on potential negatives impacts of this renewable energy on air quality, especially in the Arve valley in the French Alps, where the scientific program POVA showed an unexpected high participation of biomass burning to PM_{10} local concentrations. Studies on emissions completed these results revealing that 98% of wood-heating PM_{10} emissions came from individual systems. On the main time, great improvements had been made on technologies, especially with the development of the French “Flamme verte” label, putting on the market efficient individual wood-heating systems that emitted much less pollutants and had greater energy efficiency.

In France, domestic wood-heating currently emits 29% of PM_{10}, 42% of $PM_{2,5}$ and 67% of PAHs. These national emissions trends are confirmed in 9 of the 10 French areas that do not comply with the European regulation on PM_{10} limit values, as well as by local concentrations measures: in some areas and at certain times of year, biomass burning can be responsible of more than 50% of the PM_{10} concentrations. Therefore, acting on air pollutants emissions from biomass fuels has to be a priority in order to improve air quality in France.

Proposal for the presentation content
The presentation will illustrate the essential two-way relationship between scientific work and policy making, focusing on how ADEME works with all wood-heating stakeholders (researchers, decision-makers, professionals, citizens…) in order to reduce the negative impacts of biomass burning on air quality, while supporting the development of this attractive sustainable energy when efficient. In doing so, it will address the main strategic stakes of that topic:

- Improving knowledge on the actual air quality impacts of wood-heating (progresses on emission factors including primary and secondary pollutants, measures based on actual households use of wood-heating systems instead of official protocols…) and the different households practices (in terms of wood humidity and species, ways of starting a fire…) ;

- Improving technologies by developing efficient wood-heating systems (example of the French label “Flamme verte”) ;

- Improving fuel quality by creating a network of quality wood supply (example of the French label “France bois bûche”) and by strengthening public awareness ;

- Guaranteeing best practices among professionals by creating qualified professionals networks (example of the French certification “Reconnu garant de l’environnement”) ;

- Designing efficient policies to reduce emissions from the fleet of individual wood-heating systems, acting both on technologies and changing behaviours and social practices. To illustrate that point, the pilot operation in the Arve valley (2013-2017) will be presented. It aims to reduce by 25% the local PM_{10} emissions of that source, by financially supporting households to replace their inefficient wood-heating systems (open fireplaces and stoves built before 2002) by the most efficient products available (5 stars “Flamme verte”). Communication campaigns to raise public awareness on the best practices and strengthening the network of local stakeholders are also part of this operation. A scientific evaluation (impacts on air quality and on local economy as well as studies on social determinants) is currently running and will be introduced. This evaluation shall be of great interest for the future of public policy-making in that field. Based on the success of the Arve valley fund, the French government mandated ADEME to reproduce this experience in other French territories.

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MODELED TRENDS IN BACKGROUND OZONE FOR THE UNITED STATES OVER FIVE DECADES FROM 1970 TO 2020

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Summary

In this study we conduct modelling experiments to show how the US Background ozone may have changed over time from 1970 to 2020. The purpose of the study is to investigate the effect of changing anthropogenic emissions outside the U.S. on the background ozone and how that might impact the policy decisions regarding attainment of ozone standards.

Introduction

Estimates of the US Background (USB) for ozone (O_3) are critical inputs to the regulatory process for setting and implementing National Ambient Air Quality Standards (NAAQS) for ozone in the United States. USB is defined as the O_3 concentration in the absence of anthropogenic O_3 precursor emissions from the US. Analyses of trends in O_3 at rural locations near the west coast find that background O_3 is rising in response to increasing emissions outside the US over recent decades (Parrish et al., 2012).

Methodology and Results

First we used a global CTM, GEOS-Chem, to model global ozone and for several years between 1970 and 2020. The 2005 meteorology was used from the Goddard Earth Observing System Model, Version 5 (GEOS5). We developed year-specific anthropogenic emissions for all source categories and conducted GEOS-Chem simulations for the years 1970, 1980, 1990, 2000, 2005 and 2020. We then used a regional CTM, CAMx, to simulate regional ozone within the continental United States for the same years as the GEOS-Chem simulations, the results of which were used to provide boundary conditions to the CAMx model. For the CAMx simulations we zeroed out the U.S. anthropogenic emissions to obtain the USB concentrations of ozone.

Over five decades, from 1970 to 2020, estimated USB for the annual fourth highest maximum daily 8-hour average O_3 (H4MDA8) in the western US increased from mostly in the range of 40-55 ppb to 45-60 ppb, but remained below 45 ppb in the eastern US. USB decreased in the northeast US after 1990 follow declining Canadian emissions. Figure 1 shows predicted USB ozone for five representative cities in the USA. Background ozone concentrations in the western U.S. cities (Denver, Los Angeles, and Phoenix) have been rising from 1970 and are predicted to continue to rise from 2005 to 2020, whereas Philadelphia shows a decline after 2000 and Atlanta shows flattening of background ozone from 2005 to 2020.

Conclusions

In summary, U.S. background ozone concentrations have been steadily increasing in the western U.S., and is predicted to continue to increase in the future due to rising emissions from Asia and Mexico. This has implications for increased difficulty of attaining the revised ozone standards in the U.S., and must be taken into account.

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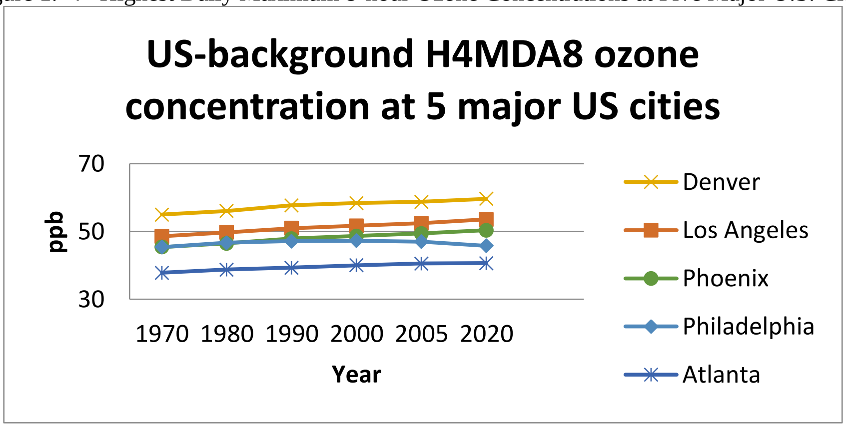
Figure 1. 4th Highest Daily Maximum 8-hour Ozone Concentrations at Five Major U.S. Cities



ENVIRONMENTAL ASSESSMENT OF LAST-MILE LOGISTIC OPTIMIZATION STRATEGIES

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Summary
This study aims to evaluate the effectiveness of different strategies involving last-mile logistic in urban areas. By means of traffic, emission and atmospheric dispersion models it was possible to quantify the environmental effects of freight transportation in city centres of two Italian cities, exploring the potential of different policies and scenarios in reducing the impact of this human activity on air pollution levels.

Introduction
Air pollution levels strongly influence well-being and life quality in urban areas, therefore municipal policies aim to increasingly act on sectors mainly responsible of pollutant emissions, like road traffic. Within it, commercial vehicles represent a key factor: the concentration of human activities rises the need of goods delivery, causing also obstructions in traffic circulation and increased rates of fuel consumption and pollutants releases due to vehicles weight and dimension. In 2014 a network of SMEs and Research centres promoted Opti-LOG project (http://www.optilog.it/en/home-eng.html) in Lombardy region (N Italy), promoting a system for monitoring sustainable mobility solutions concerning last-mile logistic and investigating their environmental effects, quantified in terms of emissions savings and related advantages on pollutants concentrations.

Methodology and Results
The assessment follows a "bottom-up" method, starting from the characterization of the current situation in freight distribution for two Lombard cities, Milano and Cremona, whose municipality were partners of the project, being interested in exploring effects of new policies. Alongside, the state-of-art alternatives in duty distribution involving fleet changes, selective circulation bans, interchange facilities or other experimental solutions like pack-stations and smart-platforms were quantified in terms of transport modifications on every link of the city road network. Then for each scenario the assessment of changed vehicles emissions, by means of models based on official EU methodologies (COPERT and HBEFA) of on-road emission factors for toxic and greenhouse gases. These data finally fed air dispersion models, together with meteorological data and detailed urban structure information. The analysis was focused on two different spatial scales, using different dispersion models: the whole historical center of Cremona, employing a Gaussian model, and a smaller domain including few street of Milano city centre, over which a micro-simulation was carried out by means of a Lagrangian model (SPRAY) including obstacles effects. Simulation results allowed to evaluate the absolute and relative improvements on air quality levels, pointing out that optimal logistic management in experimental area can lead to a reduction of pollution from duty vehicles up to 40% in case of trips optimization or 20% introducing pack-stations in Cremona historical centre, with respect to the business-as-usual scenario.

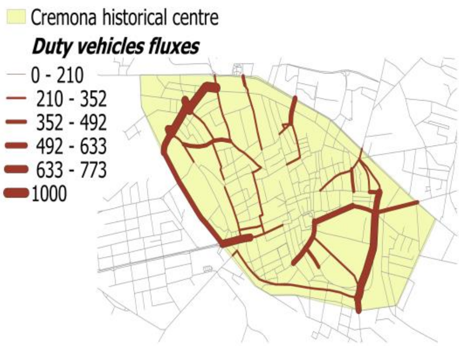

Fig. 1 Cremona road network assigned with commercial vehicles fluxes

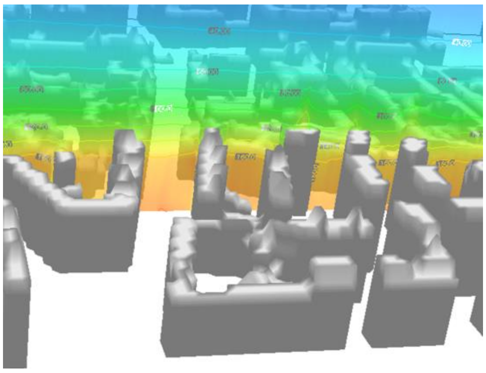

Fig.2 Vertical decay of NOx concentration in urban canyon estimated with micro-scale simulation

Conclusions
This work assessed the impact on traffic flows, emissions and air concentration of different last-mile logistic solutions. The combined use of traffic, emission and dispersion models in evaluating the effectiveness of alternative transport scenarios involving freight distribution and their contribution to urban air quality, allows to provide scientific bases for supporting decision makers in choosing the best urban development planning, evaluating the alternatives, quantifying their effects, and delineating their spatial extents.

Acknowledgement
Opti-LOG was cofunded by Regione Lombardia, Smart Cities and Communities call for proposals.

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SCALE ISSUES IN REGIONAL AIR QUALITY MODELING FOR POLICY SUPPORT

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Summary

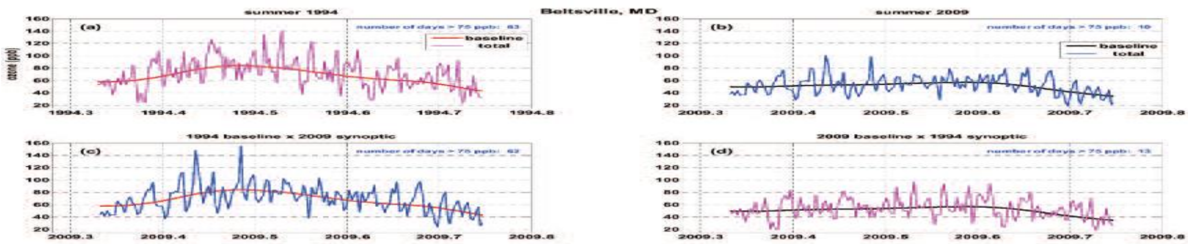
This study examines the issues relating to the use of regional photochemical air quality models for evaluating their performance in reproducing the spatio-temporal features embedded in the observations and for designing emission control strategies needed to achieve compliance with the relevant air quality standards. It is well known that various atmospheric processes, operating on different time and space scales, affect the pollutant concentration levels (Hogrefe et al., 2008). In this study, we apply a spectral decomposition method to observed and modeled pollutant concentration time series spanning a 21-year period from 1990 to 2010 for discerning the scales of most interest for policy-making. The results reveal that the long-term component (i.e. the sum of seasonal and inter-annual variations) and the synoptic component (i.e. weather-induced variations) are particularly relevant to the air quality management decisions.

Introduction

In the United States, regional-scale air quality models are being used to determine the emission reduction needed to comply with the national ambient air quality standards (NAAQS) for ozone and fine particulate matter. To address the ozone non-attainment problem, regional models are applied for an ozone season or less to determine the top ten percent of modeled ozone concentrations for the base case scenario. Then, emissions are reduced to assess how these high ozone concentrations change in response to various emission reduction options. The relative change in the modeled high ozone concentrations for different emissions control scenarios is then applied to the observed design value (i.e. the 4th highest ozone concentration) until the estimated design value is in compliance with the ozone NAAQS. The focus on episodic high modeled days in the regulatory application provides the motivation for this study, i.e., to gain a better understanding of the key processes and time scales controlling episodic events as well as the time scales most affected by emission reduction policies.

Methodology and Results

We applied the Kolmogorov-Zurbenko (KZ) filtering (Rao et al., 1997) to the time series of observed and CMAQ-simulated ozone concentrations to separate the long-term forcing (seasonal and inter-annual variations) and short-term forcing (intra-day, diurnal, and synoptic variations). The following figure illustrates the long-term variation (baseline) embedded in ozone time series for two years with substantial changes in emissions loading.



These four plots display the ozone levels at Beltsville, MD, for 1994 and 2009, two years distinguished by large differences in emission loading. Ozone levels were very high in the summer of 1994, with 63 days exceeding 75 ppb; this is because the baseline was very high. Given the same baseline but the weather conditions (synoptic forcing) that prevailed in 2009, also reveals the prevalence of high ozone levels, with 62 days exceeding 75 ppb (Plot c). Note, ozone levels were substantially reduced in 2009; a large decline in the baseline resulted in only 10 days exceeding the 75 ppb threshold (plot b). Given the 2009 baseline and the synoptic variation that prevailed in 1994, ozone exceeded 75 ppb on only 13 days (Plot d). For the present study, we extend this preliminary work to 21 years of both observed and CMAQ- simulated ozone time series data.

Conclusions

Emission control policies focus primarily on reducing the emissions burden over longer time scales. Results of this study clearly demonstrate that regional air quality models are most useful for evaluating the baseline (i.e. seasonal and long term forcing) reduction needed to comply with the relevant NAAQS. Integrated observational-modeling approaches are needed for the purposes of air quality forecasting, regulatory policy-making, and health risk assessments.

Acknowledgement

Although this work was reviewed and approved for publication by the U.S. Environmental Protection Agency, it does not necessarily reflect Agency's views or policies. Two of the authors (MA, HL) gratefully acknowledge EPRI's support for this project.

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FORECASTING AND ANALYSIS OF PM2.5 EPISODES AFFECTING THE UK - CONTRASTING LOCAL AND REGIONAL INFLUENCES

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Summary
A WRF-CMAQ based air quality forecasting (AQF) system has been developed at the University of Hertfordshire (supported by NCAS). A 72 hours forecast of particulates and gaseous pollutants have been performed on multiple grids. The emissions are based on the TNO inventory, which consists of anthropogenic emissions which are processed using SMOKE. MEGAN is used to process biogenic gas emissions. Air quality forecast has been evaluated for year 2014 to test the performance of the forecasting system. Measurement datasets from Automatic Urban and Rural Network (AURN) have been used to conduct discrete and categorical forecast verifications. Special emphasis has been given on fine particulate matter (PM2.5) concentrations and ozone. While the AQF system is able to capture the temporal variation of the particulate matter episodes, it tends to underpredicts peak concentrations. It has been found that the urban PM2.5 forecast tends to be more biased than the rural one. An analysis has been conducted to understand the evolution of particulate matter episodes across UK in 2014. The associated uncertainties in the forecasts are analysed in terms of the representation of boundary layer mixing processes, potentially missing emissions and chemical reaction rates for secondary pollutants.

Introduction
Ambient air quality is still a major problem in Europe because of adverse health impacts due to exposure to pollutants exceeding the EU limit. In order to follow EU guidelines and prevent critical exposure, real time forecast has to be provided. There is an increasing use of advanced meteorological and chemistry transport models to produce air quality forecasts. Although weather forecasting has a long history, the field of air quality forecasting is relatively new (Kukkonen et al., 2012). Over the last decade, there are significant developments in numerical weather prediction and chemistry transport modelling; and improvements in emission inventories and chemical boundary conditions (eg: MACC). This work presents a WRF-CMAQ based forecasting modelling system to investigate the causes of high air pollution episodes such as anticyclonic conditions, long range transport and entrainment of secondary air pollutants and to improve modelling capabilities to forecast air quality over urban to regional scales.

Methodology and Results
The AQF modelling system is based on CMAQ for chemical transport, WRF model as the meteorological driver. The forecast is set to run on multiple grids using one-way nests down from a European domain with 50km grid size to a UK domain with horizontal resolution of 10 km with 24 vertical levels up to 10 hPa. The emissions are based on the TNO inventory, which consists of anthropogenic emissions which are processed using SMOKE. MEGAN is used to process biogenic gas emissions. Meteorological initial (ICs) and lateral boundary conditions (BCs) of the outer domain are derived from the National Centers for Environmental Prediction (NCEP) GFS data. The chemical boundary conditions for CMAQ simulation will be derived from MACC-II. The simulated concentrations are in good agreement with the measurements across UK. The analysis of episodes suggests that there are two major episodes during 2014 when the PM2.5 concentration exceeded 50 μg/m^3. Lower PBL height and wind speeds were simulated and observed during these episodic events. The similar chemical composition of PM2.5 during episodes at urban and rural locations suggests the contribution of long range transport. The episode which occurred near 11-14 March 2014 is mainly dominated by nitrate aerosols originating from Eastern Europe. The second episode 31 March-04 April 2014 shows maximum contribution from the dust aerosols arising from the Sahara region.

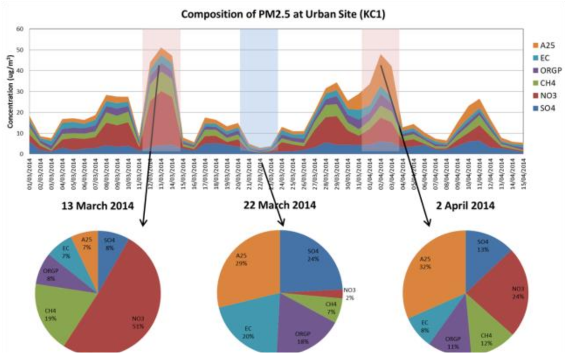

Figure 6: Composition of PM2.5 during episodes

Conclusions
A WRF-CMAQ based operational AQF system has been developed to provide near real time short term forecast across UK. Daily forecast has been compared with AURN network show satisfying agreement in terms of statistical indexes. While the AQF system is able to capture the temporal variation of the particulate matter episodes, it tends to under predicts peak concentrations. Urban PM2.5 forecast tends to be more biased than the rural one. The evolution of episode can be attributed to lower PBL height, wind speed and contribution from long range transport sources. The analysis suggest that some of the episodes were dominated by nitrate aerosols which are chemically produced due to ammonia emissions and some episodes show contribution of the dust aerosols arising from the long range transport from the Sahara region.

Acknowledgement
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SHORT TERM ACTIONS FOR ABATEMENT OF NO2: TRAFFIC AND AIR QUALTIY MODELING

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Summary

Norway is still not in compliance with the EU limit values and needs to apply more measures to reduce air pollution. In this paper we do a comparison of examples of short term actions for reducing exceedances of the NO_2 hourly limit value in the city of Oslo. We used a traffic model and a dispersion model to estimate the effect of each measures. All measures gave a reduction in NO_2 levels, but will likely not be enough in strong inversion episodes.

Introduction

Urban air pollution is a challenge in several European cities. For most Norwegian cities the major challenge is the reduction of the NO2 annual mean to comply with the limit value, but also too many high NO_2 hourly values do occur during strong inversions in cold winter periods. Such an event do not happen every year, but when it does the number of hours above 200 µg/m^3 quickly passes the legal limits of 18 and has reached up to more than 200 hours. Norway was summoned by ESA for air quality breaches and judged guilty by EFTA in September 2015. The legal process led to extra pressure on finding effective short-term as well as long-term measures in Oslo and other cities in Norway. In Oslo the main source of the NO_2 concentrations is diesel exhaust and hence the proposed short-term measures are targeting traffic.

Methodology and Results

Several examples of short-term measures were modelled for Oslo and surrounding areas. The 10 measures are variations of bans and sharply increased tolls, also including the proposal of temporary free public transport. The effect on traffic was evaluated with the use of a Regional Transport Model (RTM 23+) which is a transport and travel demand model calibrated with the Norwegian Travel Survey. The results from the traffic model, giving change in traffic volumes, were used as input to the Air Quality modelling system AirQUIS/Episode (Slørdal et al. 2008). The results from the example calculations were analysed in terms of relative reductions of NO_2 compared to the reference case. This was done for a week with high NO_2 levels, at several receptor points at traffic sites.

Most measures including an increase in the toll, up to more than 30 Euros, effectively reduced traffic over the toll passages, but increased the traffic inside and outside of the perimeter delimited by the tolls. The NO_2 reductions of the highest hours were estimated to be 4-24 % at the selected sites. Introducing a ban in a zone covering the central area of Oslo for diesel passenger cars gave a traffic reduction both inside and outside the zone and reduced NO_2 levels by 7-22%. Introducing a ban for older heavy duty vehicles (Low emission zone) as a permanent measure in combination with a short-term measure for light vehicles gave good results assuming Euro VI do have low emissions also in real driving. The effectiveness of a ban is hugely dependent on the sanctions for breaking it. On the other hand, only talk of introducing a diesel ban might already have changed people's car purchase as diesel fractions have decreased the last years. So even if short-term measures will not affect the annual mean directly such behavioural changes might. Previous studies have shown that traffic must be reduced to reach the annual limit value, which in return will decrease the need of short-term actions.

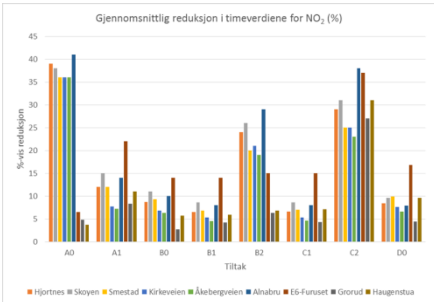

Fig.1 Relative reductions of NO_2 concentrations (in percent) for some of the modelled short-term measures, given at several road site receptors.

We will describe the examples of measures and present both effects on traffic and air quality. We will further discuss the limitations and challenges of introducing measures using the situation of Oslo as a case study.

Conclusions

Short term measures have to be severe in Oslo for preventing exceedances according to the EU legislation in years with episodes of strong inversions. All measures tested in this study will improve the air quality and hence protect a larger part of the urban population from negative health effects, but without any further measures there will still be risk of braking the hourly limit value.

Acknowledgement

This work was supported by Norwgian Public Road Administraions (NPRA). We acknowledge the working group, Oslo municipality and TØI- The Institute of Transport Economics for valuable discussions and input to the project.

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CHINA'S REVISED AIR QUALITY INDEX (AQI) COMPARED TO OTHER AQI-S

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Summary
China revised its air quality standards and its AQI in 2012. Air quality data is currently being published in real-time. We compare the new Chinese AQI to several other AQI-s from across the world by applying the AQI to unvalidated Chinese air quality data (obtained from online sources). Comparing different AQI-s is complicated as they differ widely in concept and tend to use different scales and averaging times. We devised criteria that allow us to make a semi quantitative comparison of different AQI-s if they were used in China. Secondly we look at the way the hourly PM AQI is implemented.

Introduction
Facing major challenges China revised its air quality legislation (amongst others): the national ambient air quality standard (NAAQS): GB3095-2012, and the accompanying Technical Regulation on the Air Quality Index (AQI) (HJ633-2012 – on trial). Real-time monitoring data is published by the Chinese authorities as well as non-government websites and apps. The latter tap the official Chinese websites to obtain data. One of these sources was used to obtain a time-series of unvalidated hourly air quality data. Time-series of monitoring data are not generally available for study purposes. The Chinese public had demanded an update of the old air pollution index (API) and was critical about the new AQI. The AQI, still on trial, underwent a further change in 2014 when the authorities started to publish hourly PM sub-indices (previously a 24-hour moving average was used). The use of hourly PM data (on trial) is an improvement and innovation of the AQI. However, the way in which it is currently implemented in China leads to inconsistencies in the communication.

Comparing AQI-s
AQI-s are a communication tool: making complex data understandable to the public and providing behavioural advice. AQI-s are often linked to the prevailing air quality conditions: hence many different AQI-s exist and an AQI is not automatically suitable in another context. From a communication point of view an AQI needs to change from time to time, else message fatigue will occur and people will neglect the information. AQI-s can be compared by their calculation methodology and the breakpoints between their bands. As averaging times for pollutants tend to differ, this kind of comparison is not straightforward. Chinese monitoring data were used to calculate several different AQI-s. To compare the results the AQI classes were divided in three groups: good/no health warning; classes with behavioural advice; the highest class. Frequencies were calculated for each group. Also the ratio of the average AQI result to the highest AQI class was calculated. See table 1. The Chinese and US AQI-s mainly differ at the lower end of their scales. The UK AQI, the CAQI and the HongKong AQI are certainly more appropriate in areas with less air pollution. All AQI-s point to PM as the most relevant pollutant; according to the US AQI it would be mainly $PM_{2.5}$ whereas using the Chinese and UK AQI PM_{10} would dominate.

Table 1: Comparing different AQI-s: frequencies (%) of the state of the AQI (five city sample)

Criteria	China hourly	China Daily	US	UK	HongKong	CAQI
No health warning	68	60	33	13	21	n.a.*
Some, to severe health warnings	32	40	67	38	75	n.a.*
Maximum AQI class or above	0	0	0	49	9	21
Average AQI result/highest AQI class	0.19	0.21	0.26	0.90	0.73	0.78

Averaging times for PM
If providing behavioural advice is an objective, timely information is important. Information based on 24-hour moving averages arrives late and might not reflect the perceived air quality. The Chinese public occasionally complained that pollution was visible (haze) while reported AQI readings were still low (and vice versa). Hence, in 2014 the authorities started issuing AQI calculations based on hourly PM concentrations. Other recently updated AQI-s use shorter averaging times for PM as well (a.o. Canada, HongKong, the Netherlands). However, China uses the same AQI calculation grid for hourly and daily PM readings, ignoring the lognormal nature of the concentration distribution. Occasionally very high hourly PM AQI values occur, which are subsequently not reflected in the official daily report (using daily average measurements).

Conclusions
China has updated and modernised its air quality information supply by introducing a new AQI. The Chinese AQI calculation grid (on trial) reflects the current air quality situation in China and hence differs from AQI-s from countries with lower air pollution (US, Europe). The use of hourly PM monitoring values for AQI communication (on trial) is state of the art, though its implementation could be improved and made more consistent with the daily AQI report.

Acknowledgement
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FUGITIVE DUST: A REVIEW OF SUSPENSION PROCESSES AND CONTROL MEASURES

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Summary
Minerals from fugitive dust constitute important fractions of PM_{10} and $PM_{2.5}$. These emissions result from both mechanical- and wind-generated forces. Fugitive dust emission factors are inaccurate, and emission inventories commonly overestimate these emissions. Practical emission control measures include paving surfaces, decreasing trackout from unpaved to paved surfaces, minimizing surface disturbances, applying suppressants, and constructing wind barriers.

Introduction
Fugitive dust (Watson et al., 2000) refers to small particles of geological origin that are suspended into the atmosphere from non-ducted emitters. Mining pits, open fields and parking lots, paved and unpaved roads, agricultural fields, construction sites, unenclosed storage piles, and material transfer systems are the major sources of fugitive dust. Large dust plumes are often noticed over these sources when wind speeds are high or when vehicles are moving. These visible plumes do not necessarily correspond to significant amounts of PM_{10} or $PM_{2.5}$ (particles with aerodynamic diameters less than 10 µm and 2.5 µm, respectively) measured by nearby air quality monitors. Fugitive dust emissions depend on particle sizes, surface loadings, surface conditions, wind speeds, atmospheric and surface moisture, and dust-suspending activities. Emission rates and control measures are also closely related to these properties. Little is known about the PM_{10} and $PM_{2.5}$ in surface dust deposits as these fractions are too small to be determined by simple sieving methods. Modern technology allows these emissions to be better characterized.

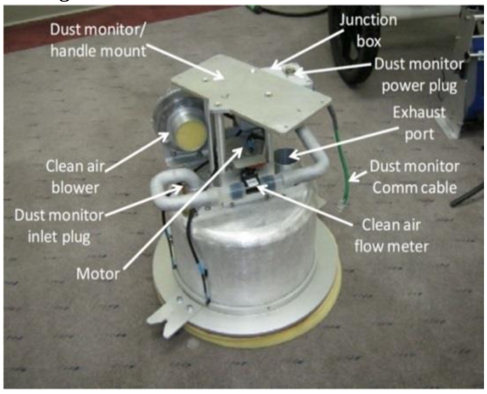

Fig.1. The Portable In Situ Wind Erosion Laboratory (PI-SWERL, Etyemezian et al., 2007), is used to determine the windblown fugitive dust suspension potential of erodible surfaces. It is also used to evaluate control strategy effectiveness.

Methodology and Results
Portable wind tunnels (Fig 1) can be equipped with continuous PM size monitors, such as the DustTrak DRX, to obtain real-time measurements as a function of wind speed for various surfaces. Figure 2 illustrates typical results from such an experiment. The monitors can also be mounted in a vehicle with the inlet next to the tire to evaluate mechanical suspension potential on roadways as a function of vehicle speed. This technique identifies hot-spots, such as trackout from unpaved areas onto paved roads. Trackout is a major fugitive dust source, as the traffic grinds this dust to smaller particles, and transports it down the roadway via vehicle wakes. Mitigation measures include: 1) reducing suspendable dust reservoirs, 2) preventing its deposit, 3) stabilizing it, 4) enclosing it, and 5) reducing the activities that suspend it. These methods are applied with various degrees of effectiveness and diligence. Surface watering is often applied on disturbed land such as construction sites or unpaved surfaces to reduce particle resuspension by vehicles. The application of chemical suppressants and vegetation to unpaved surfaces is effective under some circumstances, but not under others. Increasing the surface roughness reduces wind shear at the surface, which also lowers suspension potential. Normal brush sweepers often raise more dust than they collect. Vacuum sweepers are more effective for dust control, and several U.S. air quality districts have specified collection efficiency tests that are required for emission reduction credits.

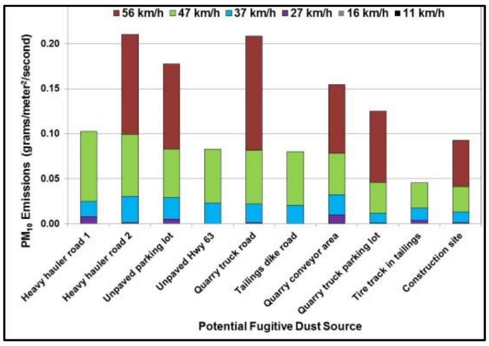

Fig.2 Fugitive dust emission fluxes as a function of wind speed (at 10 m AGL) for different surfaces in northern Alberta, Canada (Wang et al., 2015). These can be coupled with land use maps and measured or modelled wind speeds to provide more realistic estimates of annual emissions.

Conclusions
Fugitive dust is a large PM contributor, but effective control technologies exist to minimize its emissions.

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SUPPORTING NATIONAL AIR QUALITY POLICIES WITH A CHEMICAL TRANSPORT MODEL: THE ITALIAN EXPERIENCE WITH THE MODELLING SYSTEM MINNI

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Summary

This paper describes the development of the MINNI modelling system for Italy, centered on the Chemical Transport Model FARM, developed by Arianet S.r.l. (Kukkonen et al., 2012), aimed to provide the Italian Ministry of Environment with a tool able to link policy and atmospheric science. Starting from 2002, there have been many applications of the system supporting policy decisions at different level: international negotiations (revision of the Gothenburg protocol; revision of the Thematic Strategy on Air Pollution, etc.); air quality state and trends on Italian domain in different years; support to regional administrations in charge of developing abatement measures and related plans; supporting data for requests to postpone deadlines for national compliance with limit values of Directive 2008/50/EC (source apportionment, air quality scenarios), and cost-effective analysis.

In recent years the model was applied to the design of the Italian Special Purpose Stations Monitoring Network (Italian Legislative Decree 13/08/2010, n.155 for the compliance with Directive 2008/50/EC) having extended POPs and Hg gas-phase chemical mechanism in FARM.

In this context, particular attention was dedicated to the development of methods to identify Spatial Representativeness (SR) of air quality monitoring stations in terms of size and shape. A presentation of the SR method based on CTM model simulations is given here.

Introduction

SR area of monitoring stations, allowing to extend the information retrieved in a site to a wider area surrounding it, is a relevant issue in air quality assessment. From 2014, provisions for official reporting of air quality measures to EU request Member States to provide a SR information for each reported station. According to scientific literature, the SR of a monitoring site is related to the variability of concentrations around the site, so its assessment has to be based on additional air quality data. CTM results are a cost-effective approach because models are fully capable to take the main atmospheric pollutant processes into account with wide spatial coverage. We developed and applied a plain original method to assess SR, based on MINNI data base time series analysis.

Methodology and Results

The CSF (Concentration Similarity Frequency) tool developed by ENEA for SR assessment (Piersanti et al., 2015) is based entirely on MINNI data base, exploiting the completeness of a CTM with national coverage in Italy, hourly concentrations on many reference years, calculation of all regulated pollutants, state-of-art description of atmospheric physical and chemical dynamics, solid validation.

The implemented procedure recursively compares model concentration time series at the site of interest and at each grid point in the model computation domain. The percentage difference between concentration values is compared with a threshold and a frequency function, $f_{site}(x,y)$, is so defined for the site of interest, counting positive occurrences of "concentration similarity" at each grid point. According to Nappo et al., 1982, the representativeness area of each site of interest is finally assessed as the area where the condition $f_{site}(x,y)>0.9$ is verified. A geo-referred data base has been finally realised, describing SR areas for each site and each pollutant.

Conclusions

The application of the CSF approach, within the context of the design of the Italian Special Purpose Stations Monitoring Network, evidences the reliability of the use of CTM results to detect the spatial representativeness by means of an advanced statistical formulation. Such work is likely to be of interest for official air quality reporting to EU, for appropriately designing new monitoring networks and for the improvement of exposure estimates.

Acknowledgement

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SPECIAL SESSION – CLIMATE CHANGE AND HUMAN HEALTH

VARIABILITY IN TEMPERATURE-RELATED MORTALITY PROJECTIONS UNDER CLIMATE CHANGE

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Background
Most studies that have assessed impacts on mortality of future temperature increases have relied on a small number of simulations and have not addressed the variability and sources of uncertainty in their mortality projections.

Objectives
We assessed the variability of temperature projections and dependent future mortality distributions, using a large panel of temperature simulations based on different climate models and emission scenarios.

Methods
we used historical data from 1990 through 2007 for Montreal, Quebec, Canada and Poisson regression models to estimate relative risks (RR) for daily non-accidental mortality in association with three different daily temperature metrics (mean, minimum, and maximum temperature) during June–August. To estimate future numbers of deaths attributable to ambient temperatures and its uncertainty, we used 32 different simulations of daily temperatures for June-August 2020-2037 derived from 3 global climate models (GCMs) and a Canadian regional climate model with three sets of RRs (one based on the observed historical data, and two on bootstrap samples that generated the 95% confidence interval of the attributable number of deaths), We then used an analysis of covariance (ANCOVA) to evaluate the influence of the simulation, the projected year, and the sets of RRs used to derive the attributable numbers of death (ANs).

Results
We found that <1% of the variability in the distributions of simulated temperature for June-August of 2020-2037 was explained by differences among the simulations. Estimated ANs for 2020–2037 ranged from 34 to 174 per summer (i.e. June-August). Most of the variability in mortality projections (38%) was related to the temperature-mortality RR used to estimate the ANs.

Conclusions
The choice of the RR estimate for the association between temperature and mortality may be important to reduce uncertainty in mortality projections.

Acknowledgements
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CAUSAL EFFECTS OF EXTREME HOT DAYS ON MORTALITY IN LOS ANGELES

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Summary
Health effects resulting from climate change, e.g., extreme temperature conditions, are unclear, but can be catastrophic. Epidemiological studies have reported associations between temperature changes and mortality. This study aims to address causality (instead of associations) by formulating the problem precisely. We consider a causal framework by reconstructing a hypothetical experiment in which “Nature” randomizes “treatment”, i.e., exposure to hot days between 1999 and 2006 in Los Angeles. This work aims to examine and quantify the causal effect of heat waves on daily counts of deaths.

Introduction
Exposure to extreme hot temperatures has been associated with cardiovascular mortality. However, evidence of causality still needs to be demonstrated.

Methodology and Results
We obtained individual mortality data from the National Center for Health Statistics (NCHS) for the years 1999 to 2006. Mortality files provided information on the exact date of death and the underlying cause of death. For this study, our primary outcome of interest is cardiovascular disease (CVD, ICD-10: I01 through I59) and stroke (ICD‐10: I60 through I69) related mortality. We capitalize on classical insights from experimental design and compare our novel approach to the standard approach (i.e., based on Poisson regression model and time series) used in environmental epidemiology. We propose four stages: 1) Approximation of a hypothesized randomized experiment from the observational data, in which Nature “randomizes” daily maximum temperature (≥30°C) to one day of a matched pair of days. 2) We use a matching strategy to recreate balance before “exposure” is assigned. We create pairs with “identical” background variables, e.g., day of the week, dew point temperature, air pollution, etc. 3) We directly calculate the difference in daily cardiovascular mortality count and the associate Fisher “exact” p-value underlying the random assignment. 4) We conclude whether there is a causal effect or not under the transparent assumptions described in the 2nd matching stage. In Los Angeles, we found that the difference in daily CVD death count (Tmax≥30°C vs. Tmax<30°C) is equal to 0.048 death/day.

Conclusions
If our assumptions are valid, the causal effects of maximum temperature over 30°C on cardiovascular mortality can be substantial, especially among the growing elderly population that is known to be susceptible to extreme hot temperatures.

Acknowledgement
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REVIEW OF BLACK AND BROWN CARBON MEASUREMENTS AND EFFECTS

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Summary
This review summarizes research on the multiwavelength light absorption properties of suspended particulate matter (PM) and how they relate to PM composition and adverse effects on human health, climate, visibility, and material damage.

Introduction
Although PM light absorption spectra have been assigned to categories of black carbon (BC) and brown carbon (BrC), filter deposits show a wide range of colors that do not fall into these simple categories. Not all PM carbon compounds absorb light, and not all light-absorbing aerosols are carbon. Saharan dusts, rich in iron, have a reddish appearance, Asian dusts are bright yellow, while many ores are black to brown. Although light absorption [babs(λ)] measurements are useful in both the near ultraviolet (UV, 370 nm and near infrared (IR, 880 nm) spectral regions. Fig 1 demonstrates that a wider range of wavelength measurements provides distinctive profiles that can be related to chemical composition and sources.

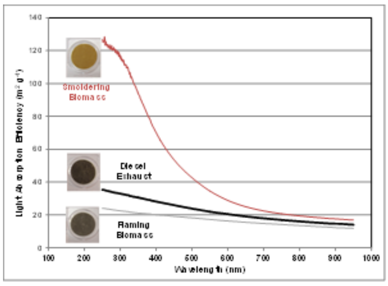

Fig.1. Spectral light absorption coefficient per unit of elemental carbon for flaming biomass, diesel exhaust, and smoldering biomass determined by light transmitted through deposits on Teflon-membrane filters. Differences in these light transmission patterns can be used to distinguish the smoldering phase that dominates biomass burning emissions from other sources of carbonaceous aerosols. This non-destructive method can also be applied to samples related to fugitive dusts and SOA end-products using filters that are commonly acquired in compliance monitoring network.

Methodology and Results
The chemical nature of the light absorbing species is not fully understood. Polycyclic aromatic hydrocarbons (PAH) in fresh emissions, such as fluoranthene ($C_{16}H_{10}$), chrysene ($C_{18}H_{12}$), retene ($C_{18}H_{18}$), perylene ($C_{20}H_{12}$), benzo[a]pyrene ($C_{20}H_{12}$), indeno[1,2,3-cd]pyrene ($C_{22}H_{12}$), anthanthrene ($C_{22}H_{12}$), and coronene ($C_{24}H_{12}$) exhibit UV absorption. Some secondary organic aerosols (SOA) also absorb light, including -nitrophenol ($C_6H_5NO_3$), 4-nitrophenol ($C_6H_5NO_3$), 2,4-dinitrophenol ($C_6H_4N_2O_5$), 4-nitro-catechol ($C_6H_5NO_4$), 3-methyl-4-nitrophenol ($C_7H_7NO_3$), 3-methyl-5-nitrocatechol ($C_7H_7NO_4$), 3-methyl-6-nitrocatechol ($C_7H_7NO_4$), 4-methyl-5-nitrocatechol ($C_7H_7NO_4$), 2,6-dimethyl-4-nitrophenol ($C_8H_8NO_3$), and Humic-Like Substances (HULIS). These can all be detected on filters currently acquired in chemical speciation networks.

Two- and seven-wavelength aethalometers are most commonly used to obtain multiwavelength PM absorption properties. Fig. 2 shows an example of how this information can be used to map the spatial distribution of biomass burning. With a larger wavelength span, other sources, such as fugitive dusts, can be identified. A new development includes the addition of multiwavelength light absorption as part of the thermal/optical carbon analysis currently applied in chemical speciation networks. These data will be reported for the U.S. IMPROVE network beginning with samples from 2016, and will migrate to other networks soon thereafter. A large data base of such measurements should help to elucidate sources and composition.

While much of the interest in BC and BrC has been climate-related, there is growing evidence that some of the light-absorbing compounds cited above can have adverse health effects. A more precise association of PM chemistry with spectral properties holds potential to improve epidemiological relationships between ambient exposures and health.

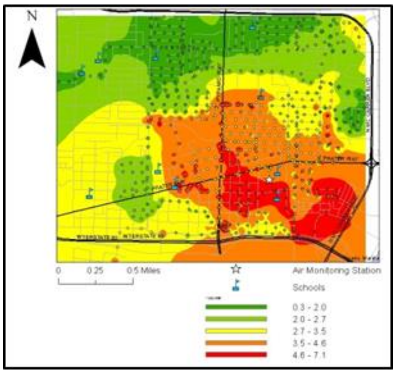

Fig.2 Spatial distribution of BrC, in µg/m^3, asa marker for the smoldering phase of biomass burning, measured with a 2 wavelength (880 nm and 370 nm) microaethalometer around a neighborhood-scale site (star) in Sparks, Nevada, USA from ~8 pm to ~2 am. Data were spatially interpolated by kriging from average values assigned to evenly-spaced grid squares.

Conclusions
Since PM chemical speciation networks are being established in many countries, it makes sense to add multiwavelength light absorption measurements to the analysis suite to better evaluate sources, composition, and effects.

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EU POLICIES FOR AIR QUALITY: EXPECTED IMPACTS ON CLIMATE CHANGE IN THE MEDITERRANEAN BASIN

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Summary

This work presents an evaluation of the impact of future pollutant anthropogenic emission reductions, as foreseen from the EU air quality policy, on summertime aerosol feedbacks over the Mediterranean basin. The fully coupled climate/chemistry on line model Wrf/Chem has been used to simulate the aerosol feedbacks associated with the direct absorption and scattering of solar radiation. A Base Case (BC) and a Maximum Feasible Reduction (MFR) scenario at 2020 have been simulated; direct aerosols feedbacks for both BC and MFR have been computed and compared.

Introduction

The Mediterranean region is considered a critical area in air quality studies, as it plays a key role in the global interaction between air quality and climate change. A correct assessment of the aerosol feedbacks over the region is therefore crucial for air quality planning and for the application of different reduction and control emission strategies. This study attempts to compute the summertime direct effects of aerosol particles over the Mediterranean basin, and quantitatively estimate their variation due to the implementation of the EU air quality policies by means of the Wrf/Chem model. Numerical simulations were performed in order to investigate the impact of the direct effects on downward short-wave solar radiation and meteorological variables (namely temperature, short wave incident solar radiation, boundary layer height, albedo and cloud fraction). The model domain is a 40x40 km^2 resolution grid over the Mediterranean area; the simulation period covers a summer month (July 2005). The aerosol feedback for a Base Case (BC) and a Maximum Feasible Reduction (MFR) scenario at 2020 have been simulated.

Methodology

The computation of direct aerosol effects has been performed by running Wrf/Chem with two different configurations, as suggested by Wang et al. (2014). Two simulations have been carried out for both MFR and BC; the features of the two tests are summarized in table 1. S1 is the same simulation as BASE except that aerosol direct feedbacks are switched off; the difference between BASE and S1 provides the impact of direct effects on Wrf/Chem predictions.

Table 1. Wrf/Chem simulations configurations

Simulation	*Aerosol Emissions*	*Cloud chemistry*	*aerosol chemistry*	*Aerosol direct feedbacks*
BASE	On	On	On	On
S1	On	On	On	Off

Aknowledgements

Authors would like to acknowledge EMEP for providing the emission datasets used in this study. This work has been carried out in the frame of the COST Action ES1004 EuMetChem.

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SÃO PAULO MEGACITY: *N*ARROWING THE *UN*CERTAINTIES ON *A*EROSOL AND *C*LIMATE CHANG*E*S IN *S*ÃO *P*AULO (NUANCE) PROJECT

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Keywords: particulate matter, air quality, urban air pollution.
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Introduction

The megacity has been defined as a "metropolitan area with more than 10 million inhabitants", and its air pollutants emissions can cause serious impact not only in the air quality, but also on the climate at the regional to global scale (Folberth et al., 2015). That said the knowledge about the interactions of the gases and particulate matter air pollutants emissions with the natural atmospheric components and meteorological parameter has been a challenge. São Paulo megacity (MASP) is the biggest and most populated in South America (Fig. 1), with more than 20 million inhabitants and a total vehicular fleet surpassing 6.5 million units, including heavy-duty (HDV) and light-duty (LDV) vehicles. The NUANCE project started in 2010, involving continuous monitoring, special field campaigns (p. ex., tunnel) and modeling atmospheric chemistry (Brito et al, 2013, Nogueira et al., 2015). The results of the gases monitoring, particulate matter ($PM_{2.5}$ and $PM_{2.5\text{-}10}$) and rainwater chemical composition will be presented and highlighted. The proposal is to present a substantial view of the results already published along with the consolidated new ones.

Methodology and Results

The Picarro monitors were used for gases ammonia (NH_3), carbon dioxide (CO_2) and methane (CH_4) analysis. Ethanol and carbon monoxide (CO) were analyzed by Innova monitor. For systematic hourly measurement of more than 50 NMHCs was optimized with a Perkin Elmer® system consisting of a sampling module, a thermal dessorption (ATD), a Clarus 500 gas chromatography with two columns and two flame ionization detectors (FID). The particulate matter was sampled using Thermo Partisol sampler and a cascade impactor MOUDI to evaluate size distribution, for 12h (day and night). The filters mass were weighed using a balance with a precision of 1 µg, after remaining at least 24 hours inside the humidity and temperature controlled room. Black Carbon (BC) concentrations were obtained by light reflectance. The filters were analysed by Energy Dispersive X-ray Fluorescence (XRF-ED) technique, allowing the determination of the chemical elements with atomic number (Z) greater or equal to 11 (Na) concentrations. For rainwater study, the wet-only sampler was used. Ion chromatography (Metrohm model 851) was used to evaluate major inorganic ions in rainwater and aqueous phase of PM. The São Paulo State Environmental Agency (CETESB) air quality network provided the O_3, SO_2, NO_x ($NO+NO_2$), CO, PM_{10} and $PM_{2.5}$ concentrations. Meteorological data were obtained from INMET (Instituto Nacional de Meteorologia), IAG Meteorological Station, and CETESB. In Brazil, only HDVs run with diesel (3% biodiesel). The LDV and motorcycles correspond to approximately 90% of this fleet, burning gasohol (75% gasoline with 25% of anhydrous ethanol), and being 40% of those flexible fuel vehicles running with hydrated ethanol besides gasohol. Ethanol burning reached the same magnitude as gasoline after 2006 (Cetesb, 2015).

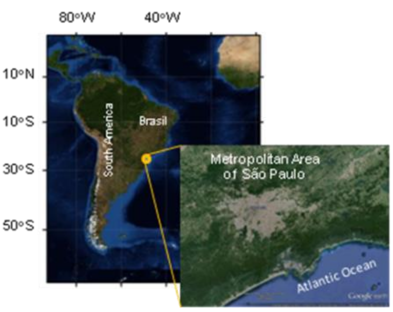

Figure 1. MASP localization.

Conclusions

In conclusion, although the air pollutants concentrations decreased, the air quality has been seriously affected by traffic, despite the fact that the emissions control program started 40 years ago. The high level of air pollutants for the annual average and 24-hours peak concentrations exceeded the WHO guidelines, mainly for PM and O_3 (WHO, 2006).

Acknowledgement

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CLIMATE VARIABLES AND MICRORNAS IN ELDERLY MEN

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Summary

This study aims to investigate the associations between climate variables and miRNA related to inflammation in elderly males. We found significant linear associations between meteorological variables and several miRNAs, positive for temperature and water vapor pressure and negative for barometric pressure, while we did not find any significant association for relative humidity. In our exploratory analysis we found a specific time window to be relevant for each climate variable, in term of strength and consistency of the associations with miRNA. "Toll-like receptor signaling pathway" and "NF-kappa B signaling pathway" were among the most enriched in targets of miRNAs associated with the investigated exposures. This is the first study linking exposure to meteorological variables to a dysregulation in the expression of candidate miRNAs involved in inflammation. Changes in miRNAs expression may represent a mechanism mediating responses to these variables. Different time window should be considered for each climate variable.

Introduction

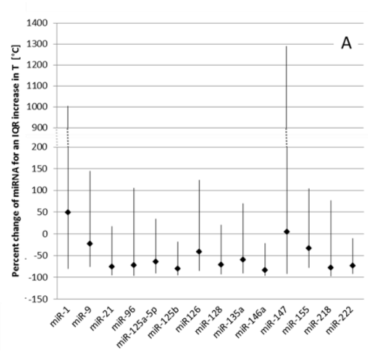
Changes in meteorological variables have been associated with increased morbidity and mortality for all causes, including cardiovascular disease (CVD). Potential mechanisms include inflammation, coagulation and endothelial dysfunction. MicroRNAs (miRNAs) control gene expression at a posttranscriptional level. Altered miRNAs expression has been reported in inflammation, coagulation and endothelial dysfunction processes. We investigated the association between temperature [ºC], barometric pressure [inches Hg], relative humidity [%] and water vapor pressure [hPa], in different time windows and expression changes in fourteen candidate microRNAs.

Methodology

166 elderly males from the greater Boston area were studied (one visit between 2005 and 2007). Weather parameters were obtained from the National Weather Service Station at Logan Airport. Based on previous results in the same cohort investigating temperature and inflammatory markers we tested the 7-days moving average as primary hypothesis and shorter and longer averaging times (i.e. 4-hours to 28-days) as an exploratory analysis. We performed an in silico pathway analysis on both experimentally validated and predicted targets of miRNAs associated with each meteorological variable.

Results

Complete data were available for 153 participants (mean[SD] age 77[6] years). In our main analysis we found a significant positive linear association between 7-days mean temperature and miR-125b, -146a and -222 and between 7-days mean water vapor pressure and miR-96. We found a significant linear association between 7-days mean barometric pressure and miR-96 and -125b. In our exploratory analysis we found the largest and most consistent associations being with 7-days mean temperature, 21-days mean barometric pressure and 2-days mean WVP (Fig. 1). We found a statistically significant negative association between 2-days mean WVP and miR-9 and -146a. We observed a statistically significant positive association for 21-days mean P and miR-1, -96 -135a and -146a. In both the main and the exploratory analysis we did not observe any significant association with relative humidity. "Toll-like receptor signaling pathway" and "NF-kappa B signaling pathway" were among the top ten pathways enriched in targets of miRNAs associated with climate variables.



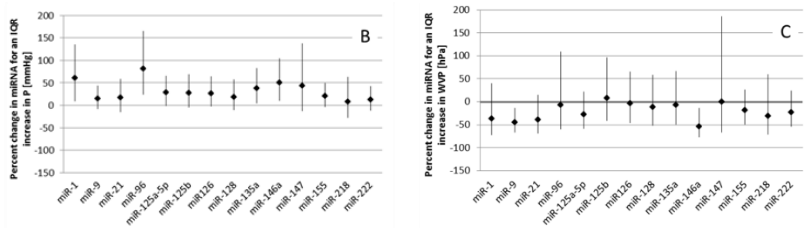


Fig. 1 Estimated Percentage Change (CI 95%) in miRNA for an IQR in 7-d temperature (Fig. A), 21-d barometric pressure (Fig. 1B) and 2-d water vapor pressure (Fig. 1C). Model adjusted for age, BMI, cigarette smoking (never, former, current), pack-years, granulocytes (%), platelets, seasonality and miRNA batch. (Results From the Exploratory Analysis)

Conclusions

This is the first study linking exposure to meteorological variables to a dysregulation in the expression of candidate miRNAs involved in inflammation. Changes in miRNAs expression may represent a mechanism mediating responses to these variables. Different time window should be considered for each climate variable.

CARDIORESPIRATORY MORBIDITY AND MORTALITY DUE TO MULTIPLE EXPOSURES TO AIRBORNE POLLUTANTS IN SANTIAGO DE CHILE

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Summary
High concentrations of various air pollutants have been associated with hospitalization due to development and exacerbation of cardiovascular and respiratory diseases and increased cardio-respiratory mortality. This study aimed to quantify associations between airborne exposures by particulate matter as well as gaseous pollutants and morbidity as well as mortality due to different cardio-respiratory disease groups in Santiago de Chile.
The study was performed in the metropolitan area of Santiago de Chile during 2004-2007. We applied a time-stratified case-crossover analysis taking temporal variation, meteorological conditions and autocorrelation into account. We computed associations between daily ambient concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter (PM10 and PM2.5 - particulate matter with aerodynamic diameters less than 10 or 2.5 µm, respectively) or ozone (O_3) and health effects.
We found for CO, NO_2, PM10 and PM2.5 adverse relationships to hospital admissions and mortality while effect strength and lag depended on the pollutant and on the disease group. Adverse effects of O_3 could not be detected.

Introduction
Santiago de Chile is surrounded by Andean Mountains in the east and the Cordillera of the Coast. The specific atmospheric and geographic conditions cause high contamination levels due to relatively high anthropogenic and natural emissions. Depending on season, the main contamination is due to primary emissions: particulate matter, sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) and carbon monoxide (CO) (Cakmak et al., 2009). Previous studies found health risks also for the conditions of Santiago de Chile (Cakmak et al., 2009; Vera and Cifuentes, 2008). But, results on health effects of particulate matter, CO, NO_2, and especially O_3 vary between studies.

Material and methods
In the city of Santiago live around 5.39 Mio inhabitants (census 2002) which is more than one third of the total population of the country. The city lies in the center of the Santiago Basin, a large bowl-shaped valley between the Andes and the Cordillera de la Costa mountains. This location limits ventilation and dispersion of air pollutants. High temperatures, high pollutant concentrations and clear sky favor the formation of O_3 through photochemical reactions. Health data were kindly provided by the Departamento de Estadísticas e Información de Salud (DEIS). The data included all cases of hospital admissions (in total 75,303) and all cardio-respiratory death cases (in total 25,687) from January 1, 2004 until December 31, 2007. Averages of concentrations measured by seven monitoring stations of the atmospheric pollution monitoring Network at Santiago de Chile were used for the estimation of the exposure. In the present study we applied a time stratified case-crossover analysis (CCO) using daily numbers of respiratory hospital admissions and daily mean values of the concentrations of airborne pollutants.

Results
Depending on disease group, all investigated pollutants except O_3 were adversely related to cardiovascular and respiratory admissions. By trend, in 1-pollutant models of cardiovascular admissions most adverse pollutants were NO_2 and particulate matter (PM10 and PM2.5) followed by CO, while in 2-pollutant models effects of PM10 persisted in most cases whereas other effects weakened. In 1-pollutant models most adverse respiratory effects were induced by CO and PM10 followed by PM2.5, while in 2-pollutant models effects of NO_2 persisted in most cases whereas other effects weakened and significant effects remain for PM2.5, only. In 1-pollutant models cardio-respiratory mortality was found to be increased by exposure of 2 – 8 days to CO, NO_2, PM10, and PM2.5. Effect strength increased if exposure concentrations were elevated for two or more consecutive days. 2-pollutant models indicate that combined exposures may be responsible for the majority of observed adverse effects on death cases rather than a single pollutant, only.

Conclusions
Our results provided evidence for adverse health effects of combined exposure to airborne pollutants. Different pollutants accounted for varying adverse effects within different disease groups. Taking case numbers and effect strength of all cardiovascular diseases into account, mitigation measures should address all pollutants but especially NO_2, PM10, and CO. NO_2 and PM are adversely associated with respiratory health even if their effects were controlled for other air pollutants. With respect to mortality, mitigation measures should address all pollutants but especially NO_2 and also CO.

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SHORT TERM EFFECT OF EXTREME TEMPERATURES ON MORTALITY AND INTERACTION EFFECT WITH AIR POLLUTION IN ITALIAN CITIES

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Summary:
The study aims to provide cause-specific estimates of the effect of heat and cold in 16 Italian cities, to evaluate inter-annual variations, and to estimate the interactive effect of heat and cold with air pollutants. Extreme temperatures have a significant effect on mortality in Italian cities, and are heterogeneous among cities. A temporal variation in the effect of summer extreme temperatures was observed, with a declining trend in the effect of heat. When considering the interaction between temperatures and air pollution an additional effect of PM10 was observed in most cities and for ozone in central and southern cities. Future heat adaptation measures should include interventions to reduce air pollution during heat waves episodes.

Introduction:
Considering the increase in frequency and intensity of extreme events predicted under climate change scenarios for the Mediterranean the future health threat for Italy is considerable. Although the effect of heat and cold on mortality are well documented, the temporal variation of the effect need to be evaluated. Moreover there is still limited evidence on the interaction between extreme temperatures and air pollution. The aim of the study was to provide cause-specific estimates of the effect of heat and cold in 16 Italian cities, to evaluate inter-annual variations, and to estimate the interactive effect of heat and cold with air pollutants.

Main Body format:
Methodology
The annual temperature-mortality relationship was modelled using Poisson distributed lag non-linear models (DLNM) with a lag window of 14 days to account for both the short and long-term effects of heat and cold. The effect was estimated as the RR of mortality for a change in temperature between the 90-95th percentile and the 10-5th percentile of the annual mean temperature distribution for heat and cold respectively. City-specific and pooled results were estimated for total and cause specific mortality (cardiac, ischemic heart disease, cerebrovascular, respiratory disease, COPD and asthma). Secondly the combined effect of temperature and air pollution (PM10, NO2 and Ozone-summer only) was analysed using a GAM with a tensor smooth in order to model both exposures with a non-parametric approach. Temperature effects were then estimated at different pollution levels (low, medium, high). Lastly, time-varying coefficient regression models were used to assess the temporal variation in the effect of extreme heat on mortality.

Results
Extreme temperatures have a significant effect on mortality in Italian cities, and heterogeneity among cities was observed for both heat and cold. Cause specific effects were observed with a greater impact on respiratory causes during summer (pooled results +17%) and cardiovascular causes in winter (pooled results +5% for circulatory causes).
A temporal variation in the effect of summer extreme temperatures was observed between 1995-2015. Overall, a declining trend in the effects of heat was observed for high temperatures, while for less extreme summer temperatures 30-32°C no change in the effect estimates was observed. Years with very high summer temperatures still have a significant impact on mortality, such as summer 2006 and 2015. Heterogeneity was observed between cities, possibly also reflecting local dose-response curves and adaptation measures introduced.
When considering the interaction between temperatures and air pollution, in summer we observed an additional effect of PM10 in most cities and for ozone in central and southern cities. In winter no effect modification by air pollution was observed.

Conclusions
Although a declining trend in the effects of heat was observed for high temperatures in Italian cities high and low extreme temperature continue to represent a threat for health in Italian cities. In large Italian cities during summer PM10 and ozone amplify the effect of heat exposure on mortality. Future heat adaptation measures should include interventions to reduce air pollution during heat waves episodes.

EVALUATION OF THE AEROSOL-RADIATION AND AEROSOL-CLOUD INTERACTIONS IN AN ON-LINE COUPLED MODEL OVER THE IBERIAN PENINSULA

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Summary

The effects of atmospheric aerosol on the Earth's climate are produced mainly by their optical, microphysical and chemical properties, which condition the radiative budget of the Earth. In this sense the objective of this work is to assess whether the inclusion of aerosol radiative effects in the on-line coupled WRF-Chem model improves the modelling outputs over the Iberian Peninsula. The methodology relies on the evaluation of modelled aerosol optical properties with remote sensing data under diverse model configurations. The results indicate that although there is only a slight improvement in the results when including the radiative feedbacks, the BIAS and the correlation coefficients are improved for some stations and regions.

Introduction

Atmospheric aerosols together with greenhouse gases and clouds are the main forcing agents of the climate system, modifying the Earth's radiative budget. The uncertainty of the aerosol effects over the aforementioned budget is much higher than any other climate-forcing agent. With the aim of reducing this uncertainty and estimating the radiative forcing causes for this forcing agent, the study of atmospheric aerosols by chemistry-climate models is needed. Hence, the object of this work is to assess the representation of aerosol optical proprieties by an online-coupled model (WRF-Chem) and to determine whether the inclusion of aerosol radiative feedbacks improves the modelling outputs over the Iberian Peninsula.

Methodology and Results

The evaluated data comes from regional air quality-climate simulations performed using the WRF-Chem online-coupled meteorology/ chemistry model (Grell et al., 2005). The modelling domain covers all Europe, but for the purpose of this work data from the Iberian Peninsula with a resolution around 0.2º has been extracted for two important aerosol episodes in the year 2010 (a Saharan desert dust outbreak and a forest fires episode). The simulations are run for two different scenarios differing in the inclusion (or not) of aerosol radiative feedbacks, denoted NRF and RF, respectively. The evaluation of the simulations has been performed by using classical statistics. The evaluated variables are aerosol optical depth (AOD) and Angström exponent. (AE) The observational data used to performance the evaluation are providing from different satellite sensors as MODIS, OMI or SeaWIFS; or ground-based instrument network as AERONET or EARLINET.

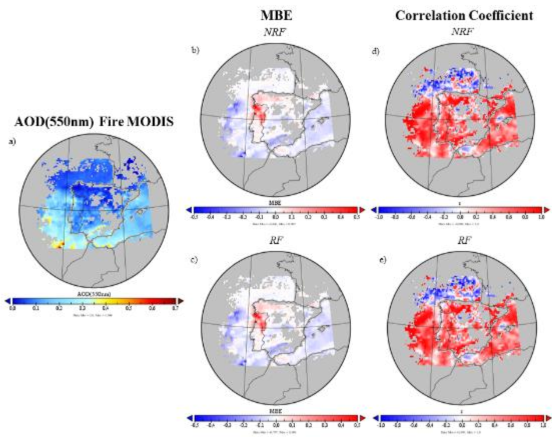

Fig.1 AOD at 550nm model output vs. data from Aqua Platform (left) for the 2010 fire episode: bias (central

The results indicate a general slight improvement (around 0.3% for MBE in both episodes) in the case of including the aerosol radiative effects in the model and a slight worsening for the Angström exponent. On the other hand, the model overestimates AOD for fire particles (see Fig. 1) and underestimates for dust particles. Regarding the correlation coefficient, both episodes show similar values of this statistic, which are higher than for Angström exponent. Generally, for the Angström exponent, the model tends underestimate the variability of this variable. For the comparison between model output and EARLINET profiles, the results show a general improvement around 8% in the representation of vertical aerosol distribution when the radiative feedbacks are taken into account.

Conclusions

For the spatial distribution the best-represented variable is AOD. For this variable the bias and correlation coefficient values are better than for AE. Concerning the improvement of the simulation including feedbacks, although there is not a general significant improvement, the BIAS, the MBE, the MAE and the correlation coefficient are improved for some stations and regions, usually the nearest to the emission sources of aerosol particles, where the main aerosol radiative effects can be found. The representation of aerosol vertical distribution improves when the radiative feedback simulation is included.

Acknowledgement

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STREET-LEVEL MODELLING OF CLIMATE ADAPTATION MEASURES AND THEIR CONSEQUENCES ON SUBJECTIVE BIOLOGICAL INDICES AND URBAN AIR QUALITY

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Summary
This study aims to quantify the effect of climate change urban adaptation strategies. We evaluate the effect of different measures (planting trees, building wall paint colors) in respect of the thermal comfort of inhabitants and air pollution levels.

Introduction
Cities play an important role regarding potential climate change impacts. Urban areas are often vulnerable and poorly prepared to respond to climate change impacts, such as heat waves, drought or floods. **The project UrbanAdapt aims** to start the process of preparation of cities adaptation strategies, develop adaptation scenarios and test their effects and benefits in the three pilot cities in the Czech Republic. In this study, we assess the impact of different adaptation measures on citizens who live under the conditions of growing urban heat island effect. Different adaptation measures were proposed (planting tree alleys, changing wall paint colors) which are orientated to lower the temperature in the streets during hot summer days. We evaluate here the effectiveness of such measures. However, the question arises what is the impact of those measures on pollutant dispersion. A tree represents an obstacle for turbulent flow in the street, further it can influence the temperature through evapotranspiration, while wall paint color modifies radiation from buildings, thus changing the energy balance. All these effects influence the resulting flow and have an effect on air pollutant distribution.

Methodology and Results
The heterogeneity of urbanized land surface leads to a need for a very fine resolution when modelling air flows and temperature near to the surface. We have chosen the atmospheric model PALM [1, 2] as a tool for our simulations. PALM is a LES model which includes parametrizations of many atmospheric processes (e.g. land surface, plant canopy, solar radiation and convective processes) and also enables to involve pollutant dispersion. On the other hand, the parametrization of building surface energy balance is not included in the model. We implemented a new module in the PALM to account for those effects inspired by the wall heatflux treatment in TUF3D model [3].

Fig. 1: snapshot from IR camera measurement

We performed a field experiment, during which temperature of building facades and road surface on Prague crossroad were measured with infrared camera, during a summer heat wave episode. The results of the measurements show that temperature of the wall vary based on wall material and paint colors (Fig. 1). Also, the difference between parts shaded by trees and those exposed to direct sunlight can be substantial. Fig. 2 shows the time variation of temperature of four differently oriented walls. The results will serve for verification of the radiation module.

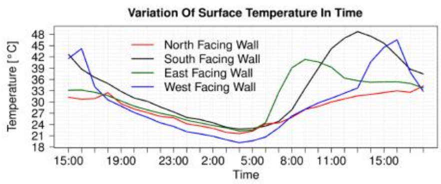

Fig. 2: temperature on different walls

To evaluate the connection between objective meteorological variables and subjective biological indices we adopted the concept of Physiological Equivalent Temperature (PET) and for its simulation a micro-scale model RayMan [4] is applied. Our preliminary results show that tree alleys in the streets bring improvement in the PET which may be up to 4°C.

Acknowledgement
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GHG LANDFILL EMISSIONS DETERMINATION USING A FLUX CHAMBER

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Summary
Fugitive emissions from the surface of landfills constitute an important source of carbon dioxide and methane that are emitted to the atmosphere and contribute to the greenhouse effects. Quantifying those emissions can give valuable information, not only, on the amount of those gases which are released into the atmosphere but on their environmental consequences. They can also help to evaluate another aspects related to the landfill management like the seal efficiency or the gas recovery. Quantifying fugitive emissions is not an easy task, due to the heterogeneity of the waste into the landfills, their huge dimensions and the influence of others factors like the site meteorology. Several measurement methods as well as prediction models for determine this type of emissions can be found in the bibliography. In this study a flux box method has been used.

Fig.1 Measure of surface gas emissions with a flux chamber

Material and methods
For the implementation of this method a process in two steps, as described on the Guidance on monitoring landfill gas surface emissions (EA 2010), was followed in order to obtain the fugitive emissions of two landfill sites in Madrid (Spain). The first step consists on a walkover survey. At this stage the gas concentration close to the surface is monitored and zones with equal concentrations are defined. At the same time, significant emission sources and failures in the gas collection system are identified. All this information is used to choose the sample points for the second step, the flux box study. A flux box or flux chamber is a well known volume dispositive that allows to accumulate and to quantify over time emissions emanating from a given area of the landfill. To measure the composition of methane inside the flux box, a portable detector based on Infrared (IR) Absorption Spectroscopy (Sensit PMD) in combination with an electronic narrow band pass filter technology is being used. Carbon dioxide emissions were obtained using a passive IR sensor for CO_2 (Kimo HQ210). Some preliminary results show the possibility of quantifying emissions rates from less than 1 mg/m2·h to 104 mg/m2·h or even

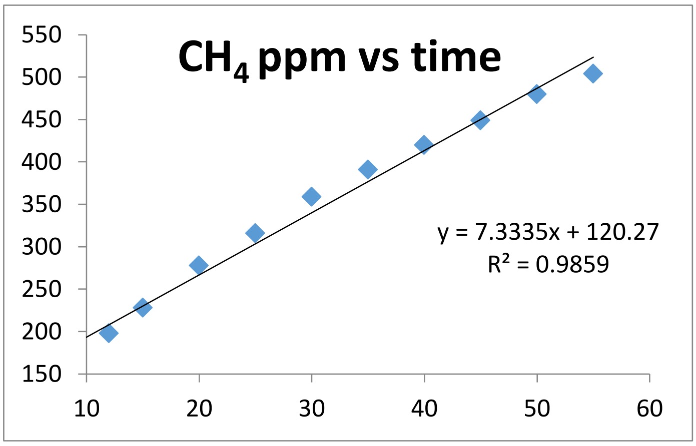

Fig.2 Variation of methane concentration over time inside the flux chamer

Results and Conclusions
This method has been used in two landfills. The first one is a closed landfill that has been exploited for almost 40 years and was closed in 2000. In this case the landfill gas extracted is being used to generate electricity. The other one corresponds to a landfill which is still in use and the extracted gas is being burnt in a flare. Another critical difference between the two landfills is the type of cover used. In the closed landfill there is a high density polyethylene film while in the other one there is only a clay and sand barrier as cover. The walkover survey results show lower concentrations of methane on the closed landfill. This is an evidence of the effectiveness of a good seal combined with the active extraction and use of the gas to reduce methane release.

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THE IMPACT OF HEAT WAVES ON ISCHEMIC HEART DISEASES IN GERMANY – PRESENT SITUATION AND CLIMATE CHANGE

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Summary

This is the first nation-scale study analyzing the relationship between the impacts of heat and morbidity/mortality of ischemic heart diseases (IHD) in Germany - at present and in the climate changed future. The results show that (a) heat waves in Germany are associated with increased IHD mortality rates; (b) heat wave characteristics are strongly modulating mortality results; and (c) heat impacts are different concerning regions, gender, and diseases.

Introduction

Weather affects public health in many ways. Heat is one of the primary weather-associated threats to life, as dramatically shown by the death toll of the 2003 heat waves in Europe with around 50,000 excess deaths. Heat waves are defined as extended periods of extreme high temperatures, exert a stronger influence on health than isolated hot days. Elderly and chronically predisposed people are the most vulnerable group to be at high risk, while the heat impact is highest e.g. on the cardiovascular system. Heat-related studies frequently report that the temperature-mortality relationship is stronger than the one for temperature-morbidity.

Methodology and Results

The impact of heat waves on ischemic heart disease (IHD) mortality and morbidity in Germany was analyzed for the decade 2001-2010. Heat waves are defined as periods of at least 3 consecutive days with daily mean temperature above the 97.5th percentile of the temperature distribution. Daily excess mortality and morbidity rates are used from a nationwide database. All calculations were performed separately for 19 regions to allow for the investigation of regional differences.

The results show that IHD mortality during heat waves is significantly increased (+15 % more deaths on heat wave days). In stark contrast, no heat wave influence on hospital admissions due to IHD could be observed. Regional differences in heat wave IHD mortality are present, with the strongest impact in the Western part, and weaker than average effects in the Southeastern and Northwestern regions. The increase in mortality during heat waves is generally stronger for females (+19 %) than for males (+11 %), and for chronic ischemic diseases (+18 %) than for myocardial infarctions (+12 %). Longer and more intense heat waves feature stronger effects on IHD mortality, while timing in season seems to be less important.

Furthermore, the influence of future climate change on the occurrence of heat waves in Germany is studied. Simulations of 19 regional climate models with a spatial resolution of 10-25 km are analyzed. All of the models use a moderate green house gas forcing according to the SRES scenario A1B. Three model time slices of 30 years are evaluated, representing present climate (1971-2000), near future climate (2021-2050) and remote future climate (2069-2098).

Based on the model simulations, future heat waves in Germany will be significantly more frequent and longer lasting. By the end of the 21st century, the number of heat waves will be tripled compared to present climate. Additionally, the duration of heat waves will increase by 25 %. Altogether, the number of heat wave days will be four times higher in the period 2069-2098. Regional analyses show that stronger than average climate change effects are observed particularly in the Southern regions.

Conclusions

The study demonstrated a significant increase in IHD mortality in Germany especially on days with high average temperatures and heat-waves. A potential relationship between the atmospheric environment and IHD morbidity remains unclear. The used methodology does not imply possible adaptations to climate change, but it is most likely that the individual heat burden will increase considerably. The obtained results point to public and individual adaptation strategies to reduce the future heat wave impact on mortality.

Acknowledgement

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CHRONIC EFFECTS OF TEMPERATURE VARIABILITY ON MORTALITY IN SOUTH EASTERN UNITED STATES: IMPLICATIONS FOR PUBLIC HEALTH RISK OF FUTURE CLIMATE CHANGE

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Summary

Global warming threatens human health, particularly in the South Eastern United States, because the elderly population who are most vulnerable to climate change is rapidly growing in this area. Hence, it urges temperature-related health effect studies in such areas. Here we demonstrate that both seasonal mean values and standard deviations (SDs) of temperature could modify the long-term survival among the 13 million Medicare population (aged 65+) in the South Eastern USA. It is important to separate the spatial and temporal variation in temperature, since the latter is more relevant to climate change. Therefore we broke down the seasonal mean temperatures and temperature SDs into long-term geographic contrasts and annual anomalies. For the anomalies, each 1 °C increase in summer mean temperature was associated with a 0.8% higher death rate, whereas a rise in winter mean temperature of 1 °C corresponded to a 1.4% decrease in mortality. Increases in within season temperature SDs in both summer and winter also contributed to more deaths. For future climate scenarios, seasonal mean temperatures may in part account for the public health burden, but excess public health risk of climate change may also stem from changes of within season temperature variability.

Introduction

The rapid buildup of greenhouse gases is expected to increase the Earth surface mean temperature, with unclear response of temperature variability. This has added some urgency to better understand the direct effects of such changes on human health. Many previous studies demonstrated that short term exposure to extreme temperatures were associated with increased mortality. In addition to the seasonal mean temperature, its variability may also play a significant role in raising the risk of mortality (Zanobetti et al, 2012). However the chronic effects of temperature are less clear. Recently we demonstrate that long-term survival was significantly associated with both seasonal mean values and standard deviations of temperature in New England (Shi et al, 2015). The objective of this study is to identify the chronic effects of seasonal mean temperature and temperature variability on mortality in the South Eastern United States.

Methodology and Results

We used a novel prediction model that incorporates land use terms, meteorological data, and satellite surface temperature to generate high resolution (1×1 km) daily air temperature estimates. We applied Cox's proportional hazard regression models, adjusting for individual risk factors, to examine the chronic effects of mean temperature and temperature variability for both summer and winter in the Medicare population (age>=65) across South Eastern states.

A rise in summer mean temperature of 1ºC was associated with a higher risk in mortality (HR=1.008, 95% CI=1.006-1.010) while a 1ºC increase in winter mean temperature corresponded to a lower mortality risk (HR=0.986, 95% CI=0.985-0.987). For a 1ºC increase in temperature standard deviation, hazard ratios of 1.040 (95% CI: 1.034-1.046) and 1.006 (95% CI: 1.004-1.008) for mortality were seen in winter and summer, respectively.

Conclusion

This study found a significant chronic effect of temperature on mortality for both mean values and variability. For future climate scenarios, while the opposite effects of summer/winter mean temperatures may compensate each other, excess public health risk of climate change may still stem from changes of within season temperature variability.

Acknowledgement

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FINE SCALE SPATIAL AND TEMPORAL VARIATION IN TEMPERATURE AND ARRHYTHMIA EPISODES IN THE VA NORMATIVE AGING STUDY

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Summary

Many studies have demonstrated that cold and hot temperatures are associated with increased deaths and hospitalization rates; new findings indicate also an association with more specific cardiac risk factors. Most of these existing studies have relied on few weather stations to characterize exposures; few have used residence-specific estimates of temperature, or examined the exposure-response function. We investigated the association of arrhythmia episodes with spatial and temporal variation in temperature, and we also evaluated the association between monitored ambient temperature (central) and the same outcome. We found that increased levels of cold and warm temperature may increase the risk of ventricular arrhythmia.

Introduction

Cardiovascular and cerebrovascular diseases are among the greatest causes of morbidity and mortality in adults in the United States and world-wide. Ventricular tachycardia and ventricular fibrillation are common mechanisms of sudden cardiac death. The recently released Intergovernmental Panel on Climate Change report provided strong evidence that CO2 emissions will lead to warmer temperatures, and more extreme heat and cold events. Several studies have found associations between temperature and temperature extremes and health. Most epidemiologic studies have relied on weather data from the major city airport to characterize exposure, ignoring important factors that may influence temperature at individual residences including urban heat islands, distance from water, and amount of impermeable surface, which can introduces substantial exposure error. We have recently presented and validated a temporally-and spatially-resolved prediction model utilizing satellite surface temperature data (Kloog et al 2014) to estimate daily ambient temperature at the participant's home address. In a previous study (Zanobetti et al 2013) we found that temporally and spatially resolved black carbon (BC) and PM2.5 were associated with increased risk ventricular ectopy (VE) in the Veterans Affairs (VA) Normative Aging Study (NAS). In this follow up we investigated the association between fine scale spatial and temporal variation in temperature and VE episodes study in the same population residing in the greater Boston area. We compared the estimated health effect estimates based on our spatio-temporal exposure prediction model to those based on a single local weather monitor located at Boston Logan Airport.

Methodology and Results

This longitudinal analysis included 701 older men participating in the VA Normative Aging Study. Arrhythmia episodes were measured as ventricular ectopy (VE) (bigeminy, trigemini or couplets episodes) by 4min electrocardiogram monitoring in repeated visits during 2000-2010. The outcome was defined as having or not VE episodes during a study visit. We applied a mixed effect logistic regression model with a random intercept for subject, controlling for seasonality, weekday, medication use, smoking, diabetes status, body mass index and age. We also examined effect modification by personal characteristics, confounding by air pollution, and the exposure-response function.

For 1° C increase in the same day residence-specific temperature, the odds of having VE episodes was 1.10 (95%CI: 1.04-1.17). The odds ratio (OR) associated with 1° C increase in central temperature was 1.05 (95%CI: 1.02-1.09). The exposure-response function was non-linear for averages of temperature, presenting a J-shaped pattern, suggesting greater risk at lower and higher temperatures.

Conclusion

This study provides evidence that temperature is associated with increased risk of ventricular arrhythmias, and that the use of spatially resolved temperature data reduces downward bias due to exposure error.

Acknowledgement

This work was supported by National Institute of Aging R21 AG040027-01, NIEHS grants P01 ES009825, P30 ES000002, R21 ES020194-01. This work was also made possible by USEPA grant (RD-83479801). Its contents are solely the responsibility of the grantee and do not necessarily represent the official views of the USEPA.

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SPECIAL SESSION – MODELLING AND MEASURING NON-EXHAUST EMISSIONS FROM TRAFFIC

NON-EXHAUST CONTRIBUTIONS TO PM10 AND PM2.5 AT FIVE EUROPEAN CITIES

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Summary

Results of the PM10 and PM2.5 source apportionment at 3 urban background sites (Barcelona, Florence and Milan, BCN-UB, FI-UB, MLN-UB) 1 sub-urban background site (Athens, ATH-SUB) and 1 traffic site (Porto, POR-TR) during 2013 are presented. Road traffic (sum of vehicle exhaust, non-exhaust and traffic-related secondary nitrate) was the most important source of PM10 (23-38% at all sites) and PM2.5 (22-39%, except for ATH-SUB and BCN-UB). Non-exhaust fraction represented 8-11% of PM10 and 1-9% of PM2.5. The non-exhaust/exhaust ratio varied from 0.4 (at POR-TR) to the range 0-8-1.2 at the SUB and UB sites. Non-exhaust profiles from PMF were compared to local road dust, brake pads and tires composition revealing a main road dust origin in BCN and ATH and brake origin in POR, FI and MLN, probably due t the drier climate of BCN and ATH. In addition short campaigns with 1 hour resolution PM elemental composition allowed investigating intra-daily variability of non-exhaust contributions.

Introduction

There are still few source apportionment studies reporting non-exhaust contributions rather than total road traffic contributions. Separating exhaust from non-exhaust is important in order to design different mitigation measures and investigate health effects from distinct sources. Moreover source apportionment studies are often distinct in procedures and direct comparison is not possible. The AIRUSE LIFE+ project offers the first results of an harmonized source apportionment study at 5 South European cities using the same protocol (Milan, Barcelona, Porto, Florence and Athens).

Methodology and Results

PM measurements were carried out from January 2013 to February 2014, simultaneously at five urban stations in Barcelona, Porto, Florence, Milan and Athens. PM10 and PM2.5 samples were collected simultaneously over 24 hours, every third day, on quartz microfiber and/or Teflon filters. Then filters were destined for several analytical determinations(PIXE, ICP-MS, ICP-AES, XRF, IC, TOT for determination of over 60 components of PM. Hourly samples of PM2.5 and PM2.5-10 were collected with the streaker sampler, and analyzed by PIXE. Non-exhaust emissions from traffic contributed 2.9, 2.6, 3.4, 1.9 and 1.8 $\mu g/m^3$ at Porto, Barcelona, Milan, Florence, and Athens on annual basis respectively. Day-to-day, intra daily variability and non-exhaust/exhaust ratios were explored.

The Vehicle non-exhaust source generally shows a mixed composition, including crustal species (Fe, Ca, Al, Si among others), carbon compounds (EC generally higher than OC) and trace elements (Cu, Zn, Mn and occasionally Sn, Sb and Ba) from brake wear. However, rather dissimilar chemical profiles were found comparing different cities. Although the enrichment in Fe is common to all the cities, the main component of NEX can be either Ca (in BCN-UB), EC (in POR-TR and MLN-UB), OC (in FI-UB), or S (in Athens-SUB). These differences can be due to several factors:

- the proximity to the source: at the traffic site (POR-TR) the NEX source is dominated by the brake wear (EC)
- the climatic conditions: Ca is higher in drier regions (BCN-UB and ATH-SUB) due to the enhanced resuspension, when compared to POR-TR and MLN-UB
- the type of materials used for brakes and road pavement (the higher OC in Florence might be due to higher road wear compared to other cities).
- the "rotational ambiguity" of receptor modeling which may produce false bias.

Conclusions

Non-exhaust emissions were responsible for 8-11% of PM10 and 1-9% of PM2.5 concentrations at five South European cities, on annual basis. Contributions were higher during days of exceedances of the PM10 daily limit value. Chemical profiles indicated a main relation to road dust resuspension and brake wear.

Acknowledgement

This work was funded by the AIRUSE LIFE+ EU project.

ADVANCED RECEPTOR MODELLING TO QUANTIFY EXHAUST AND NON-EXHAUST TRAFFIC EMISSIONS: RESULTS FROM A CASE STUDY IN FLORENCE (ITALY)

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Summary

An advanced receptor modelling (i.e. constrained multi-time ME-2) approach has been implemented to perform a source apportionment study combining particulate matter datasets with different time resolution (Crespi et al. 2016). Results from the application of the enhanced modelling approach to a case study will be presented focusing on the separation between traffic exhaust and non-exhaust emissions.

The implemented approach was tested on a PM2.5 dataset composed of 24-hours samples collected during one year and hourly data sampled in parallel for two shorter periods in Florence (Italy). The daily samples were chemically characterized for elements, ions and carbonaceous components while elemental concentrations only were available for high-time resolved samples. The application of the advanced model revealed the major contribution from traffic and allowed an accurate characterization and estimate of the exhaust and non-exhaust emissions. Moreover, the comparison with the results computed by ME-2 base model applied to daily and hourly compositional data separately demonstrated the advantages provided by the multi-time approach.

Introduction

The most recent developments in monitoring techniques allow aerosol components measurement with higher and higher time resolution; in particular, besides 24-h resolution data carried out in compliance with regulatory purposes, hourly samples of different PM fractions can be collected by higher resolution instruments. Traditional multivariate techniques need to reduce all data to a single time schedule; either the modeller has to average high-time resolution data over the longest sampling interval - typically 24-h - or to interpolate the low-resolution data to the shortest sampling period. Therefore, the source apportionment modelling is typically limited to the separate analysis of high-time or daily samples thus either important source markers given by the complete chemical speciation often available on daily samples or the high-time resolution information get lost.

In order to properly take into account all the temporal details provided by experimental data without averaging or interpolating, an advanced receptor model was developed (Zhou et al., 2004) using Multilinear Engine (ME-2) which is a flexible algorithm program implementing a scripting language able to solve multivariate receptor problems (Paatero, 1999). By the multi-time approach, apportionment problems can be solved inserting each data value in its original time schedule.

Methodology and Results

Advanced receptor models have been recently developed and tested in order to improve the resolution of apportionment problems reducing rotational ambiguity of results and aiming at identifying a larger number of sources.

By means of the flexibility of ME-2 program, in this work the multi-time model has been expanded 1) to perform a continuation run; and 2) to assess uncertainties on the solutions. More precisely, during the continuation run physically meaningful constraints can be imposed on the resolved sources in order to reduce rotational ambiguity and enhance the problem solution. Usually the constraints derive from a-priori knowledge on the features of sources influencing the monitoring site. The ME-2 model implemented in this work was applied to PM2.5 samples collected at a traffic site in Florence (Italy) both with daily and hourly time resolution in the framework of the regional project PATOS2 - Particolato Atmosferico in TOScana 2. Constrained multi-time ME-2 resolved seven factors which were assigned to traffic exhaust (36% as annual average) and non-exhaust emissions (7%), biomass burning (21%), soil dust (4%), sulphate (16%), nitrate (12%), and aged sea salt (4%). It is noteworthy that the ME-2 application to the daily and hourly resolution data separately did not give the same detailed source apportionment results and, in particular, exhaust and non-exhaust traffic emissions cannot be singled out separately.

Conclusions

This application of the enhanced ME-2 revealed the importance of developing advanced receptor models which could lead to a better understanding of the sources impacting on a studied area. In particular, the multi-time model can be considered an advantageous tool to resolve apportionment problems as high-time details allow to take into account fine scale variations of specific tracers improving identification of factors and resolving in certain situations a greater number of sources.

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TURBIDITY AS A PROXY FOR ROAD SURFACE DUST LOAD (DL180)

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Summary
Understanding the spatial and temporal distribution of the road dust load in cross sections of city streets is of importance in order to abate problems with traffic induced PM_{10} emissions related to road dust. Methods for determining the road dust loads are however time consuming and tedious, why a simple proxy would be of big help. Turbidity showed to be a possible proxy for the city streets tested (R^2=0.95).

Introduction
The wear of road surfaces from the use of studded tyres during winter time contributes to high levels of PM_{10} during dry spring periods in Nordic cities. Some of this PM_{10} is directly emitted and some is suspended from the road dust depot, which may have different origins but mainly consists of road wear particles. Understanding the road dust depot behaviour is therefore important in order to understand the processes responsible for high PM_{10} levels, and therefore also the ability to mitigate PM_{10}. Road dust has been sampled in the city of Stockholm since 2011 (Gustafsson et al., these proceedings) and the dust load of wheel tracks and in-between wheel tracks areas has been determined. The involved sample analysis methods are however tedious and time consuming, why a faster proxy method would be desirable in order to determine the dust load in entire street cross-sections instead of just the two segments wheel track and in-between wheel tracks. Therefore turbidity is in this paper tested and evaluated as a proxy for road surface dust load.

Methodology and Results
Road dust is sampled with the VTI Wet Dust Sampler (WDS) (Jonsson et al. 2008), which is based on a high pressure water appliance where the road dust is cleansed from a confined area of the road surface and then pneumatically flushed from the road surface to a sampling bottle (Figure 1). At the laboratory the samples are sieved in order to get rid of particles >180µm and thereafter filtered in Büchner funnels. The pre-weighed filters are dried, weighed with the sample and burned at 550°C in pre-weighed pots and the remains are determined by weighing the pots after burning. To compare with the gravimetrically determined dust load, the turbidity of the samples was measured before sieving at the laboratory with an infrared light scattering (90°) turbidity meter (Lovibond PC_H). The turbidity of the samples showed a nonlinear relationship to the dust load (DL180), where a bend in the curve seemed to occur at approximately 200 FNU, which corresponded to a dust load of approximately 100 g/m^2. The data was fitted by a Hoerl equation ($y=a\cdot b^x\cdot x^c$) with a R-square coefficient of determination of 0.95.

Fig.1 Sampling road dust load with Wet Dust Sampler

Conclusions
Turbidity showed to be a possible proxy for the load of road dust on a road surface. The method should, however, be evaluated also for road dust of different origins and during different seasons since this may affect the optical properties of the suspended particles in the sample bottle.

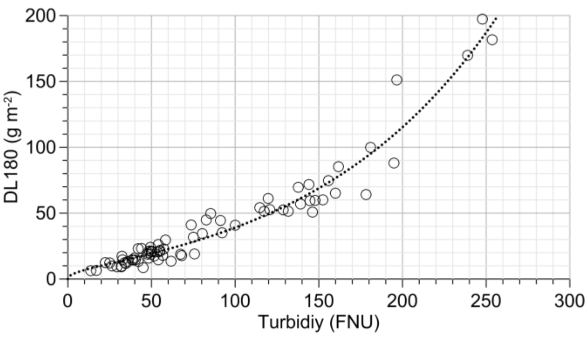

Fig.2 Relation between turbidity and dust load DL_{180}

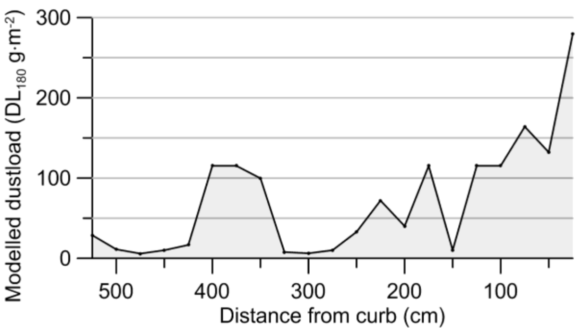

Fig.3 Calculated dust load with turbidity as proxy

Acknowledgement
This work was supported by the Swedish Transport Administration. We acknowledge Emelie Karlsson and Måns Kyhlbäck for their help during sampling and/or analysis.

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CONCENTRATIONS AND EMISSION FACTORS FOR $PM_{2.5}$ AND PM_{10} FROM ROAD TRAFFIC IN SWEDEN

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Summary
Emission factors for PM_{10} and $PM_{2.5}$ were estimated using NO_X as a tracer. Monitoring data from kerbside and urban background sites in Gothenburg during 2006-2010 and in Umeå during 2006-2012 were used. NO_X emissions were estimated from the traffic flow and emission factors calculated from the HBEFA3.1 model. $PM_{2.5}$ constitutes the finer part of PM_{10}. Emissions of the coarser part of PM_{10} (PM_{10} - $PM_{2.5}$) are supressed when roads are wet and show a maximum during spring when the roads dry up and studded tyres are still used. Less than 1 % of the road wear caused by studded tyres give rise to airborne $PM_{2.5\,-10}$ particles. The NO_X emission factors decrease with time in the used model, due to the renewal of the vehicle fleet. However, the NO_X concentrations resulting from the roads show no clear trend. The emission factors for PM_{10} decreased with time, and the average factor was 0.06 g km^{-1} $vehichle^{-1}$. The emission factors for $PM_{2.5}$ are very uncertain due to the small increments in $PM_{2.5}$ concentration at the thoroughfares, and were on average 0.02 g km^{-1} $vehichle^{-1}$.

Introduction
Airborne particles of the size fractions $PM_{2.5}$ and PM_{10} are associated with health problems, such as cardiovascular disease and chronic obstructive pulmonary disease. However, health risks related to wear particles have not yet received much attention (Denier van der Gon et al., 2013). The main source of $PM_{2.5\text{-}10}$ and NO_X in Swedish cities is the local urban traffic. Long-range transport of particles belonging to the accumulation mode is, however, the main source of urban $PM_{2.5}$ in the southern parts of Sweden. A high background concentration of $PM_{2.5}$ is not only an issue when measures to reduce the particle concentration are to be taken, but also when $PM_{2.5}$ emissions from the road are quantified.

Methodology and Results
Particle concentrations were measured with TEOM (Tapered Element Oscillating Microbalance) instruments. NO_X was measured using chemiluminescent instruments with Mo-converters. Two cities with thoroughfares belonging to the international E-road network were selected for this study. The E6 runs through Gothenburg in the south-western part of Sweden and the E4 runs through Umeå situated in the north-eastern part of Sweden. NO_X, $PM_{2.5}$ and PM_{10} concentrations were measured on an hourly basis at the two thoroughfares and the corresponding urban background stations. The traffic flow of different vehicle categories was measured by inductive- loop sensors embedded in the pavement. While this is not the most accurate technique, it was chosen due to the fact that it requires very little maintenance. Hourly averages of the speed and traffic flow were measured for each vehicle category in each lane in the two cities. The measurements started in 2006 in both cities and ended in 2010 in Gothenburg and in 2012 in Umeå. Equation 1 was used to estimate the emission factors for PM_{10} and $PM_{2.5}$. Average emission factors during a certain week day, month, year etc. was not calculated using the arithmetic average of hourly calculated emission factors for particulate matter (EF_{PMX}), but from average arithmetic average concentration increase of NO_X and PM_X at the road. This calculation resulted in more consistent averages compared to arithmetic averages of hourly calculated emission factors.

$$\overline{EF}_{PMx} = \overline{EF}_{NOx} \frac{\overline{\Delta PM_X}}{\overline{\Delta NO_X}} \qquad (1)$$

The diurnal variation of the traffic flow was very similar during all workdays, but the concentration varied widely due to the large variation in the air dispersion. Air dispersion was estimated from the traffic flow and the NO_X emission for each vehicle category and the increased NO_X concentration at the road. The average air dispersion was about three times as high in the summer compared to winter and about three times as high during midday compared to midnight. The road wear is mainly caused by cars with studded tyres. The pavement rutting has been measured with a non-contact laser profilometer that was placed on fixed devices cast in the roadway. To estimate the fraction of the road abrasion caused by studded tyres that will give rise to PM_{10} particles, EF_{PM10}-$EF_{PM2.5}$ was calculated for the periods November-April and May-October. The difference between the two periods was 0.05 g km^{-1} $vehichle^{-1}$ in Gothenburg and 0.02 g km^{-1} $vehichle^{-1}$in Umeå. These emission factors for $EFPM_{2.5\text{-}10}$ are only 1.5 % and 0.8 % of the total road wear caused by studded tyres in Gothenburg and Umeå respectively. These percentages may also include emission of road salt and reemission of road dust and abrasion caused by e.g. sand on the roads.

Acknowledgement
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ROAD DUST LOAD VARIABILITY IN STOCKHOLM, SWEDEN

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Summary
Road dust is a main source to PM_{10} in Nordic cities, mainly originating in studded tyre road pavement wear and winter road operations and makes up an important contribution to PM_{10} exceedances. Effective PM_{10} mitigation is therefore depending on knowledge on road dust sources, properties and the dynamics of the road dust depot. This study presents variability in road dust data measured in Stockholm streets during four seasons and its causes.

Introduction
The Nordic countries Sweden, Finland and Norway are experiencing regular high PM_{10} peaks in springtime attributed to suspension of road dust formed during the winter season when studded tyres are used and winter road operations are frequent. EU limit values are exceeded in some cities and intensive abatement measures has been taken to reduce the concentrations. Stockholm has been the city with highest and most pronounced exceedances in Sweden and has also worked with an abatement program since 2005. As part of the follow-up program, road dust load has been regularly measured and studied resulting in a unique road dust load time series, presented in this abstract.

Fig.1 Road dust sampling using the VTI wet dust sampler

Methodology and Results
Road dust was sampled and presented as DL180 (dust load smaller than 180 µm) using the VTI wet dust sampler (WDS) (Jonsson et al., 2008, Figure 1). Samples were taken in left wheel track and between wheel tracks of four streets in Stockholm city between October and May. The results show an annual variation with road dust load peaks normally occurring in mid-winter and low road dust loads in October and May (Figure 2). The amounts vary between a few g/m^2 in wheel tracks in October and May, to around 200 g/m^2 between wheel tracks in early spring. The onset of the studded tyre season (1st of October), beginning of winter road operation and the wetter road surfaces during winter, increases the accumulated dust amounts, while the end of the studded tyre season (15th of April) and removal of accumulated wear dust and winter sand causes the decrease in spring. The surface in between wheel tracks normally has a higher dust load than in wheel tracks due to the cleaning effect of passing wheels. Variability between streets are high, which has previously been shown to relate to differences in road surface texture (e.g. Blomqvist et al., 2014). A thorough overview of road surface texture would improve the possibility to abate road dust load as source to PM_{10} emissions.

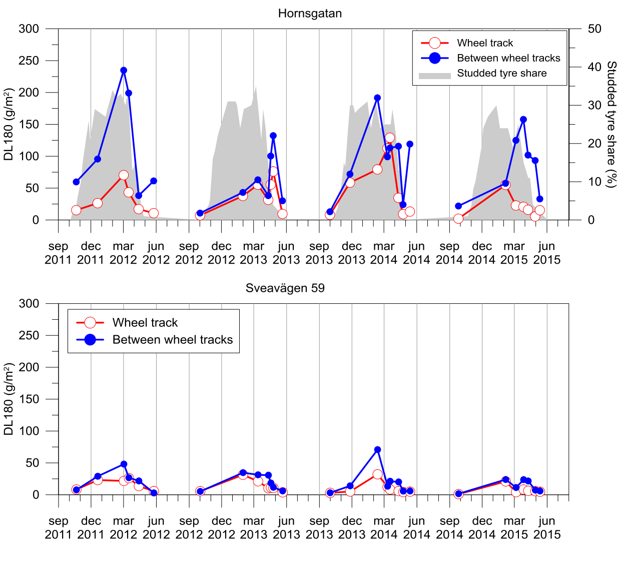

Fig.2 Road dust variation in two Stockholm streets 2011 – 2015. For Hornsgatan also studded tyre share is shown.

Conclusions
Road dust load, measured as DL180, varies from a few to over 200 g/m^2 in Stockholm streets during October to May. The dust load has a regular seasonal pattern which is similar from year to year and co-varies with studded tyre use but also relates to winter operation and humid road surfaces during winter.

Acknowledgement
This work was supported by the City of Stockholm and the Swedish Transport Agency.

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ROAD CLEANING ABATING ROAD DUST –TEST OF ROAD SWEEPERS IN TUNNEL AND STREET

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Summary
This study aims to quantify the changes in road dust load (DL180) in a tunnel and at a street from cleaning the surface with three different road sweepers. Dust load (DL180) is measured using a Wet Dust Sampler (WDS) that collects the dust by high pressure distilled water, and then analyse the weight and the particle size distribution. The analysis shows that there is a large difference in the effect on dust load between different road sweepers, but also between the tunnel and the street. At the street two of the sweepers reduce the dust load efficiently, while one road sweeper didn't succeed in road dust removal. In the tunnel the measured road dust load generally increased after the cleaning. The possible reasons for this is discussed in the presentation.

Introduction
Particle pollution is closely related to health issues and in the Nordic countries the road dust is an important source of air particle pollution. Thus, efforts are made to reduce the road dust load, in order to limit the emissions of road dust into the air. The importance of road dust as a source of particle air pollution in other countries is growing as exhaust emissions of particles is regulated and reduced. The abatement strategies used in the Nordic countries will then be of increasing importance also to other countries with high dust loads.

Methodology and Results
Road dust is sampled using the Wet Dust Sampler (WDS), developed at VTI, Sweden (Jonsson et al, 2008) that has the possibility to sample road dust equally efficient from a dry and a wet road surface. The sampler is used to collect road dust in distilled water, which is analysed in laboratory for total weight per area and size distribution. The maximum dust size analysed is 180 µm diameter and the size distribution is measured using a laser granulometer, Mastersizer 2000. During the sampling the road lane is closed for safety reasons. The measurement campaign included many other aspects of road cleaning in tunnel and at street, but this presentation focus on the effects on road dust. Strindheimtunnelen, Trondheim, was divided into three different test road stretches, and the road dust load at each of the stretches was analysed using the WDS. Then each test street was cleaned with one of three machines and the road dust at each surface was analysed again, now shifted slightly in location in order not to sample road dust where it was recently sampled. The same set up was used for the street campaign at Haakon VII Gate in Trondheim the following night.

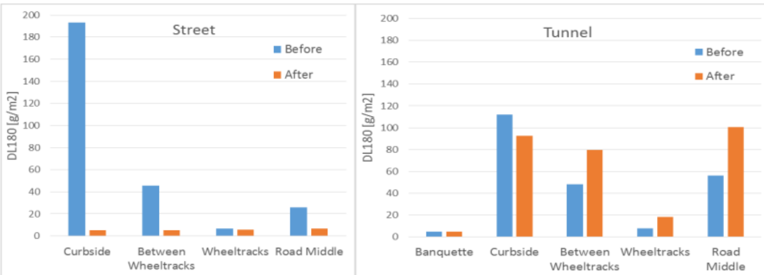

Fig.1 Road Dust, DL180, before and after cleaning with the same machine; street and tunnel.

Figure 1 shows the measured road dust before (blue) and after (orange) the cleaning for one of the tested road sweepers. The result was very convincing for the street study, while the tunnel study results were disappointing. The distribution of road dust over the transect of the road is also shown in Figure 1, as the wheel tracks in both studies has a lower load of dust, due to the transport of the dust from the wheel track by the movement of traffic. The reason for the very low road dust load on the banquette is that this is an area close to the asphalt but made of concrete and thus without a large texture that can collect road dust. On the street instead the dust can be collected at the road close to the walking path, as the dispersion of the dust is limited close to the curbstone.

Conclusions
The different cleaning equipment did not have the same efficiency in removing road dust. At the street the road dust was removed efficiently using two out of three tested road sweepers, while the tunnel cleaning was not successful for road dust removal. For most of the sweepers the road dust concentration instead increased by cleaning.

Acknowledgement
This work was supported by Norwegian Public Roads Administration, Norway. We acknowledge Karl Andersson and Thomas Lindström for their help during sampling and Ida Järlskog for analysis.

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DUST EMISSIONS FROM HEAVY VEHICLE TRAFFIC ON PAVED INDUSTRIAL ROADS

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Summary
To calculate emission factors for dust emissions from heavy vehicle traffic on paved industrial roads, Standard VDI 3790 Part 3 refers to a method of calculation of the US EPA. To check this method and possibly adapt, a working group within the Association of German Engineers (VDI) was established. As objective of the Working Group a new Standard VDI 3790 Part 4 will be created. As a basis for testing and adaptation of the emission factors model the Institute of Particle Technology at the University of Wuppertal completed a study on the verification of the US EPA model by field measurements in cooperation with the North Rhine Westphalian State Agency for Nature, Environment and Consumer Protection (LANUV). For this purpose, a measuring method has been developed which simplifies the measurement of the dust emissions. This method and the results of the measurements are presented here.

Introduction
For the calculation of non-motor dust emissions of trucks on paved roads within industrial sites, the currently valid Standard VDI 3790 Part 3 refers to the calculation method of the US EPA AP-42 directive (section 13.2.1). This method is based on site-specific parameters (road surface silt loading, days with precipitation) and fleet-specific parameters (average weight of the fleet).

$$E = \left[k\,(sL)^{0.91} \cdot W^{1.02}\right]\left(1 - \frac{P}{4 \cdot N}\right)$$

E: particulate emission factor
k: particle size multiplier for particle size range
sL: road surface silt loading / g m^{-2}
W: average weight (tons) of the vehicles traveling the road (US short ton: 907.18 kg)
P: number of "wet" days with at least 0.254 mm (0.01 in) of precipitation
N: number of days in the averaging period

Fig.1 Passage for dust measurements

The velocity of vehicles is not a factor in this model, but was used for the calculation of the two exponents. This was point of criticism (e. g. Venkatram 2000).

Methodology and Results
The EPA approach for the calculation of emission factors for paved roads is based on a limited data collection (e. g. Klenk 2013). To determine the applicability of the US EPA AP-42 calculation method for European industrial sites, a method for the measurement of the dust emissions was developed (Fig. 1) and used for two different kind of trucks at four different weights and up to four different velocities. Fig. 2 shows as an example the particle number concentration for a scattering equivalent particle diameter > 2 µm for one truck at two different weights and three different vehicle velocities. It can be seen, that weight and velocity is an important factor for the calculation of emission factors.

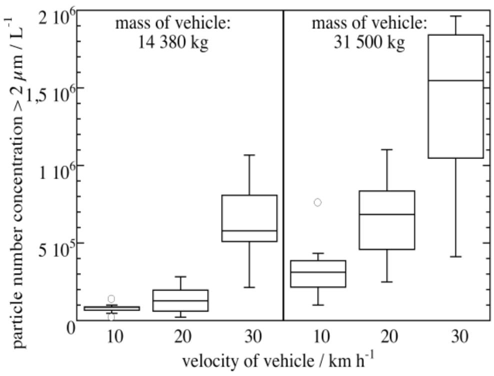

Fig. 2 e. g. dust concentration depending on velocity

Conclusions
The calculation of emission factors for the test vehicles based on the measurements are for a vehicle velocity of 30 km h^{-1} at the same order like the emission factors calculated based on the US EPA AP-42 equation. This shows, that the EPA-42 calculation method of emission factors from heavy vehicle traffic on paved roads within industrial sites is an applicable and simple approach under usual conditions (Klenk 2013). But it has to be discussed, if more parameters should be used in the equation, e. g. for the velocity and other methods of dust control. Another grouping of vehicle speeds (and masses, not shown here) will lead to other exponents in the equation. This work will show the fundamentals for those further discussions.

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EVALUATION OF AIR POLLUTION BY PM10 AND PM2.5 ON ST. PETERSBURG RING ROAD: MOBILE MEASUREMENTS AND SOURCE APPORTIONMENT MODELLING

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Summary
The aims of the present study were: 1) to estimate the level of PM10 and PM 2.5 concentrations in the air on St. Petersburg Ring Road in spring 2015; 2) to evaluate the effect of rain and road washing on PM level; 2) to quantify exhaust / non-exhaust emissions by combining experimental and calculating approaches. The study reveals that road dust resuspension in combination with other non-exhaust emissions (brake wear, tire wear, road surface wear) may become a key source of excessive PM concentrations at dry weather conditions in St. Petersburg. Thus, it demonstrates the need to proceed with investigations in order to develop a suitable modelling approach for the calculation of traffic related non-exhaust emissions of particulate matter.

Introduction
Despite, that weather conditions are mostly favourable for the precipitation of PM pollutants, the problem of excess PM10 and PM2.5 air pollution on the roads is significant for St. Petersburg in early spring when the roads are covered with huge dust-deposits accumulated through the winter. In this case, road dust resuspension contributes considerably to particle concentrations in the air. At the same time, a widely used national calculating methodology for the calculation of road transport related air pollution considers only exhaust PM10 and underestimates, thus, the modelled PM concentrations in comparison with the measured ones [1], highlighting the need to investigate non-exhaust emissions and their sources. Considering this, we measured PM10 and PM2.5 concentrations and quantified exhaust / non-exhaust emissions at different weather conditions using experimental and calculating approaches.

Methodology and Results
Two laser DUCTTRAK 8530 (TSI Incorporated / USA) spectrometers were used for the simultaneous mobile measurements of PM10 and PM2.5 concentrations on St. Petersburg Ring Road (SPbRR) with traffic volume 7500-12000 vehicle per hour and the share of heavy duty vehicles (HDV) ranging within 6-23%. The investigations were carried out at different weather conditions in March, April and May 2015: (1) Dry sunny day after 8 dry days in March (high visible level of dusting); (2) Dry sunny day after night drizzle in March (high visible level of dusting); (3) Dry sunny day after some rainy days and road washing in April; (4) Rainy day after road washing in April; (5) Dry sunny day after some rainy days and road washing in May.

Table 1. Average PM at different weather conditions on SPbRR

Average PM, µg/m^3	Conditions of PM monitoring / date				
	1/19.03	2/20.03	3/06.04	3/14.04	4/24.05
PM10	236	167	59	38	27
PM2.5	117	84	31	25	21
PM2.5/PM10	0.496	0.503	0.525	0.657	0.777

The measured PM10 concentrations exceeded LV_{24h} (24 hours Limit Value) by 2.8-3.9 times and PM2.5 – by 2.4-3.3 times in March 2015. After some rainy days and washing, the PM concentrations have fallen below LV. At the same time, the share of PM2.5 has increased from 49.6 % in March to 77.7 % in May, indirectly showing the trend of the increasing share of exhaust PM. This trend was confirmed by numerical experiments carried out using modified versions of the National models MAGHISTRAL 3.0 and ECOLOG 4.0. The results have shown that the share of combined non-exhaust PM10 emissions (52 %), including brake wear (6 %), tire wear (6.5 %), road surface wear (RSW) + resuspension emissions (39.5 %), was higher than the share of exhaust PM10 (48 %) in the middle of March 2015 (Fig. 1). Road cleaning activities and rainy weather resulted in the lowering of PM10 concentrations to 20-30 µg/m^3 and in the decline of the share of the resuspended PM10 to 14 % in May 2015. As expected, the use of on-road PM measurements and data on the real volume and structure of the traffic flows on SPbRR has significantly improved the results of calculations.

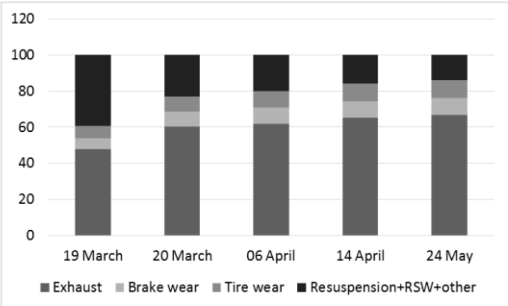

Fig.1 Source apportionment of PM 10 emissions.

Conclusions
The study has shown that non-exhaust emissions have a considerable air polluting effect in St. Petersburg, especially, in early spring. Hence, there is a need to develop a model forecasting road resuspension emissions in order to contribute to the optimization of environment quality management in the Russian Federation.

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MODELLING ROAD DUST EMISSION ABATEMENT MEASURES USING THE NORTRIP MODEL: VEHICLE SPEED AND STUDDED TYRE REDUCTION

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Summary
We used the NORTRIP model to analyse the impact of real world abatement measures on non-exhaust traffic induced particles. The model well reproduces the observed concentration including the effects of the measures. At RV4 in Oslo the decrease in PM_{10} concentration could be attributed to the reduction in speed signage. At Hornsgatan in Stockholm a ban on the use of studded tyres had the most significant effect in the reduction of observed PM_{10} concentrations.

Introduction
Non-exhaust traffic induced particle emissions are known to contribute significantly to the total concentrations of PM_{10}. The problem in Nordic countries is most related to studded tyre wear, the build-up of road dust during the wet winter period and the subsequent suspension of this dust during the dry spring period. A number of abatement measures have been introduced to reduce road dust emissions in the Nordic countries including speed regulations and regulations in the use of studded tyres.

Methodology and Results
The NORTRIP road dust emission model (Denby et al., 2013) is a coupled road dust and surface moisture model that describes a range of processes related to the generation and removal of dust and salt on the road surface as well as their subsequent suspension and emission. In this paper we apply the NORTRIP model to analyse real world abatement measures. RV4 is a major arterial road into Oslo with an average daily traffic (ADT) of over 40 000 veh/day. Speed signage was changed prior to the winter of 2005 which resulted in an observed change of average speed from 75 to 65 km/hr. Hornsgatan is a street canyon in Stockholm with an ADT of 29 000 veh/day in 2007. From 2010 the Stockholm city council introduced a studded tyre ban which reduced the maximum number of vehicles using studded tyres from 70% in 2009 to 27% in 2014. At the same time traffic volume dropped significantly to 22000 in 2011.

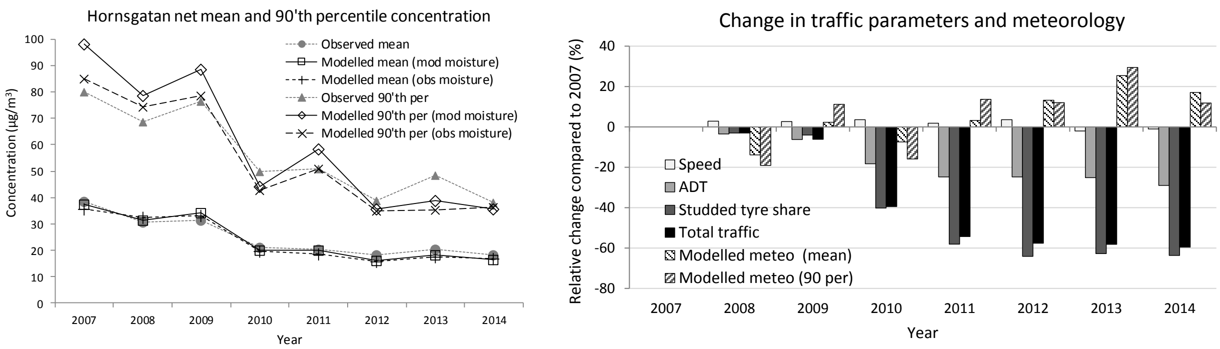

Fig. 1 Left: Summary statistics of the calculations for Hornsgatan. Right: Changes in various traffic and meteorological parameters and their separate influence on the net mean concentrations relative to 2007.

The NORTRIP model reproduces well both the mean and the 90th percentile concentration for both sites and for all years. Sensitivity studies using the model found that for RV4 the reduction in speed and the studded tyre share are the major contributors to the reduction in concentrations for 2005 while for 2006 the reduction is dominated by the meteorological conditions. For Hornsgatan the combination of studded tyre share and traffic volume reduction are the major driving changes in reducing the emissions in the years following the introduction of the studded tyre ban in 2010. However, the impact of meteorology in the last four years tends to increase the concentrations, relative to 2007.

Conclusions
By using the NORTRIP model we could show that a reduction in speed was a major contributing cause for reduction in observed PM_{10} concentration at RV4 in Oslo. It was also shown that the introduction of studded tyre ban on Hornsgatan in Stockholm was the major cause for reduction in observed PM_{10}, although the impact of meteorology enhanced the concentrations.

Acknowledgement
This project was founded by the Nordic council of Ministers.

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CHARACTERIZATION OF PRIMARY PARTICULATE VEHICULAR EMISSIONS IN AN URBAN TUNNEL IN NAPLES, ITALY

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Summary

The principal local source of particulate matter in many European cities is road traffic. Emissions from road traffic result in enhanced levels of particulate matter in urban areas and in particular near trafficked locations. In general, trafficked sites are the most likely locations for PM_{10} levels to exceed the European Union (EU) annual limit value of 40 $\mu g/m^3$.

Road traffic emissions consist of exhaust and non-exhaust components; non-exhaust component comprises emissions due to tear/wear of vehicle parts such as brake, tyre and clutch, road surface abrasion and re-suspension of dust, and contribute primarily to the coarse mode of PM ($PM_{2.5\text{-}10}$), while exhaust emissions, e.g. emissions from the tailpipe, contribute predominantly to fine PM (aerodynamic diameter < 2.5 μm).

Until the early 1990s, road transport emissions were dominated (80-90%) by exhaust emissions. Since then, most of the research, as well as policy action, has largely focused on exhaust emissions, and stringent regulations and technological upgrades have resulted in a decline of the percentage contribution of vehicle tailpipe emissions to total ambient PM concentrations. Presently, it has been estimated that non-exhaust emissions may contribute up to 50% of local road traffic emissions.

In order to estimate the relative contribution of exhaust and non-exhaust emissions, on-road PM mass samples were collected during an experimental campaign in March of 2015 in the ‘4 giornate’ tunnel in Naples, Italy. This tunnel is part of the heavy-trafficked urban road network, connecting the city center to suburbs. Two sets of samples were collected at both sides of the tunnel, each set representing the daily cycle at a 1 hour time resolution. Distance-based – mass per kilometer – and fuel-based – mass per burned fuel – emission factors (EFs) were calculated using mass concentrations, traffic flow rates and wind speed as a function of fleet composition. Also, chemical analysis was performed for polycyclic aromatic hydrocarbons (PAHs) and trace elements.

Average particle mass concentrations in the tunnel atmosphere were more than 5 times higher than in the outside urban background air, revealing its origins almost exclusively from fresh vehicle emissions.

While EFs for most of gas species were within the range of expected values, the present study found much higher EFs for particulate matter. This suggests that the sampling methods employed in this campaign are more efficient at capturing particles from sources such as resuspended road dust and wear from tires and brakes, which are usually not included in traditional sampling methodologies for assessing vehicular emissions (e.g. dynamometer studies).

THE LOWBRASYS PROJECT: PARTICLE MEASUREMENT PROCEDURE FOR BRAKE EMISSION TESTS

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Summary
This study will present the overview of the Lowbrasys project and the particle measurement procedure developed within the project to sample brake wear particles. The Lowbrasys project aims at demonstrating a novel and low environmental impact brake system to reduce micro and nanoparticles emissions. In order to estimate an accurate emission reduction factor we developed a solid repeatable, reproducible and representative of real driving brake emission measurement procedure.

Introduction
Road traffic contributes to the total anthropogenic PM emissions as exhaust and non-exhaust (e.g. tyre, brake and road wear, resuspension) particles. Growing road traffic in Europe might entail detrimental effects on air quality, the environment and public health. Due to increasingly stringent EU policies on vehicle exhaust emissions (e.g. Regulations (EC) No 715/2007, No 459/2012, No 443/2009), fleet renewal and implementation of modern technologies (e.g. diesel particulate filter), exhaust emissions have been constantly decreasing in the last decades. But while PM originating from exhaust gases emission have been targeted by EU Legislation, the same cannot be said for PM emissions related to non-exhaust sources – including the ones from vehicles' brake systems by wear and friction phenomena - which are expected to rise in the future due to higher volume of traffic, if current technologies apply. Brake wear is estimated to contribute approximately 16-55% by mass to non-exhaust traffic-related emissions in urban locations (Grigoratos and Martini 2014). The large uncertainty on the figures is mainly due to the intrinsic complexity of the underlying phenomena, the scarcity of data, while in other cases the results reported in the publicly available studies are not consistent or even are contrasting as a consequence of the use of different measurement techniques and sampling procedures. The challenge is therefore to demonstrate a new generation of technologies that are capable of reducing traffic generated particle emissions and, at the same time, advancing the knowledge and establish framework conditions for potential future legislations on vehicle generated particle emissions and EU air quality.

Methodology and Results
The goal of demonstrating the novel and low environmental impact brake system is achieved through the following targets:
1. Novel materials formulations of the brakes pad and disc in order to reduce the total particle emissions (increased wear resistance) and have a low-environmental impact at the same time.
2. Innovation of environmental friendly braking strategies (control systems) that optimise the vehicle braking action and reduce the particle emissions, based on identified particle emission mechanisms.
3. New technology for capturing particles near the PM source in order to further reduce PM emissions.
4. System integration and testing of the novel pad, discs, components and control systems in vehicles, following an incremental approach, from demonstration of single components to testing on two types of vehicles in indoor simulated test bench with realistic cycle up to real world tests.
5. Improvement of the measurement techniques and understanding of the brake wear PM effects on health and the environment through state-of-the-art non-in-vivo techniques creating related policy recommendations.

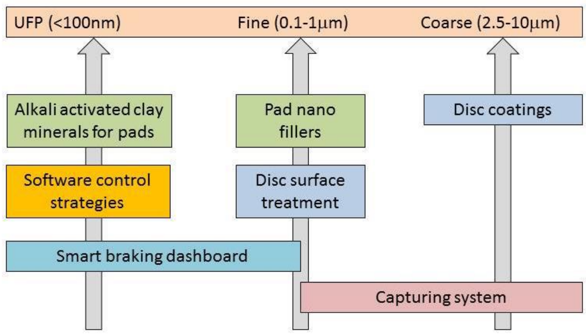

Fig.1 contribution of LOWBRASYS innovations to PM fractions

6. System analysis in terms of cost and environmental effects, through Life Cycle Costing, Life Cycle Assessment and full cost-benefit analysis of the proposed solution vs. current situation to evaluate potential monetary benefit associated with the targeted PM emission reduction.

The effect of the innovation on the emission reduction for different PM fractions is shown in Figure 1.

Acknowledgement
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THE ROLE OF DUST BINDING IN CUTTING DOWN PM_{10} CONCENTRATIONS IN URBAN AMBIENT AIR: CASE HELSINKI CITY CENTRE

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Summary
Concentrations of respirable particles (PM_{10}) in Helsinki city centre have been declining during past ten years and one of the main reasons is considered to be improved street maintenance actions against street dust, especially dust binding. Dust binding can cut down acute emissions after treatment by up to 40-90% (REDUST, 2014). A trend study was carried out for two different PM_{10} datasets from Helsinki city centre: (1) ambient air PM_{10} monitoring results and (2) street surface emissions measured with mobile laboratory Sniffer from 2006 to 2014. For both datasets the trend is decreasing and significant. Also the number of days when daily average PM_{10} concentration has exceeded the limit value (50 ug/m^3) in Helsinki city centre monitoring station has decreased.

Introduction
Street dust is a significant source of PM_{10} in urban traffic environments. This is the case especially in the Nordic countries where mineral particles from pavement wear and traction control materials accumulate to street environment during winter and are released in large quantities to urban ambient air during spring months. Additional measures are needed to mitigate PM_{10} emissions from street dust. The number of exceedance days (air quality threshold value) of PM_{10} was exceeded in Helsinki in 2006. In recent years both the concentrations of respirable particles (PM_{10}) and the number of limit value exceedance days have been declining in the Helsinki city centre. External factors (e.g. weather) affect the yearly variations, but a significant part of the positive development is linked to improved street maintenance actions, especially dust binding.

Methodology and Results
PM_{10} emission levels close to the street surface (street dust emissions) were measured with mobile laboratory Sniffer (Pirjola et. al 2009). Sniffer measures on a specific route in Helsinki city centre approximately once a week during spring months. The official PM_{10} air quality data (FH 62 I-R monitor) in Helsinki city centre is measured by the Helsinki Region Environmental Services Authority (HSY). A trend analysis for both ambient air and street surface concentrations was done using the Microsoft Excel template MAKESENS developed at the Finnish Meteorological Institute for detecting and estimating trends in the time series of annual values of atmospheric and precipitation concentrations (Salmi et al. 2002).

The use of dust binding in the Helsinki city center has increased significantly in recent years: from average three times in 2006 up to 35 times (in 2012). In the REDUST demonstration tests the effectiveness of dust binding was measured from the street surface (Sniffer) and along the test street with six pairs of PM_{10} Osiris monitors. Results from the dust binding tests show that it is possible to prevent dust emissions from the street surface and cut down acute emissions from 40% (targeted spreading) to even 90% (solution spread throughout the lane) when the initial level of street dust is high. Reductions in the PM_{10} emission levels were also detected with the streetside air quality measurements. (REDUST, 2014)

A trend analysis was done for PM_{10} air quality results and for Sniffer street surface PM_{10} emissions. For both data sets 95th percentiles were used. The 95th percentile of the PM_{10} monitoring results is considered to be attributable to street dust (Anttila et al. 2010). In the Sniffer data, 95th percentile excludes the lowest of the measuring results, which might be attributable to rainfall or other seasonal or meteorological factors. For both datasets the trend is decreasing and significant during the studied period. The number of exceedance days of PM_{10} daily limit value level (50 µg/m^3) at the Mannerheimintie air quality monitoring station is also decreasing. The decline is obvious especially for the spring period (Niemi et. al, 2014).

Conclusions
We have observed a decreasing trend in PM_{10} concentrations and resuspension emissions in the Helsinki city center. Dust binding has been demonstrated to be very efficient in reducing PM_{10} emissions and the trends observed in the Helsinki center have been linked with increasing use of dust binding ($CaCl_2$) during the study period.

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NEW DEVELOPMENTS AND APPLICATIONS OF THE NORTRIP ROAD DUST EMISSION MODEL

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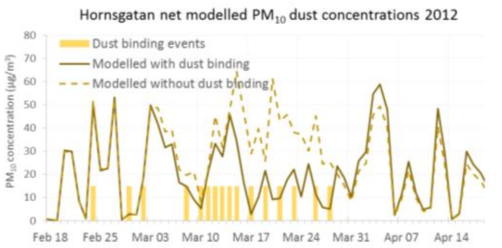
Summary
The NORTRIP model is an integrated road dust emission and road weather condition model developed in co-operation with ten institutes in four Nordic countries. The model is used in a range of applications related to road dust emissions and road surface conditions. In this paper an overview of the model and recent developments is provided along with a number of example applications including the impact of traffic speed, studded tyre share and dust binding activities on road dust emissions. In addition a comparison between observed and modelled road dust loading, road salt emissions and road surface conditions is presented. The model is unique in its ability to quantify these parameters and processes, describing the intricate coupling of non-exhaust emissions and road surface conditions.

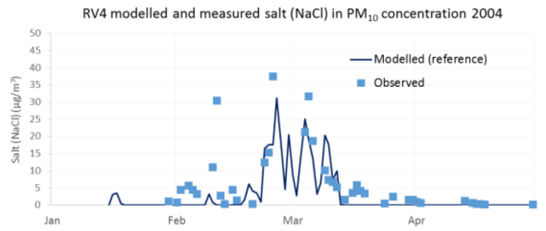
Introduction
Non-exhaust emissions from traffic continue to be a significant source of PM emissions. Whilst exhaust emissions are regulated by legislation there are currently no controls over non-exhaust emissions. Typical sources of non-exhaust include road, brake and tyre wear but also other sources such as emissions of salt, used for de-icing of road surfaces in winter, can also contribute. In order to better understand these emissions and to develop methods for optimal mitigation the NORTRIP emission model, a coupled road dust and road condition model, has been developed (Denby et al., 2013). In this paper we present an overview of the latest developments and show a range of recent example applications.

Methodology and results
Example applications of the model include:

- Calculation of non-exhaust emissions and road surface dust loading for air quality assessment and forecasting
- Assessment of measures, e.g. vehicle speed and studded tyre share reductions, for mitigating road dust emissions
- Calculation of road surface salt loading and its contribution to PM_{10} emissions
- Quantification of the impact of dust binding agents on surface conditions and PM_{10} emissions
- Prediction of road surface temperature and conditions

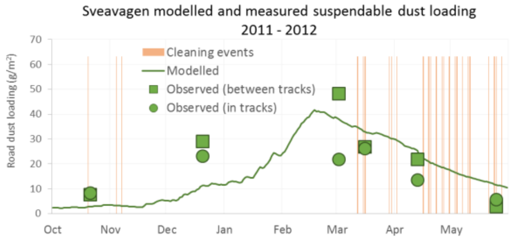
Dust binding: An observational comparison of PM_{10} concentrations near two roads in Stockholm, where dust binding was and was not applied, showed that concentrations of PM_{10} were reduced be roughly 32% due to dust binding. Application of the model to these roads shows that the model reproduces this reduction well, verifying that it can quantify the impact of dust binding on PM_{10} emissions.





Salt emissions: A comparison of modelled and observed salt concentrations in PM_{10} at four different road sites indicates that the model can reproduce some, but not all, of the observed salt concentrations. The results are shown to be primarily sensitive to the road salting activity data used as input but also to a number of the model parameterisations, concerning drainage and vehicle spray, and the quality of the input meteorological data.

Dust loading: The model prediction of road dust loading is compared to measurements of road surface dust a two streets in Stockholm, where in wheel track and between wheel track measurements have been performed. The results indicate that the model can correctly predict road dust loading to within a factor of two. Quantification of the road dust loading is unique to the NORTRIP model.



Conclusions
The model has been shown to reproduce many of the processes related to road dust emissions and road surface conditions. The model will be further developed and applied for both road weather and air quality management applications.

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THE RELATIVE IMPORTANCE OF TAILPIPE AND NON-TAILPIPE EMISSIONS ON THE OXIDATIVE POTENTIAL OF AMBIENT PARTICLES IN LOS ANGELES, CA

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Summary

This study examines the associations between the oxidative potential of ambient $PM_{2.5}$ and $PM_{0.18}$, measured by means of the dithiothreitol (DTT) assay, and their chemical constituents and modelled sources in two sampling sites in Los Angeles (LA) Basin. Multiple linear regression analysis (MLR) on DTT data and the identified Molecular Marker-Chemical Mass Balance (MM-CMB) derived sources along with sources of vehicular abrasion, crustal material, sea salt and secondary ions, demonstrated that vehicle tailpipe emissions is likely the main driver of oxidative potential in $PM_{0.18}$ but not $PM_{2.5}$ size fraction. The DTT activity levels measured in this study were compared to several previous studies conducted at the same sampling site in Central LA. This analysis of historical trends in ambient PM toxicity coupled with information on the impact of major regulations on mobile source emissions enabled us to assess the relative importance of tailpipe and non-tailpipe emissions on DTT activity.

Introduction

A large body of epidemiological and toxicological studies have investigated linkages between aerosol chemistry and health effects associated with exposure to particulate matter (PM). Furthermore, recent studies have shown that PM generated by specific sources have higher toxicity and, therefore, are strongly associated with health outcomes. In this study, association of chemical components and sources of ambient $PM_{2.5}$ and $PM_{0.18}$ with DTT activity was investigated.

Methodology and results:

Time-integrated sampling was conducted every week between July 2012 and February 2013 in Central LA, and from between July 2013 and February 2014 in Anaheim. Weekly samples were analysed to quantify the mass concentrations of PM and its chemical constituents (i.e. elemental carbon (EC), organic carbon (OC), total elemental composition, water-soluble inorganic ions). In addition, major sources of ambient $PM_{2.5}$ and $PM_{0.18}$-bound OC were identified using a novel hybrid MM-CMB model described in a companion paper by Shirmohammadi et al. (2015). OC source apportionment results from the CMB model were converted to $PM_{2.5}$ and $PM_{0.18}$ mass concentrations to evaluate the source contributions to total mass. Univariate analysis indicated high association between the DTT activity and the concentrations of carbonaceous species at both sites. The strongest correlations ($R > 0.60$) were observed between DTT and organic tracers of primary vehicle tailpipe emissions including polycyclic aromatic hydrocarbons (PAHs), alkanes and hopanes, with higher correlations for $PM_{0.18}$ versus $PM_{2.5}$ components. Moreover, metals such as Ba, Cu, Fe, Mn, Pb and Sb in both size ranges were also associated with DTT activity. In Central LA, primary biogenic, SOC and vehicular abrasion sources contributed significantly to $PM_{2.5}$ DTT activity with R^2 value of 0.69, while in $PM_{0.18}$ size range, vehicle tailpipe emissions as well as vehicular abrasion were the main drivers of the DTT activity ($R^2 = 0.50$). Similarly, in Anaheim, SOC and vehicular abrasion in $PM_{2.5}$ size range ($R^2 = 0.84$) and vehicle tailpipe emissions as well as vehicular abrasion in $PM_{0.18}$ ($R^2 = 0.80$) were identified to be the significant contributors of DTT activity. A steep decline in the oxidative potential of ambient $PM_{0.18}$ DTT activity was observed over the past decade in Central LA likely as a result of major reductions in emissions from these sources due to stringent regulations. $PM_{2.5}$ DTT activity, on the other hand, showed generally similar or even increased levels compared to earlier studies in Central LA. This trend may be explained by the overall increase in the ambient levels of indicators of non-tailpipe emissions (e.g. road dust, vehicular abrasions) over the past decade at this site.

Conclusion:

Our findings illustrated the relative importance of different traffic sources on the oxidative potential of ambient PM. Despite rapid reduction of tailpipe emissions, the lack of similar reductions (and possibly an increase) in non-tailpipe emissions make them an important source of traffic-related PM emissions in Los Angeles and of paramount concern for public health.

Acknowledgment:

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ROAD DUST MODELING FOR AIR QUALITY FORECASTING IN NORWAY

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Summary
Air quality forecasting has for several years been performed for cities in Norway, but a large challenge has been to predict the non-exhaust emissions due to the complex underlying processes. The NORTRIP model is a unique coupled road dust and road surface condition model which has been developed to handle the build-up of dust load and consequently the large variability in the non-exhaust emissions. This study has applied, for the first time, NORTRIP in a forecasting system for cities. The forecasting system will be presented together with the results from applying the NORTRIP model.

Introduction
Air quality prognoses of NO_2, PM_{10} and $PM_{2.5}$ are performed for several city agglomerations in Norway. The prognoses are used to send out forecasts to the public as well as the decision makers in the municipalities during the months with the highest concentration levels (October/November to end of April). A challenge has been to predict the non-exhaust contribution to PM because of the large variability in these emissions and the underlying complex processes. The use of studded tyres contributes to large road wear, and wet or icy winter conditions retain the dust on roads, building up a large dust layer. This retained dust is later released during dryer periods, typically in the spring. The springtime road dust emissions often cause several exceedances of the PM_{10} daily limit values (see figure 1), making it crucial to have a good estimate of these emission to make a reliable and useful prognosis of PM.

Methodology and Results
The prognosis system consist of high-resolution meteorological, emission and dispersion models giving hourly concentration values at street level for the next 48 hours in 7 city areas. In previous forecast seasons a road dust emission model which lacked the possibility to include the build-up and suspension of road dust has been used. This has led to large under-estimations in situations where road dust contributes to high PM levels (se figure 1). NORTRIP is a unique emission model as it takes into account the processes all the way from wear and retention to suspension by coupling a dust model and a road surface condition model. The model has performed well in several locations in Nordic countries (Denby et al., 2013). So far, however, the complete NORTRIP model has only been used in single street applications. Our work is the first full city multi-road NORTRIP model application.

The results for the forecast season 2014/2015 will be presented both using the former road dust emissions as well as the newly implemented NORTRIP model comparing the predicted values with observations. We will provide an overview of the forecast system and describe the use of the NORTRIP model in a multi-road forecast application, addressing the challenges of implementing winter activities like salting and dust binding in the prognosis system. The evaluation of the model performance is basis for further improvements of the system.

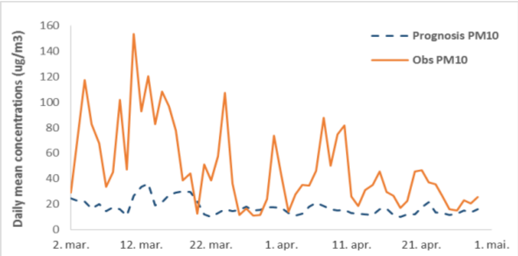

Fig.1 Daily means during a road dust episode in spring 2015 at a road site in Drammen showing observed and calculated (using the existing road dust emissions) concentrations

Conclusions
The NORTRIP model has previously been shown to predict the non-exhaust emissions well for individual roads. Implementation of the NORTRIP multi-road model is hence an important step to improve the forecasts of PM in Norwegian cities. The use of NORTRIP in the prognosis system will continue to be developed.

Acknowledgement
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SPECIAL SESSION – TRANSPORT RELATED AIR POLLUTION PM AND ITS IMPACT ON CITIES AND ACROSS EUROPE

AIR POLLUTION AT THE CHARILAOS TRIKOUPIS BRIDGE (GREECE)

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Summary

This study aims to assess the atmospheric pollution level in the area of the Charilaos Trikoupis bridge (Greece). The bridge, also known as bridge of Rio-Antirrio, is one of the world's longest cable-stayed bridges with multiple openings and a total length of 2,252 meters. It crosses the Gulf of Corinth near Patras, linking the town of Rio on the Peloponnese peninsula to Antirrio on mainland Greece. In this paper an overview of air pollution levels in the area in 2013-2015 is presented and the respective emission sources are identified. The study shows that overall the contribution of the Rio Antirrio bridge to the air pollution levels in the area can be considered very low mainly due to the low traffic volume, the fleet composition and the prevalent climatic conditions favorable to a rapid dispersion of the emitted pollutants

Introduction

Traffic is considered as one of the most important sources of air pollution in urban and periurban settings. However, only rarely is the impact of trafficked bridges on local air pollution thoroughly assessed due to the complexity of the engineering structure and the respective landscape. The Charilaos Trikoupis bridge is considered an engineering masterpiece with two vehicle lanes per direction plus an emergency lane and acts as a major road artery at the national level. Obtaining a thorough overview of its impact on air pollution taking into account seasonal variation is of both regulatory and scientific interest.

Methodology and Results

Six campaigns were performed in the course of the last three years covering both summer and winter periods. The exact periods of the campaigns were selected taking into account the high traffic seasons after a careful examination of the bridge traffic patterns. In each of the campaigns dynamic measurements of CO, NO_X, SO_2, $PM_{2.5}$ and PM_{10} were continuously executed over ten days near the edges of the bridge, i.e. in the urban areas of Rio and Antirrio. $PM_{2.5}$, PM_{10} and TSP were sampled every 24 hours using low-volume automatic sequential samplers. TSP was collected on quartz filters (203 mm × 254 mm) of high volume samplers (total volume of air sampled was approximately 2000 m^3). These filters were used for chemical analysis of particle-borne lead. Moreover, meteorological data (wind speed and direction, temperature, cloud cover and humidity) were recorded. The pollution data were analyzed statistically and the quality of the air was characterized using the US Environmental Protection Agency indices and the European Common Air Quality Index framework. Chemical speciation results in $PM_{2.5}$ and PM_{10} were used as input to Principal Component Analysis and Positive Matrix Factorization in order to identify the contribution of various sources (including bridge traffic) to the overall particulate loading in the local atmosphere.

Results show that air pollution levels are in generally under regulatory thresholds. $PM_{2.5}$ and PM_{10} levels were below 25 and 50 $\mu g/m^3$ on both sides of the bridge almost every day. These limits were exceeded only one day (5/12/2013) on the side of Antirrio (26.4 and 52.2 $\mu g/m^3$ for $PM_{2.5}$ and PM_{10} respectively). Moreover, traffic emissions from the bridge are not the main source of particulate pollution in the area. The low contribution from traffic emissions is exemplified by the low $PM_{2.5}/PM_{10}$ ratio, which is on the average 0.49 ($\sigma = 0.12$). Thus, long range transport of PM is more significant than local sources. During the winter $PM_{2.5}$ and PM_{10} levels are higher due to the use of light oil and biomass burning for space heating. Pb levels were very low; the daily value recorded (4.2 ng/m^3) is two orders of magnitude lower than the regulatory limit of 0.5 mg/m^3. Hourly average concentrations of CO, SO_2, NO and NO_2 in Antirrio were 4.0 mg/m^3, 1.9 $\mu g/m^3$, 6.8 $\mu g/m^3$ and 38.9 $\mu g/m^3$, while in Rio the respective levels were 5.3 mg/m^3, 4.5 $\mu g/m^3$, 3.8 $\mu g/m^3$ and 23.1 $\mu g/m^3$. SO_2 levels were reduced in 2013 compared to 2005, while they have been slightly increased for NO_2. $PM_{2.5}$ and PM_{10} samples were analyzed for black carbon and different elements for source apportionment analysis. Factorization software (EPA PMF 5.0) was used in order to determine the sources of $PM_{2.5}$ and PM_{10}. The analysis revealed that major emission sources for $PM_{2.5}$ were biomass burning (37.4%), traffic (23.5%) , shipping (19.2%), soil dust (11.2%), road dust (5.1%) and sea spray (3.6%). For PM_{10} the main sources are biomass burning (33.8%), sea spray (19.3%), shipping (16.1%), traffic (11.3%), road dust (11.4%) and soil dust (8%). Shipping, sea spray road and soil dust increased during the warm period of the year while biomass burning increased during the cold season. Wind back-trajectories showed that emissions from residential space heating associated to biomass burning come mainly from residential areas in the southeast. Shipping emissions come mainly from west and southwest and they are connected with both local and Patra's ports.

Conclusions

Overall the contribution of the Charilaos Trikoupis bridge to air pollution levels in the vicinity is very low. This is the result of the relatively low daily volume of vehicles (~ 10,000 vehicles per day), the respective traffic fleet composition (~80% of the traffic fleet are passenger vehicles) and the speed limit (80 km/h) which does not favor traffic emissions. In addition, the strong and frequent winds further contribute to the rapid dispersion of the emitted pollutants. The higher levels of PM observed during the winter period are attributed to local sources of space heating, as well as to the meteorological conditions in the area, which are characterized by lower mixing height.

MODELLING AND MEASUREMENT OF URBAN AEROSOL PROCESSES FROM ROADSIDE TO AMBIENT

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Summary
Particles from road traffic exhaust emissions are subject to complex dilution and transformation processes in the urban environment. This model study evaluates the influence of aerosol processes on the particle number (PN) concentration on the spatial and temporal range between the street scale, typically represented by measurements at a traffic monitoring site, and the neighbourhood scale, with a characteristic length scale of 1–2 km. Measured particle size distributions in the cities of Helsinki, Oslo and Rotterdam and modelling with the aerosol dynamics model MAFOR, was used to develop a simplified parameterization of aerosol processes for use in Gaussian and Eulerian urban dispersion models. The simplified parameterization of aerosol processes can predict particle number concentrations between roadside and the urban background with an inaccuracy of ~10%, compared to the fully size-resolved MAFOR model.

Introduction
Motor vehicle exhaust emissions constitute the major source of ultrafine particle pollution in urban environments. Particles emitted from road transport, as they are transported from the emission sources, are subject to complex dilution processes (turbulence generated by moving traffic, atmospheric turbulence) and transformation processes (nucleation, coagulation, condensation, evaporation, deposition, and heterogeneous chemical reactions), acting on different time scales. Urban dispersion modelling of particle numbers is challenging, because aerosol dynamic processes continuously change the number and size distribution after the particles have been released into air. This model present study aims at (i) the quantification of the impacts of relevant aerosol processes on the neighbourhood scale and (ii) the derivation of a reasonably accurate, simplified parameterization of the most important aerosol processes, to be used in urban air quality models.

Methodology and Results
The development of the particle size distribution with increasing distance from the roadside was modelled using the multicomponent aerosol dynamics model MAFOR. Aerosol processes considered in this study were condensation and evaporation of n-alkanes, coagulation of particles due to Brownian motion, and dry deposition. The evolution of vehicular emissions from the engine to the roadside concentrations were not considered in this study, as the particle size distributions measured at the roadside locations were used as a starting point. A simple treatment of horizontal dilution of particle numbers was used to approximate atmospheric dispersion. Model runs were performed with different dispersion conditions to address the influence of aerosol processes for a wide range of meteorological dispersion regimes. Coagulation was found most efficient for the removal of nanoparticles (in this study particles of the sizes 8–25 nm), which accounted for 70 % of the total PN of the mean traffic-related aerosol. The time scale of coagulation was similar to the time scale of dry deposition for nanoparticles. The sensitivity of modelled PN concentrations towards dry deposition of particles on various surface types and roughness conditions was studied. Typical time scale of dry deposition of particles with 8–25 nm diameter in the urban environment using different deposition schemes was 0.5–3 hours. Average dry deposition velocities were in the range of 0.2–0.9 cm s^{-1}.

Conclusions
Dry deposition and coagulation of particles were identified to be the most important aerosol dynamical processes controlling the removal of particles from emitted from vehicular exhaust on the neighbourhood scale. Under inefficient dispersion conditions, condensational growth contributed significantly to changes of the PN concentration. However, as expected, these processes were less relevant in efficient dispersion conditions, for which dilution clearly dominated the change of total PN.

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MODELLING OF THE PARTICLE NUMBER CONCENTRATIONS IN FIVE EUROPEAN CITIES

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Summary
We present the modelling of particle number concentrations (PNC's) in five major European cities, namely Helsinki, Oslo, London, Rotterdam and Athens, in 2008. Novel emission inventories of particle numbers have been compiled both on urban and European scales. We use atmospheric dispersion modelling for PNC's in the five target cities and on a European scale, and evaluate the predicted results against available measured concentrations. The concentrations of PN in the selected cities were mostly influenced by the emissions originated from local vehicular traffic; however, in some of the cities, also harbour and airport activities were significant. The predicted and measured annual average PNC's in four cities agreed within approximately ≤ 36 % (measured as fractional biases), except for one traffic station in London.

Introduction
While a large base of scientific information exists on particle mass, there are substantially less studies on particle number (PN). This is particularly true on modelling in city environments. A number of studies indicate that UFP's have specific health effects.

Methodology and results
All of the urban emission and dispersion modelling systems were locally or nationally developed ones; these were different for each city. However, the regional background concentrations for all the urban scale modelling systems were computed with the same model, the LOTOS-EUROS chemical transport model. A new European-scale emission inventory was compiled for the EU-wide transport and non-transport activities. All the models included the emissions from vehicular traffic, and some of the models included also the emissions from stationary sources and other sources. The shipping emissions were explicitly included in the computations of Oslo and Athens, and the importance of primary shipping emissions was separately evaluated for Helsinki. Measured PNC data was available in four of the cities, in three of these for a complete year; however, only at one or two measurement stations for each city. In all cities, the spatial distributions of PNC were dominated by road traffic emissions; the major traffic networks were clearly visible. Especially in Helsinki and London, the main ring roads surrounding the city were clearly visible. In Oslo, the PNC's were enhanced near road tunnel entrances and in the harbor region. In Athens, there are substantially elevated PNC's near the Athens International Airport and near the harbour regions.

Conclusions
Novel emission inventories of particle numbers have been compiled both on urban and European scales. We have presented the results of the modelling of PNC's in five European cities in 2008. It has not previously been possible to conduct such computations on a European scale, due to the deficiencies of the previously available emission inventories. As expected, the most important local source category in terms of the PNC's was local vehicular traffic in all the target cities. The concentrations were also elevated in city centers, especially for the megacities of London and Athens. The highest values of the predicted PNC's were relatively higher in the megacities, London and Athens, and also in Rotterdam, whereas these were relatively lower in Helsinki and Oslo. The amount of experimental data for model evaluation was modest: only one or two stations per city. More long-term hourly measurements of PNC's would therefore be valuable for a more extensive model evaluation in various urban locations.

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HEALTH RISK ASSESSMENT OF REDUCED AIR POLLUTION EXPOSURE WHEN CHANGING COMMUTING BY CAR TO BIKE

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Summary
In this study we have assessed the reduction in traffic emissions and population exposure assuming all potential car commuters would switch to biking if they live within 30 minute travel by bike. The scenario would result in more than 100 000 new bikers and due to the reduced traffic emissions 42 premature deaths would be avoided per year. This is almost twice as large effect as the congestion tax in Stockholm.

Introduction
Regular physical activity has important and wide-ranging health benefits including reduced risk of chronic disease, and physical inactivity is mentioned as perhaps the most important public health problem of the 21st century. At the same time, the direct effects of traffic emissions is a major health problem. Transferring commuting by car to bike will increase physical activity and reduce emissions and reduce population exposure to traffic pollution. The exposure of commuters will also change; new bikers may get higher exposure whilst old bikers and car drivers may get lower exposures, depending on commuting route and distance.

Methodology
In this study we have calculated the potential number of car-to-bike switching commuters depending on distance, travel time, age of commuters etc. We have made calculations for a 30-minute biking scenario, i e transferring all car commuters to bike if their travel time by bike is less than or equal to 30 minutes. The commuting distance depends on age and sex. For the travel and traffic modelling the LuTrans model was used. It includes all different modes of travel; walking, bicycling, public transport systems and car traffic. The model was developed based on travel survey data and is regularly calibrated using traffic counts. Emissions from road traffic were calculated based on HBEFA 3.2. A Gaussian dispersion model was used estimate exposures over the county of Stockholm.

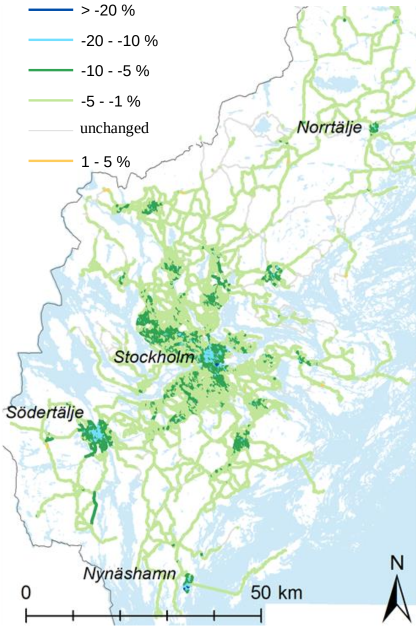

Figure 7. Calculated percent reduction in NOx concentration due to traffic emission for the 30 minute scenario.

Results
The 30 min scenario resulted in 106 881 more bikers, an increase of 2.6 times compared to base scenario. Of all bikers 50% were men and the mean age of all bikers was 42. The traffic emissions of NOx was reduced by up to 7%. Up to 20% reduction in traffic contribution to NOx concentrations was calculated as shown in Figure 1. The mean reduction in concentration for the whole area is 6% and the largest occur were most people live.

The population weighted mean NOx concentration for 1.6 million people in Greater Stockholm is estimated to be reduced by 0.41 µg m^{-3}. Assuming that the premature mortality is reduced by 8% per 10 µg m^{-3} (Nafstad et al., 2004), this corresponds to 42 avoided premature deaths every year or 514 gained life years gained. This is even somewhat more beneficial than the effects of the congestion charge in Stockholm (Johansson et al., 2009), which was estimated to save 27 premature deaths per year. The gain in reduced mortality is almost as large as the gain in health of the increased physical activity.

Conclusions
Transferring car commuters to bike is not only beneficial for the physical activity, but will also lead to reduced traffic emissions and reduced population exposure. Our estimates show that it may be even more beneficial for mortality due to air pollution exposure than the congestion charge in Stockholm.

Acknowledgement
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HIGH-RESOLUTION SOURCE APPORTIONMENT MODELLING FOR AMSTERDAM AND ROTTERDAM

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Summary

This study investigates the possibilities of using LOTOS-EUROS with the labelling technique for source apportionment at city scale. The model was run at 3.5x3.5 km^2 resolution over the Netherlands, which is higher than previously used resolution, and using a high-resolution emission set. Labels were set to different sectors, with special attention to the transport sectors by separating out road transport, shipping and other transport, and using labels for Rotterdam, Amsterdam, rest of the Netherlands and rest of Europe. The year 2011 was modelled, with particularly high observed PM2.5 concentrations during several episodes in spring. The high resolution made it possible to label emissions more accurately and to better model gradients in and around the cities.

Introduction

The transport sector makes an important contribution to NOx an PM concentrations in cities. For Rotterdam and Amsterdam, not only road transport plays a role, but also shipping may contribute significantly. To investigate the relative contribution of several sources and source areas, a high resolution simulation was performed over the Netherlands for 2011.

Methodology and Results

LOTOS-EUROS was run at 1/16x1/32° lon x lat resolution over the Netherlands (3-9 E, 49-55 N), which is higher than previously used resolution. A high-resolution emission set was used for this domain. The run was nested in a simulation on European domain using the default 1/2x1/4° lon x lat resolution. Labels were attributed to two rectangular regions closely encompassing the Rotterdam Rijnmond area and encompassing Amsterdam (excluding Amsterdam Airport), to the rest of the Netherlands and to the rest of Europe (Kranenburg et al 2013) and several source sectors (Fig.1). Analysis was done for total PM2.5 and PM10, but also for the contributing species like elemental carbon (EC) and sulphate. PM2.5 (and PM10) results were validated against observations from Airbase, and showed a fairly good correlation for PM2.5 (around R=0.8), with an average bias of around -7µg/m^3. The underestimations were most notable for two pollution episodes in March and October. Analysis of the labelled concentrations revealed that in Rotterdam and Amsterdam road transport contributed in general more to PM2.5 than shipping, but in particular for the highest and lowest concentration ranges the contribution of shipping nearly equals that of road transport for these cities (Fig 1). The contribution of Rotterdam Rijnmond area to total PM2.5 concentrations in Rotterdam city centre varies around 20% for the different concentration bins, for Amsterdam the contribution of the Amsterdam area to concentrations in the city centre is a few percent lower, which is consistent with the smaller area that is assigned to Amsterdam, excluding Amsterdam Airport and nearby highways. The high resolution made it possible to identify differences between the city centre and a suburban residential area. For example for Amsterdam the absolute and relative contribution of the sector 'other transport' to EC concentrations is larger in the city centre than in the suburbs IJburg and Sloten. Depending on the policy-relevant or science question, the most suitable presentation of the wealth of information can be chosen.

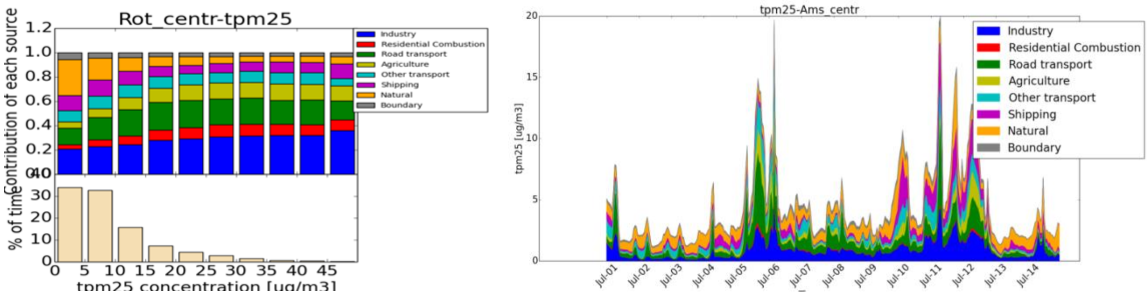

Figure 1: Analysis of annual results for Rotterdam city centre (left) and summer episode for Amsterdam city centre (right).

Conclusions

The high-resolution simulation gives meaningful results and contributes to a better representation of the contributions of several sources and source areas in space and in time. For example the contribution of shipping to PM2.5 is nearly as large as the contribution of road transport for some episodes, indicating the relevance of this sector for local air quality policy.

Acknowledgement

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OPERATIONAL APPLICATION OF AN EMPIRICAL APPROACH FOR DETERMINING CONCENTRATION INCREMENTS AT THE STREET LEVEL

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Summary
This study aims to develop a simple approach for the accurate estimation of the local scale contribution on the air pollution in urban areas. The method employs a functional relationship between the concentration increment, the local meteorological parameters, the street characteristics, the traffic emissions and the urban background concentrations. The necessary pollutant concentrations for the multiple regression process are derived both from measurements and model results. In order to explore the applicability of this approach, the methodology was incorporated in the operational module of an Air Quality Management System (AQMS). Although this specific approach can be used for a series of traffic emitted pollutants, within the frame of the present evaluation the methodology is applied only for PM_{10} and NO_2. Results demonstrate the capability of this simple approach to reproduce the street-scale concentration increment with satisfactory accuracy, thereby confirming its suitability as a reliable tool for operational air quality assessment at urban hotspots.

Introduction
The main objective of the methodology developed within the frame of this study is to determine on an hourly basis, the contribution of road traffic emissions on air pollution at urban hotspots. To this end, a functional relationship associating the estimated street increment with local meteorological parameters, street characteristics and traffic emissions on the basis of measured or calculated increments in representative locations is determined. As part of the method's validation, a computational module based on this approach is implemented and incorporated as an enhancement in the computational core of an existing operational AQMS, which was been developed and installed in the Department of Labour Inspection of the Republic of Cyprus (Moussiopoulos et al., 2012). A previous evaluation of the baseline AQMS operational core had revealed that short-term forecasts were in good agreement with the corresponding urban background measurements. Nevertheless, the forecast accuracy in predicting air pollution levels at the local/street scale was consistently lower. The present study aims to investigate the improvement in the accuracy of street-scale concentration calculations after the incorporation of the street increment module in the AQMS computational core.

Methodology and Results
The procedure for the overall determination of the street increment can be described as three step process. More specifically, these steps include the selection of representative pairs of urban background and street scale locations, a multiple regression analysis for the determination of the functional relationship and the application of the methodology on the basis of measured or calculated urban background concentrations. The concentration sets used for the definition of the statistical relationships are derived both from measurements and the application of the OSPM model for several traffic hot spots in the city of Thessaloniki during the calendar year 2013. These relationships are then incorporated in the computational core of the AQMS as an effort to improve the AQMS's performance at the street scale. A two-month pilot evaluation of the methodology was carried out whereby the AQMS's operational estimates of hourly urban background concentrations and meteorological parameters were used to provide the required input data. The results of this pilot application are compared against monitoring data. This validation process indicates a notable improvement in the AQMS's ability to predict NO_2 and PM_{10} concentration levels at the street scale (see Fig. 1). Additionally, a set of potential areas of future improvement is identified within the methodological framework of the current approach.

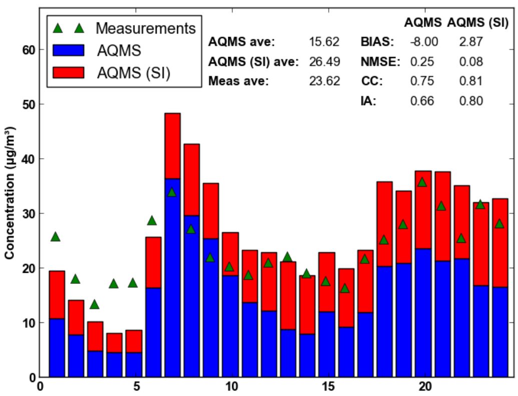

Fig.1 Indicative results for a hot spot in the city of Nicosia.

Conclusions
The street increment methodology which was developed within the frame of this study relies on a functional relationship, allowing for a correction of hourly street concentrations. This was achieved by establishing an operational correlation between the street-scale concentration increment, the local meteorological parameters, the street characteristics, the traffic emissions and the urban background concentrations. The methodology was incorporated operationally as an additional module of an AQMS for a pilot period of two months. The results of this application reveal a distinct improvement in the performance of the AQMS regarding the hourly status of air quality at the street scale.

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INVESTIGATING THE NO_2 EMISSIONS OF INDIVIDUAL VEHICLES UNDER REAL DRIVING AND ITS CONTRIBUTION TO LOCAL AIR POLLUTION

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Summary
The NO_2 emissions of a large amount of individual vehicles under real driving conditions were investigate with measuring its concentration in the emission plume. This allows investigating a large amount of different vehicles and quantifying their contribution to the local NO_2 air pollution. In an intensive study in Mainz, Germany, 2014, we observe a strong variability of NO_2 concentrations for similar type of vehicles (e.g. different cars or busses). Several vehicles show much higher NO_2 emissions as expected and support current investigations that for some vehicles the emissions under real driving conditions are much higher. 7.6% of the vehicles show NO_2 >500ppb which were responsible for 45% of the total NO_2. The observations also show large errors in the emission models due to insufficient model data input. Thus different conclusions about the main NO_2 sources and recommendations for policy makers are made.

Introduction
Nitrogen Oxide (NO_x=NO +NO_2) emissions by road vehicles are the mayor contributor for poor air quality in urban areas. High NO_x concentrations, and especially NO_2, are typically the most problematic pollutant in cities. However emissions vary significantly depending on the type of vehicle, its engine, the age, condition of the vehicle, driving properties, modifications and many more. Even if official NO_x emission data of the manufacturer exist, these are sometimes wrong and reliable data under real driving conditions are typically unavailable. Especially data showing the degree to which different cars contribute to observed NO_x levels in urban areas are missing. Significant reduction of NO_x concentrations can be achieved by identifying the strong emitting vehicles and excluding, replace or modify them.

Methodology and Results
With a specially developed high speed NO_2 CE-DOAS (Cavity-Enhanced DOAS) instrument the NO_2 concentration within the emission plume of vehicles under real driving conditions are measured. The sampling was performed with a inlet at the front of a car which was following the investigated vehicle. During the project in the city of Mainz, randomly chosen 734 vehicles were investigated and were related to the different types: cars (72,8%), buses (19.7%), trucks (4.4%) and motorcycles (3.1%). The observed concentration is categorised according to Fig.1. A large variability in the observed NO_2 can be found even within a vehicle type. Most vehicles, especially cars and motorcycles show concentrations below 200ppb. However 7.6% show concentrations exceeding 500ppb. These are mostly (75%) older busses with Euro2 and 3 emission norms but also several cars. However this small group makes up of 45% of the total NO_2 and excluding these vehicles could significantly improve the air quality. The cars with high emissions are mostly diesel engines including newer models of all different brands. They feature much higher emissions under real driving than expected from their emission norm. A comparison with the emission model show large differences to the measurements. They could be identified as insufficient model data input of the real vehicle fleet and the emissions under real driving conditions.

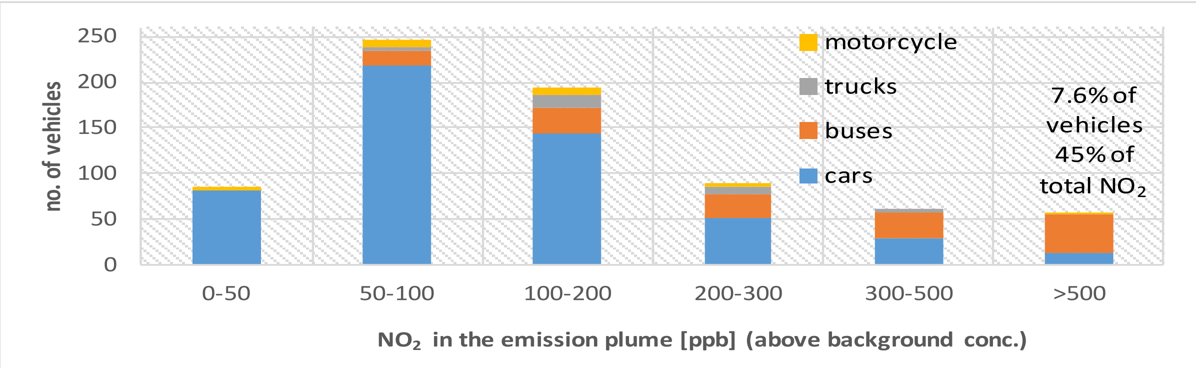

Fig.1 No. of observed vehicles per NO_2 concentration category separated in the different vehicle types.

Conclusions
It could clearly be found that real driving measurements provide a much better and more accurate picture of the NO_2 sources responsible for the high urban NO_2 pollution. The reasons are poor data on the real driving vehicle fleet and large errors in the real emission data. Thus the measurements come up with a different result of the main NO_2 sources which has a large impact on policy makers and developments in the future. To derive more accurate the total NO_x emissions for each vehicle the system will additionally be equipped with a NO and CO_2 measurement system in the near future.

Acknowledgement
The measurements in Mainz were financed by the environmental department of the city of Mainz.

EXHAUST PARTICLES AND NO_X EMISSIONS OF A SCR EQUIPPED HEAVY DUTY TRUCK IN REAL-WORLD DRIVING CONDITIONS

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Summary

This study provides information on the emission factors of the selective catalytic reduction (SCR) equipped heavy duty vehicle in different real-world driving conditions. The particle number emission was bimodal and dominated by the nucleation mode particles (diameter below 23 nm). The on-road emission performance of the vehicle was very close to the expected levels, confirming the successful operation of the SCR system of the tested vehicle. Heavy driving conditions such as uphill driving increased both the NO_x and particle number emission factors whereas the emission factor for soot particle number remains rather constant. The results are important in future emission regulation planning as well as a useful input in urban air quality modelling studies.

Introduction

Both particulate matter (PM) and nitrogen oxides (NO_x) emissions of heavy duty diesel vehicles contribute significantly to the urban air quality. Traffic, in general, produces particulate and gaseous pollutants in the vicinity of people, leading to exposure in relatively high concentrations of fresh combustion originating pollutants, which have been reported to negatively affect human health. This is why NO_x and PM emissions of vehicles are regulated within the European Union. One of the technologies to reduce heavy duty diesel truck NO_x emissions is the SCR aftertreatment system. However, there is very limited information on the emissions of SCR equipped heavy duty vehicles in real-world driving conditions. Real-world emission factors for NO_x and PM emissions of typical SCR equipped vehicle are important parameters, e.g., in urban air quality modelling. This study focuses on the real-world emissions of a modern SCR equipped heavy duty diesel vehicle. The major objectives are to determine the real-world emission factors for NO_x, soot and nucleation mode particles (down to 3 nm) and to clarify the role of real-world driving conditions in pollutants formation.

Methodology and Results

The experiments were performed on the road by measuring the total and soot particle concentrations, particle size distribution, and CO_2 and NO_x from the exhaust plume of an SCR-equipped EURO IV heavy duty diesel truck with a trailer. Pollutant concentrations in the exhaust plume were studied by chasing the test vehicle with the "Sniffer" mobile laboratory (Pirjola et al., 2004). Thus, in addition to driving conditions, also exhaust dilution and mixing corresponded to real-world conditions. In this study, we present three different methods to calculate emission factors in real-world driving conditions. First, real-time CO_2 measurement enables time-resolved emission factor calculation for NO_x and particle emissions, and emission factor levels can be investigated during different driving conditions. Second, real-time data enables emission factor calculation based on the slope between concentrations of pollutants over the CO_2 concentration. Third, emission factors can be calculated using average values over the whole measurement campaign. Results showed typically bi-modal particle size distribution (nucleation mode and soot mode), and emission factors were calculated for the both modes. Interestingly, the emission of the currently not regulated nucleation mode particles dominated the total particle number emission; for the nucleation mode particles the average emission factor was 1.1×10^{15} #/kg(fuel), whereas for soot particles the emission factor was 0.37×10^{15} #/kg(fuel). The average NO_x emission factor during the whole test run was 3.55 g/kWh, whereas the emission standard limit is 3.5 g/kWh for a EURO IV engine.

Conclusions

The nucleation mode dominated the total particle number emission of the SCR equipped heavy duty vehicle in different real-world driving conditions. The nucleation mode particles are not controlled by current regulations in Europe. However, these particles consistently form under atmospheric dilution in the plume of the truck and constitute a health risk for the human population that is exposed to those. The on-road NO_x emission performance of the vehicle was very close to the expected levels, confirming the successful operation of the SCR system of the tested truck.

Acknowledgement

This work was supported by the TEKES project "TREAM".

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PHYSICAL CHARACTERIZATION OF AIRBORNE PARTICLES IN THESSALONIKI

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Summary

The main objective of this study was to observe how the financial crisis has affected the air quality of Thessaloniki, compared to previous measurements. A number of observations suggest a scenario of decrease in traffic activity and increase in biomass burning for residential heating. To investigate the observations further, we conducted measurements at a busy roadside and at a nearby urban background site of Thessaloniki. We also measured particulate emissions from three vehicles in the laboratory and domestic heating emissions in a home burning both wood (fireplace) and diesel fuel (central heating). The results seem to support the hypothesis of domestic heating as a significant contributor of particulate pollution.

Introduction

Although motor vehicle exhaust has been identified as the primary contributor to ambient particles, other sources may be larger contributors in the overall regional inventory (Kumar et al., 2014). For example, domestic heating has been identified as a significant contributor during the winter. The current study tries to provide more insights on the changes observed, by studying a range of particulate properties at two different urban sites, at three different vehicles and at a home fireplace and central heating.

Methodology and Results

Field measurements were conducted at two different sites: a traffic-affected one in the centre of the city (23 study days) and a residential location (14 study days). The vehicles tested included one diesel Euro 5 (BMW X1 2 l), one diesel Euro 4 (Honda Accord 2.2i-CTDi) and one gasoline Euro 4(Ford Mondeo 1.8 l) in two configurations: properly operated and operated with malfunctioned three-way catalyst. The measurement of the heating emissions were conducted in a house located at the suburban area of Thessaloniki. The total particle number concentration (PNC) was measured with an ultrafine Condensation Particle Counter (CPC, TSI model 3776) and the particle number size distribution (PNSD) in the range of 14 nm to 710 nm was measured with a Scanning Mobility Particle Sizer (SMPS, TSI model 3936L). The PM mass concentrations in the field measurements were recorded through the Beta-gauge method (Ambient Air Suspended Particulate Analyzer, Model MP101M, Environnement SA). Vehicles PM mass emission were measured according to the legislation, while heating PM emissions were measured with gravimetric sampling. The traffic – affected location was about 62% more polluted than the residential one in terms of PM2.5, about 45% in terms of PNC but only 13% in terms of PM10. The reduction in diesel emissions from Euro 4 to Euro 5 technology was larger than 99% in both PM2.5 and PNC. On the other hand, fireplace and central heating showed very low PNC (90% and 97% lower than diesel Euro 5) but significantly higher PM2.5 concentration.

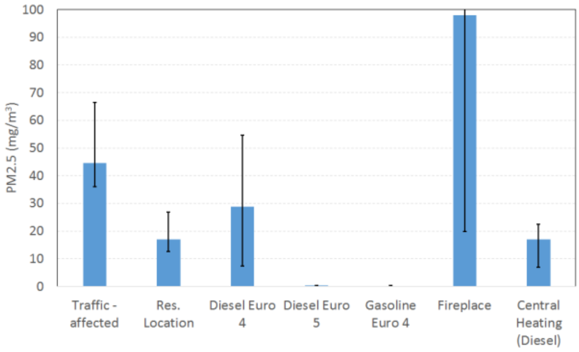

Fig.1 PM2.5 concentrations (mg/m^3) in traffic-affected and residential location and in the exhaust of various sources

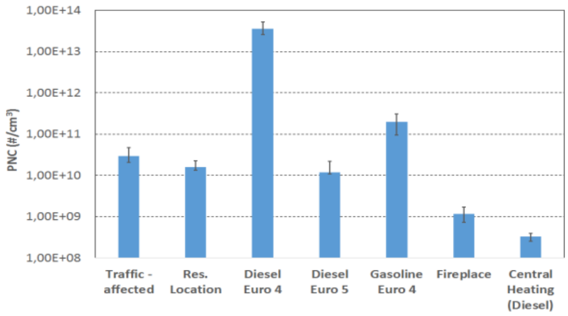

Fig.2 PNC (#/cm^3) in traffic-affected and residential location and in the exhaust of various sources

Conclusions

As traffic volume tend to decrease in Greece, wood-burning stoves and fireplaces emissions started contributing significantly to atmospheric particles. Furthermore, these emissions are associated with several carcinogenic compounds causing adverse effects on human health via several pathways.

Acknowledgement

This work was supported by the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: THALES

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PART TWO: POSTER SESSIONS

AIR QUALITY AND IMPACT ON REGIONAL TO GLOBAL SCALE

MODELLING TRENDS IN AIR QUALITY SENSITIVITY TO 20TH CENTURY CLIMATE VARIABILITY ACROSS TROPICAL TO BOREAL CLIMATES

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Summary
This paper investigates continental scale trends in a variety of particulate species, Ozone and Nitrogen Oxide concentrations over a twenty year period. We compare separately the role of emissions and meteorological change during that period, specifically investigating the varying trends in mid-lattitude, low latitude and equatorial regions where significant differences in the meteorological setting lead to changes in the key processes involved in controlling surface Ozone and Nitrogen Oxide concentrations. We evaluate model performance for GEOS-Chem across tropical to boreal climates and investigate the geographically varying importance of climate and emissions on long-term air quality trends with two model simulations.

Introduction
Air pollutants and their precursors modify the solar and terrestrial radiation budgets, forcing changes to the climate system, however regional climates are also a primary controller of air-pollutant distributions. Climate and air quality are inextricably linked, to the extent that measures designed to reduce air pollution or anthropogenic climate change often have competing interests.
There is significant regional variability in air-quality trends and sensitivity to meteorological change. This is due to varying meteorology, industrialisation, population change and urbanisation being spatially heterogeneous over regional to continental scales.

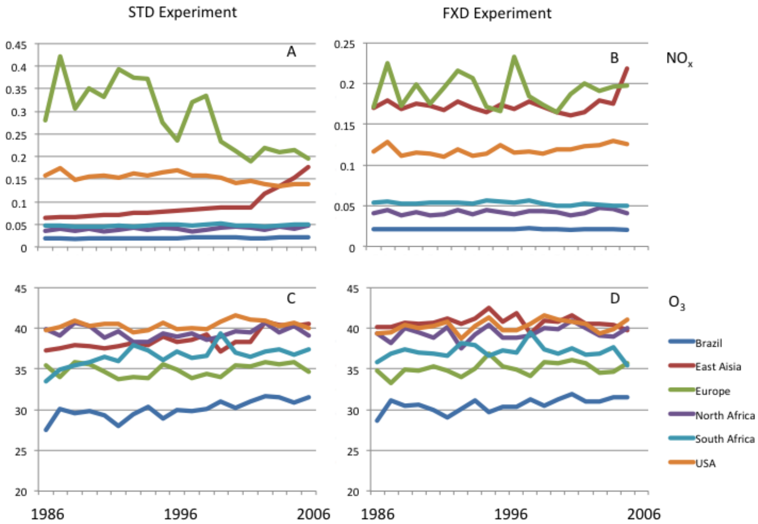

Fig.1 Regional trends from 1986 to 2006 as simulated by the GEOS-Chem model for 24hr average surface level NOx (A. standard emissions & B. fixed emissions), Ozone (C. standard emissions & D. fixed emissions) and SO_2 (E. standard emissions & F. fixed emissions)

Methods
In this study we follow the methods of Jeong *et al* (2013), who looked at changes in particulate species, Ozone and Nitrogen Oxides in East Asia over the past 2 decades. We expand the study to make inter-comparisons with two mid-latitude regions, two low-latitude regions and two tropical regions. The GEOS-Chem model was driven by assimilated met data for 20 years from 1986 to 2006 to create a baseline simulation (STD) and then run again to create a sensitivity simulation (FXD) where emissions were fixed at 2006 levels. We analyse the sensitivity of model results to quantify the effect of the meteorological variability on regional air quality over six key regions, two mid-latitude regions, North America and Europe, two low latitude regions, East Asia and South Africa and two Equatorial regions, Brazil and Equatorial Africa.

Discussion
The STD and FXD experiments allow us to dissociate the impact of emissions and meteorological change on air quality and how this varies between the six study locations. Meteorological variability has a significant impact on European and East Asian NOx concentrations (Fig 1B), although changing emissions levels remain the most important factor (Fig 1A). Ozone is a species highly sensitive to air temperature (Lin *et al* 2001). The relationship between surface O_3 and meteorological conditions may have influenced surface O_3 concentrations (Fig1D). Surface ozone concentrations simulated in the STD experiment closely resemble the trends driven by meteorology alone in each of the study areas. While it is likely that O_3 concentration increases over the past two decades are due to increases in anthropogenic precursors emissions, the contemporaneous trends in meteorology including higher temperatures, reduced cloud cover, stagnation events, elevated photochemistry and secondary processes such as biogenic and wildfire emissions further enhance O_3 increases.

Acknowledgement
This work is supported the Centre for Atmospheric and Instrumentation Research and the Science and Technology Research Institute at the University of Hertfordshire, UK.

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CLIMATOLOGY OF AEROSOLS, CLOUD AND RAINFALL CHARACTERISTICS OVER MADURAI DURING MONSOON AND DROUGHT PERIODS

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Summary
The paper presents aerosols, clouds and precipitation dynamics over a semi-arid region Madurai, India during drought and normal monsoon years, based on satellite observations. Descriptive statistics and Pearson correlation analyses were carried out to find the relationship between aerosols, cloud parameters and precipitation pattern. The minimum aerosol concentration was in 2010 along with maximum precipitation. Besides the long-range transportation of aerosol particles by air mass from the Arabian Sea, Bay of Bengal and from semi-arid region to the observing site, the high values of AODs have also been influenced by biomass and agricultural burning and frequent incidents of forest fire at local regions.

Introduction
Atmospheric aerosols from natural and anthropogenic have strong influence on the climate system by reflecting, scattering, absorbing and terrestrial radiation. Aerosol optical depth (AOD) is a dimensionless quantity which is defined as the attenuation of direct solar radiation passing through the atmosphere by scattering and absorption due to aerosols. Aerosols also involving in the formation of clouds and precipitation as cloud condensation and ice nuclei alter the microphysical structure and the lifetime of clouds within the atmosphere (Rosenfeld et al., 2006). Nowadays satellite-based analysis has been well established on globally to study the impact of aerosol and rainfall on cloud microphysics (Costantino and Breon, 2010).

Methodology
The Moderate Resolution Imaging Spectroradiometer (MODIS) launched on December 1999 and it is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. The MODIS sensor is onboard the polar orbiting NASA-EOS Terra and Aqua spacecrafts with equator crossing times of 10:30 and 13:30 Local Solar Time (LST), respectively (Levy et al., 2007). There are three different processing levels for the MODIS data level 1 is the geolocated & calibrated brightness temperatures and radiances, level 2.0 gives the derived geophysical data products and level 3.0 gives the gridded time-averaged products (King et al., 2003). There are 36 spectral bands with different spatial resolutions, 29 spectral bands with 1km, 5 spectral bands with 500m and 2 spectral bands with 250m, nadir pixel dimensions. In the present work daily mean MODIS Terra derived Level 3 gridded $1^{o}\times1^{o}$ aerosol optical depths (AOD), cloud optical depth (COD), cloud effective radius (CER) and cloud fraction (CF) are derived with collection 5.1 versions at 550nm. 550nm is closest to the central part of the whole spectral range. AODs which are above 0 and less than 1.0 are only considered due to cloud contamination (Chung et al., 2005). Tropospheric Rainfall Measuring Mission (TRMM) was launched in 1997 it is a joint US-Japan program. Precipitation Radar (PR), TRMM Microwave Imager (TMI), and the Visible and Infrared Scanner (VIRS) instruments are inbuilt within the TRMM. Daily TRMM 3B42 with a collection version of C005 level 3 measures the tropical and subtropical rainfall.

Conclusion
Aerosol, clouds and precipitation interactions are thought to nature the behaviour of the climate system. The study site was affected by various types of aerosols as well as local biomass burning. The fossil fuel and biofuel combustion are increasing over Madurai as a result of rapidly growing population and urbanization. In this work high aerosol conditions, due to biomass burning and urban air pollution may be significantly suppress precipitation. The rise of societal problems such as inadvertent weather and global climate change, acid rain, the nuclear winter, global climate change, ozone depletion and geo-engineering activities, agricultural activities, industrialization, urbanization, transportation also came to recognition that awareness about atmospheric aerosols is still quite limited and inadequate to complete any climate assessment. More research tools, alternative techniques and alternative ways should implement for understanding the dynamics of climate system and to reduce emissions.

Acknowledgement
We gratefully acknowledge the GES-DISC's interactive online visualization and analysis infrastructure (Giovanni) as a part of NASA's Goddard Earth Sciences (GES) Data and Information Services Centre (DISC).

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AEROSOL AND ENVIRONMENTAL CONTAMINATION IN A DENTAL HOSPITAL - EVIDENCE FROM INDIA

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Introduction
Patients and operators are exposed during dental practice to an infective risk, which derives especially from microorganisms suspended in aerosols. Environmental microbiological monitoring in dental settings represents a good instrument to detect critical situations.

Methodology and Results
In order to investigate environmental microbial contamination level , we analyzed water, air and surfaces samples of a dental hospital . Microbial contamination was assessed for 5 non-consecutive weeks during working days, before and at the end of the daily activity. Air was sampled also during clinical activity, through both active and passive sampling systems.Contamination of water showed a decrease during activities, while a decrease in air contamination was registered only at the end of the day. Passive sampling values resulted more often above threshold values adopted. At the same time, surfaces contamination increases at the end of the activity. It seems hospital that in the dental clinic analyzed microbial buildup represents the higher critical element. No differences have been registered among the different days of the week.

Conclusions
Our study highlights the need to improve disinfection procedures and air treatment systems in the dental hospitals. Microbiological monitoring could represent an important element to detect the presence of risk factors and to adopt control Measures.

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IMPACT OF BIOMASS BURNING ON INDIAN AIR QUALITY DURING PRE-MONSOON SEASON

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Summary

This study aims to understand the impact of biomass burning on Indian air quality during a pre-monsoon season. One month simulation for May 2015 has been carried out with and without Fire Inventory from NCAR (FINN) using WRF-Chem model (Weather Research Forecasting coupled with chemistry) to obtain the concentrations of trace gases and fine and coarse particulate matter. The model has been compared with the surface observation that shows that model is able to capture the temporal variations for ozone and NO2 qualitatively but differs in terms of magnitude. An increase in the concentration levels has been simulated with FINN emissions that show that biomass burning has significant impact on the air quality over India.

Introduction

Biomass burning is the combustion of organic matter. This emits large amount of trace gases such as nitrogen oxides, carbon mono oxide, methane, non-methane hydrocarbon, carbon dioxide and particulate matter in to atmosphere. Emissions of these trace gases produce secondary pollutants and can impact the air quality, health and climate. Particulates emitted from biomass burning can impact climate by altering radiation budget and can also affect human health when they are inhaled, causing respiratory and cardiovascular problems. Also, it has effect on the photolysis rates which can alter the concentrations of photo-chemically active species such as Ozone. Ozone can affect the crop production, health and also contributes to global warming. The aim of this study is to understand the impact of biomass burning on Indian air quality during May month of pre-monsoon season.

Methodology and Results

WRF-Chem modelling system has been used to simulate regional scale air quality over Indian domain with and without fire emissions. The input to this model includes NCEP-GFS Meteorological initial and boundary conditions, EDGAR anthropogenic, MEGAN biogenic and FINN fire emissions, Chemical initial and boundary conditions (MOZART). FINN emission estimates are based on the framework described by Wiedinmyer et al. (2011). FINN uses satellite observations of active fires and land cover, together with emission factors and estimated fuel loadings to provide daily, highly-resolved (1x1 km) open burning emissions estimates for use in regional and global chemical transport models. Fig.1 shows the FINN CO fire emissions on 6th may 2015. Simulation has been carried out for a pre-monsoon month May 2015 with a resolution of 27km. The gas-phase chemistry is based on the CBM-Z mechanism having 67 species and 164 reactions. Rates for photolytic reactions are derived using the Fast-J photolysis rate scheme. The aerosol module is the MOSAIC which includes sulfate, nitrate, chloride, carbonate, ammonium, sodium, calcium, black carbon, primary organic mass, liquid water, and other inorganic mass (dust) with 8 Bin size. The simulated concentrations have been compared with the surface observation. This validation shows that model is able to capture the temporal variations for ozone qualitatively but differs in terms of magnitude. Fig 2 is the simulated mean CO concentration (ppbv) for May 2015 without FINN Fire emissions.

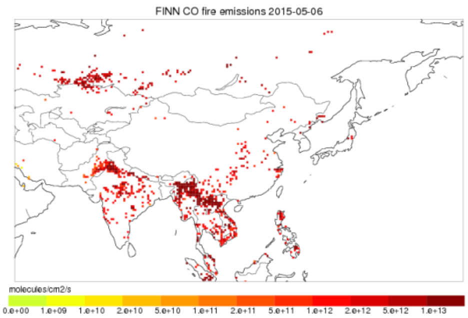

Fig.1 FINN CO fire emissions on 6^{th} may 2015

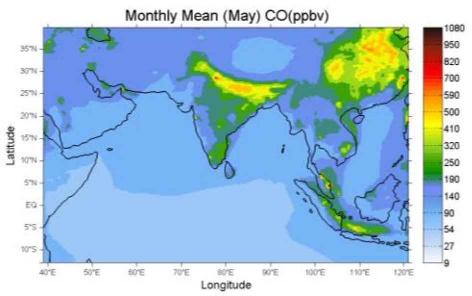

Fig.2 Simulated mean CO concentration (ppbv) for May 2015 without FINN Fire emissions.

Conclusions

Trace gases and particulate matter concentrations have been simulated over Indian region with and without FINN fire emissions using WRF-Chem model for a pre-monsoon month May 2015. It has been found that inclusion of FINN emissions increases the levels of simulated concentrations and also affects the radiation budged over India. The results show that biomass burning has impact on the air quality over India. This work is ongoing and the detailed results will be presented.

Acknowledgement

This research work is being carried out and supported by NARL (National Atmospheric Research Laboratory), Gadanki, India.

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SHORT-TERM VARIABIITY OF INORGANIC IONIC COMPONENTS IN FINE AEROSOLS OVER ATHENS, GREECE.

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Summary
To understand fine aerosol sources in Athens, Greece and the factors controlling their short and long-term variability, inorganic ions were measured at Thissio station, from December 2014 to October 2015. Concentrations of Cl^-, NO_3^- and SO_4^{-2} ions were determined using particle-into-liquid sampler (PILS) and were in good agreement with corresponding concentrations obtained by collocate filter analyses. The highest nss-SO_4^{-2} values were observed in summer (average 2.46 ± 1.30 μg m^{-3}) and the lowest in winter (average 1.56 ± 1.04 μg m^{-3}) revealing the significant impact of intense photochemistry during the warmest period of the year. On the other hand, maximum NO_3^- concentrations were observed during night-time in winter, highlighting the importance of biomass burning for domestic heating during the coldest months of the year.

Introduction
Aerosol particles constitute a significant component of the atmospheric system. They are emitted in the atmosphere by variable sources, through diverse formation and subsequent transformation mechanisms, resulting in a mixture of chemical characteristics. Particulate matter aerodynamically smaller than 2.5 μm ($PM_{2.5}$) is of particular concern because of the significant contribution to detrimental health effects. As a consequence, one of the major challenges in aerosol science is the understanding of fine particle chemical composition in cities and especially in big agglomerations such as Athens where the half of the Greek population (4,5 M Inhabitants) is living. Athens is situated in the Eastern Mediterranean, an area that constitutes a crossroad of three continents, being highly influenced by sources of both natural and anthropogenic origin, such as Saharan desert and European mainland.

Methodology and Results
Atmospheric air was sampled using a particle-into-liquid sampler (PILS) (Orsini et al., 2003), coupled with ion chromatography. Sampling was performed through a 1μm cut-size impactor and a denuder, from December 2014 to October 2015, at Thissio station (Paraskevopoulou et al., 2015). In parallel, daily samples of fine aerosol were collected on quartz fiber filters (4.7 cm, Whatman QMA), using a Dichotomous Partisol sampler (R&P Co). All collected samples were analysed by ion chromatography (IC) (Paraskevopoulou et al., 2015). The mean concentration of Cl^-, NO_3^- and SO_4^{-2} measured by PILS, was 0.29 ± 0.20, 0.69 ± 0.35 and 1.86 ± 1.6 μg m^{-3}, respectively. These results were in good agreement with the corresponding concentrations obtained by filter analysis through ion chromatography (Figure 1). On a seasonal basis, the highest nss-SO_4^{-2} values were observed in summer (average 2.46 ± 1.30 μg m^{-3}) and the lowest in winter (average 1.56 ± 1.04 μg m^{-3}). Higher summer sulphate levels were the result of enhanced photochemistry associated with more intense solar radiation, combined with less precipitation and higher regional transport. On the other hand, the diurnal variability of NO_3^- presents maximum values mostly during night-time, due to the thermal instability of ammonium nitrate (Figure 2).

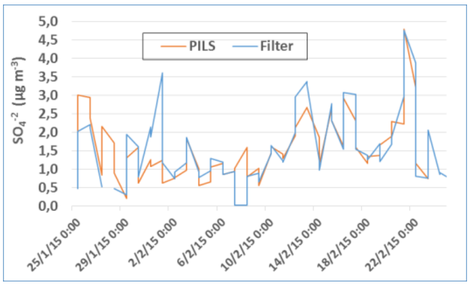

Fig.1 12-hour concentrations of SO_4^{-2} (μg m^{-3}) calculated by both PILS and IC filter analysis, at Thissio station.

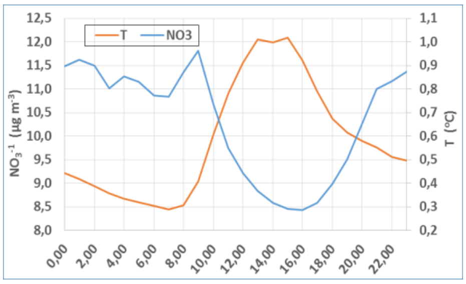

Fig.2 Diurnal variability of NO_3^{-1} concentrations (μg m^{-3}) and temperature (°C) at Thissio site.

Conclusions
Fine aerosol ionic components were determined, using two different techniques, allowing the study of their short and long-term variability, to better understand the effect of biomass burning during the coldest period of the year and, of intense photochemistry during the warmest months, in the Greater Athens area.

Acknowledgement
The authors acknowledge support by the European Project ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network) and by the "Program Agreements between Research Centers – GSRD" 2015-2017.

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PARTICLE NUMBER CONCENTRATION AND PARTICLE SIZE DISTRIBUTION MEASUREMENTS BY MOBILE LABORATORY IN TAMPERE, FINLAND

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Summary
In this study, we utilized a new mobile laboratory to produce information related to particle number concentration and size distribution as well as gaseous pollution compounds in Tampere city center. Measurements consisted of on-road measurements, dispersion measurements and road-side measurements in certain pollution hotspots. Preliminary results indicate that particle number concentrations vary a lot depending on the environment, from 1000 $1/cm^3$ in background area measurements to higher than 100 000 $1/cm^3$ near traffic. Particle number concentration was dominated by nanosized particles (< 50 nm). In general, the study indicates that traffic emissions should be taken into account when evaluating the human exposure to particles in Tampere city center.

Introduction
Particulate pollution cause severe health risks. Very high particle concentrations are typically measured in city centers and other areas near traffic (Pirjola et al. 2012, Lähde et al. 2014). Vehicle exhaust particles have been reported to form different modes in particle size distribution depending on the particle formation mechanism. Typically, vehicle exhaust particle number is dominated by nucleation mode particles whereas the particulate mass is dominated by soot mode particles. The existence of different modes depends on vehicle technologies, driving conditions and environmental parameters. In addition, the real-world emissions of vehicles may differ from laboratory studies. Mobile laboratory measurements enable the acquisition of reliable real-world data from traffic emissions and human exposure.

Methodology and Results
A two-week measurement campaign was conducted with the new mobile aerosol laboratory of TUT in the fall 2015 (between 29th September and 7th October). A wide range of aerosol instruments were applied in the measurements, including ELPI+ (Dekati Ltd.), EEPS (Model 3090, TSI Inc.), Ultrafine CPC (Model 3776, TSI Inc.), NSAM (Model 3550, TSI Inc.), Pegasor M-Sensor (Pegasor Ltd.) and a particle sensor setup from the Finnish Meteorological Institute. In addition, the concentrations of gaseous components of SO_2, CO_2 and NO_x were monitored.

Fig.1 Mobile aerosol laboratory of TUT on the measurement site in Tampere city center.

Three types of measurements were performed. Dispersion of the traffic emissions were measured at three different locations in the city. In roadside measurements, the emissions were measured at four fixed locations, one day (roughly from 9 a.m. to 5 p.m.) at each location site. On-road measurements were conducted by driving in traffic on two measurement routes during rush hours.
The preliminary results indicate that the particle number concentrations vary depending on the environment. The highest particle number concentrations (more than 100 000 $1/cm^3$) were measured in on-road measurements. High concentration peaks were observed also at roadside measurement sites as heavy duty vehicles (such as local busses) drove by the measurement site.

Conclusions
A new mobile laboratory was utilized in air quality measurements in Tampere city center (Finland). Preliminary results indicate that particle emissions of traffic should be considered in the evaluation of the human exposure to particles.

Acknowledgement
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STUDY OF THE RADIATIVE PROPERTIES OF AEROSOLS FROM SATELLITE DATA OVER AN URBAN AREA: AIR QUALITY APPLICATION

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Introduction

Aerosols are one of the most inconsistent components of the atmosphere. They affect the Earth's radiative budget and climate directly by absorbing and scattering the radiation, and indirectly by acting as cloud condensation nuclei. Atmospheric aerosols can cause either cooling or warming of the atmosphere. Moreover, aerosols have been concerned in human health and visibility reduction in urban areas.

Despite considerable development in understanding aerosol effect on climate, it is poorly quantified because of the lack of adequate information on the temporal and spatial variability of aerosols around the world. Hence, it is important to study aerosol properties across different using space technology, in order to understand their local climatic and environmental impacts. Remote sensing of aerosols from satellite-based sensors has turn into an important instrument to monitor and quantify the aerosol optical properties over the globe on a daily basis.

The fundamental aerosol properties which primarily determine the strength and sign of the radiative forcing are the aerosol single scattering albedo (SSA), Aerosol Extinction Optical Depth(AEOD) and Aerosol Absorption Optical Depth(AAOD).

Data and Methodology

In this work, results of investigation four-year of AEOD, AAOD and SSA over Tehran urban area in Iran, using satellite data from that of the Ozone Monitoring Instrument (OMI) aboard EOSAura and the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard EOS-Aqua are presented during the period from October 2004 to October 2014. We follow a multi-satellite approach to estimate the aerosol radiative properties.

Results

Regionally 4-year averaged aerosol single scattering albedo over Tehran urban area shows variation in SSA from 0.90 to 0.96 depending on the wavelength. that shows aerosols are appear more absorbing in the region and emphasise on positive warming effect. The lowest and highest value of SSA related to year 2014 and 2007. The minimum average value in the period is observed in cold season over the area.

An analysis of the variability in AAOD products indicates that the absorption optical depth appears about 0.05, 0.04 and 0.02 at 354, 388 and 500 nm, respectively. It means absorbing aerosols are dominated over the populated and polluted city of Tehran. It is in accordance with the studies in the literature for urban areas. The highest value is occurred in summertime, which show the maximum aerosol load. Over this region, the smoke particles generated from burning activities are often mixed with the dust aerosols transported from deserts.

Keywords: Aerosols, Optical properties, single scattering albedo, aerosol optical depth.

AIR QUALITY IMPACTS OF THE INCREASING USE OF BIOMASS FUELS

IMPACT OF BIOMASS COMBUSTION ON THE URBAN AIR QUALITY OF ATHENS

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Summary
Data derived from in situ measurements for the period 2000-2015 has been used for the evaluation of the extended biomass burning phenomenon in Athens since 2011, when the economic recession affected the price of oil in Greece. We discuss the impact of the financial crisis on the air quality of Athens, using measurements of black carbon (BC) carbon monoxide (CO).

Introduction
Satellite observations have shown a 30-40% reduction in nitrogen dioxide (NO_2) tropospheric columns over Athens as a result of a decline in fuel consumption due to the financial crisis which has engulfed Europe since 2008 (Vrekoussis et al., 2013). Since 2011, when the price of oil in Greece was affected by the economic crisis, a great part of Athens' population is relying on wood stoves and fireplaces for domestic heating, resulting in severe air pollution episodes during winter months. Carbon monoxide (CO) and black carbon (BC) being good indicators for combustion processes (Saurer et al., 2009), they are used in this study in order to relate the evolution of air quality to the economic recession. CO and BC measurements are strongly correlated (r^2=0.94), so we have focused on CO measurements to study longtime trends (2000-2015).

Methodology and Results
Data was acquired from three monitoring stations (Marousi, N.Smyrni, Athinas) of the National Network for Atmospheric Pollution (EDPAR), and from the monitoring site of the National Observatory of Athens at Thissio (Fig. 1). BC measured at Thissio was acquired using a portable Aethalometer (AE-42, Magee Scientific) operating at 7 wavelengths. The CO and nitrogen monoxide (NO) measurements from EDPAR were conducted using NDIR and chemiluminescence technique, respectively. An overview of CO and BC data during 2014-15 wintertime (November 2014 – February 2015), clearly shows the prevailing high values of BC and CO during evening and night due to intense wood combustion. Recorded BC mass concentrations in some cases reach 18 μg/m^3. The CO concentration throughout the day ranges from 200 to 3500 ppb, with high values again recorded during night time. Comparing the mean diurnal cycle for each month, a late evening CO and BC buildup during the transition from autumn to winter is revealed and a restore of normal values towards spring. Calculation of the mean integrals of morning (between 06:00 and 10:00 LT) and evening (16:00 and 05:00 LT) peaks for winter (December-January) and summer (July-August), reveals a gradual decrease over the years (2000-2015) of the summer and the winter morning peaks. In contrast, an increase in winter evening integrals is observed during the last 4 years (e.g. 80% increase since 2012 for Athinas station) due to intense biomass burning (Fig. 2).

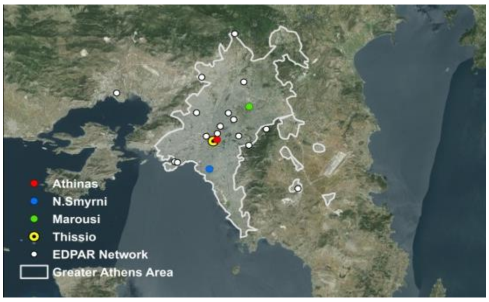

Fig.1 Locations of Thissio and EDPAR stations in the Greater Area of Athens

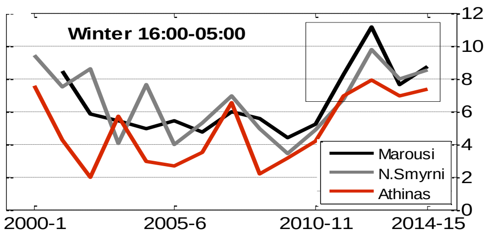

Fig.2 Mean integrals of the winter evening CO peaks for Marousi (black line), N.Smyrni (grey line) and Athinas (red line) stations

Conclusions
Both the gradual replacement of old vehicles with ones having catalytic converter and the financial recession since 2008 have resulted in a gradual decrease of gaseous and particle pollutants. However, since 2012 biomass combustion has prevailed over fossil fuel for domestic heating, resulting in sharp increase of CO and BC during evening. Hence, there is a need for suitable measures to be implemented both for the amelioration of the air quality and for the economic relief of the consumers.

Acknowledgement
The authors acknowledge the National Network for Atmospheric Pollution for providing data from its ground based stations. The work was performed in the frame of the project THESPIA-KRIPIS, Greece and European Regional Development Fund of the EU in the frame of NSRF and the O.P. Competitiveness and Entrepreneurship and the Regional Operational Program of Attica. Part of the work is co-funded by the "Programme Aggreements between Research Centers" GSRT 2015-2017.

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IMPACT OF EU CLIMATE AND AIR QUALITY POLICY ON OZONE DAMAGE IN EUROPE

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Summary

Ground level ozone concentrations and damage in Europe under mid-21st-century emission and land use conditions are explored for two PRIMES energy scenarios, including the possible effects of climate change. For both energy scenarios, health damage because of high ground level ozone concentrations is projected to decline significantly towards 2030 and 2050 under current climate conditions. The projected change in anthropogenic ozone precursor emissions is more important than land use change. However, the increase in ground level ozone caused by a warming climate might be higher than the reduction achieved by cutting back ozone precursor emissions.

Introduction

In the EU28, ground-level ozone is associated with at least 16160 excess deaths each year (EEA, 2014). Ozone production is driven by emissions of ozone precursor substances nitrogen oxides (NOx) and volatile organic compounds (VOC) and availability of light. While NOx is mainly of anthropogenic origin, vegetation is an important VOC source. European energy policy promoting bioenergy production can cause vegetation (land use) changes. Typical bioenergy crops (e.g. poplar, willow) emit high amounts of VOC (of which isoprene is one of the most relevant), in this way energy policy influences precursor emissions. Here we explore the combined effect of land use and direct anthropogenic emission changes on ozone-related health damage, including the possible impacts of climate change.

Methodology and Results

A current legislation and a decarbonisation energy scenario for the EU28 developed with the PRIMES energy model (Antoniou and Capros, 1999) were used as input to the GAINS model to generate air pollutant emissions for 2030 and 2050. The same two energy scenarios were used to drive the Global Biosphere Model (GLOBIOM) (Havlik et al, 2014). These emission and land use scenarios were used to drive the 3D regional chemistry transport model LOTOS-EUROS to calculate ground level ozone concentrations and related health damage. Meteorology for 2010 was used to represent the current climate and the extremely warm year 2003 was used as representative for the future climate. For the decarbonisation scenario in 2050, a 50% increase of isoprene emissions from vegetation is calculated. Anthropogenic ozone precursor emissions are projected to decrease significantly (70% for NO_x, 48% for NMVOC).

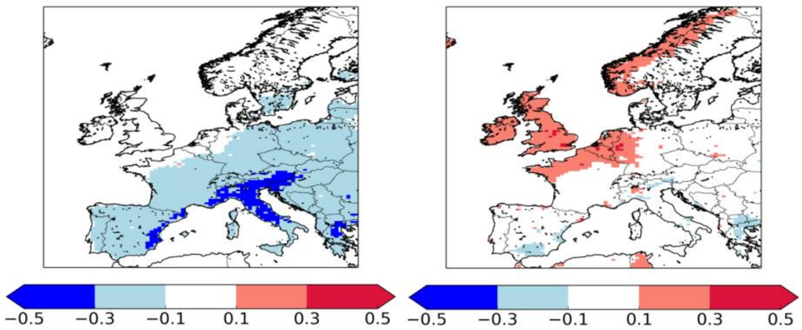

Fig.1 Difference in Relative Risk (%) with the base scenario for 2010 for the decarbonisation scenario in 2050 under current (left) and future climate conditions (right)

The land use and emission change projected for 2050 causes a decrease in ozone health damage (Relative Risk) of 10-50 %-points, with especially large reductions over Italy where the ozone health damage is almost halved. Under future climate conditions, however, this reduction is almost completely annulled and in north western Europe even an increase in health damage is modelled (see Figure 1).

Conclusions

For both energy scenarios studied in this work, health damage because of high ground level ozone concentrations is projected to decline significantly towards 2030 and 2050, especially for central and southern Europe where health damage due to ozone might be halved in 2050. The differences in ozone impact between the two scenarios were limited. However, ozone damage increases in a warming climate, which may cause total health damage in Europe due to ozone to increase towards 2050. Strong European or global air quality policies are needed to prevent this.

Acknowledgement

This work was funded by the EU FP7 project DESIRE (grant agreement No 308552) and developed during the Young Scientists Summer Program 2015 at the International Institute for Applied Systems Analysis, Laxenburg, Austria.

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ULTRAFINE PARTICLE EMISSION CHARACTERISTICS OF A RESIDENTIAL PELLET STOVE

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Summary

Two common types of pellet (beech - hardwood and fir - softwood) were burned in a commercial pellet stove (11 kW) following a combustion cycle simulating the behaviour of a real-world user. The present study was a part of the TOBICUP project (TOxicity of BIomass COmbustion generated Ultrafine Particles) designed to gain deeper insight on the possible negative health effects of ultrafine particulate matter (UFP, d_p<100 nm) by verifying the toxicological responses of UFP samples collected directly from residential wood combustion the (RWC) emissions. Here are reported only the results for the UFP physical-chemical characteristics.

Introduction

Currently RWC is increasing in Europe because of rising fossil fuel prices but also due to climate change mitigation policies. However, especially in small-scale applications, RWC may cause high emissions of particulate matter (van der Gon et al., 2015). A recent study (Díaz-Robles et al., 2014) suggests that UFP from residential wood combustion may be responsible for increased morbidity in urban areas where biomass burning for residential heating is widely used. The size and chemical composition of the particles are among the aspects related to health effects.

Methodology and Results

The experimental set-up is shown in Fig.1. UFPs were collected by means of three multistage cascade impactors in parallel. The physical-chemical UFP characterization comprised the detection of elements (Al ,As, Ba, Cd, Co, Cu, Fe, Mn, Mo, Ni, P, Pb, Sr, Ti, V, Zn) by inductively coupled plasma atomic emission spectroscopy, main inorganic ions by ion chromatography, levoglucosan by high-performance liquid chromatography coupled to pulsed amperometric detection, and total carbon (TC) by thermal-optical approach. Particle number size distribution was also performed by a fourth multistage cascade impactor.

The UFP mass concentration varies between 12 - 59 mg/m^3 (@NTP,13%O_2). A certain variability is observed especially in the fir pellets samples. The chemical analyses resolve on average 51% of the measured UFP mass. Up to 39% of the mass is water soluble inorganic ions, mostly K^+ and SO_4^{2-}. The other major species is the TC which accounts on average for about 8%. There are also minor amounts (i.e., each more or less about 1%) of organic anions (formate, acetate, propionate, oxalate), Cl^-, NO^{2-}, NO^{3-} and Ca^{2+}. The elements account for about another 1% of the resolved mass, with the major contribution from Zn and Al. Other measured cations (Na^+, NH^{4+}, Mg^{2+}) give a very limited contribution. As expected the contribution of anhydro sugars (levoglucosan, mannosan, galactosan) is nearly negligible (0.1‰). Consequently, levoglucosan, one of the traditional wood combustion tracers is found unsuitable for pellets combustion. Inorganic components of the UFP particles would serve better as tracers for pellets appliances.

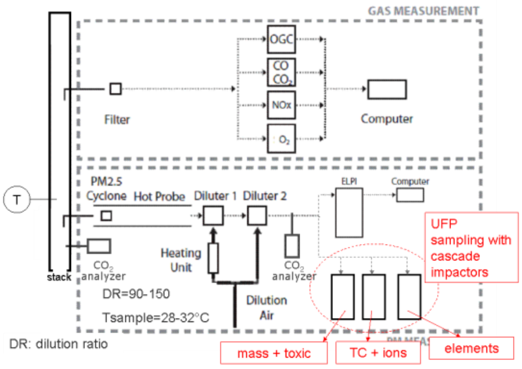

Fig.1 Experimental set-up

Conclusions

UFP mass emissions range in a relatively narrow interval (except for one fir sample); a slight difference is observed between softwood and hard wood pellets emissions. Potassium salts are dominant in every sample. UFP compositional differences between the pellets types are relevant only for TC and Cl^-. The combination of multiple tracers may serve to discriminate softwood vs. hardwood pellet combustion in the examined samples.

Acknowledgement

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MODELLING OF THE IMPACT OF CONSUMPTION OF BIOMASS FOR HOME HEATING ON AIR QUALITY IN A DISTRICT OF MADRID CITY

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Summary

In this paper, a CFD model has been applied to analyse the concentration of PM10 at pedestrian level in a district of Madrid City with a resolution of meters. Atmospheric flows and dispersion of pollutants emitted by road traffic and boilers for home heating were simulated for a winter period. The results were compared with experimental data of PM10 concentration recorded at a traffic-oriented air quality station located in the modelled domain. A good agreement between modelled and measured data was obtained. Possible future emission scenarios were then simulated considering different partitioning of fuel consumption (natural gas, gas oil, coal and biomass) for home heating. This study shows that an increased consumption of biomass for home heating can produce a significant increase of PM10 concentrations but much less than in the case of coal. The use of natural gas would reduce the PM10 concentrations. This study also shows the need of suitably regulating the use of biomass fuels and promoting the use of cleaner fuels.

Introduction

In recent years, there has been an increase in the consumption of biomass for home heating, which could have an impact on air quality. In addition, the emissions of biomass boilers for home heating depend on the physical characteristics of the biomass, the boiler technology and filtration systems. Therefore, the use of biomass as a fuel for home-heating boilers in cities should be regulated. Hence, studies for estimating the impact of using biomass for home heating on urban air quality are needed. The aim of this study is to estimate the effect on PM10 concentrations of several emission scenarios where different degrees of implementation of the use of biomass as a fuel for home heating with respect to the current situation. In addition, other scenarios taking into account the consumption of other fuels (coal, gas oil and natural gas) are analysed.

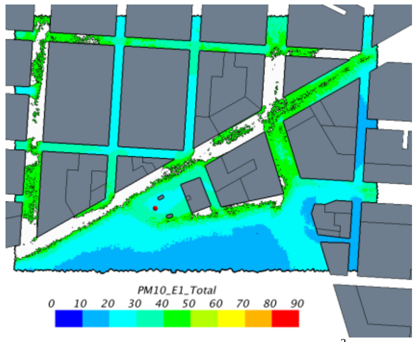

Fig.1 Average PM10 concentrations (µg/m^3) at 3 m above ground level for the period January-March 2011 considering road traffic and boiler emissions and the background concentration. Areas with concentration higher than 50 µg/m^{3}are in white.

Methodology and Results

High resolution maps of average PM10 concentrations over a large period of time (several months) were computed using a CFD model to assess how the pollution is distributed in the streets within a domain of 700 m × 700 m in Madrid City. In order to avoid a large computational load, the approach of Santiago et al. (2013) was adopted. This consisted of running only a set of scenarios (16 inlet wind directions) using steady-state CFD-RANS simulations (STAR-CCM+ code from CD-Adapco). The road traffic emissions were modelled as tracers released from line sources along every street (one for each street) and the emissions of home heating were located on building stacks. The final map of average concentrations was made by combining (weighted average) the outputs of the simulated scenarios according to the meteorological conditions that occurred during the study period (January-March 2011). The resulting PM10 concentration map is shown in Fig. 1. Several scenarios with varying degrees of implementation of the different fuel types were simulated in order to estimate the impact on PM10 concentrations in the study domain. The results are summarized in Table 1. Two emission limits for biomass boilers were adopted: the current one of 150 mg/m^3 and the limit of 60 mg/m^3 to be implemented in the near future. Currently, biomass use is very low and its contribution to PM10 levels is small. However, a high consumption of biomass can produce a significant increase in PM10 levels enlarging the area with exceedances of limit values. Natural gas and coal are the best and worst fuels, respectively, with regards to their contribution to PM10 levels.

Scenario	Fuel usage share in boilers in buildings of the studied domain (%)	Increase of the Surface of área exceeding 50 µg/m^3 of PM10 respect to base scenario	Maximum contribution to the PM10 concentrations due to house heating boilers (µg/m^3)
0 (Base)	Biomass=0.6%; Natural Gas =76.6%; Gas Oil=20.6%; Coal=2.2%	0%	1.8
1.a	Biomass(150 mg/m^3)=25% Natural Gas=75%	20%	6
1.b	Biomass(60 mg/m^3)=25% Natural Gas=75%	3%	2.5
2.a	Biomass(150 mg/m^3)=50% Natural Gas=50%	52%	11
2.b	Biomass(60 mg/m^3)=50% Natural Gas=50%	14%	4.5
3.a	Biomass(150 mg/m^3)=75% Natural Gas=25%	85%	16
3.b	Biomass(60 mg/m^3)=75% Natural Gas=25%	24%	6.5
4.a	Biomass(150 mg/m^3)=100%	117%	21
4.b	Biomass(60 mg/m^3)=100%	38%	8.5
5	Natural Gas=100%	-7%	0.5
6	Coal=100%	278%	55

Table 1. Estimated impact on ambient PM10 concentrations of several scenarios of fuel usage in home heating boilers in Madrid.

Conclusions

An intensive use of biomass as a fuel for home heating boilers is expected to have a significant impact on the ambient PM10 concentrations in urban areas, even in areas with high traffic intensities such as that studied in Madrid.

Acknowledgement

This work was supported by the Spanish Ministry of Agriculture, Food and Environment

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TRANSFORMATION RATIOS OF PHENOLS AND NITRO-PAHS GENERATED BY STOVES WOOD BURNING: A PHOTOCHEMICAL CHAMBER STUDY

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Summary

This study aims to determine formation potential of SOA within a photochemical chamber and compare concentrations of Phenols and Nitro-PAHs of primary and secondary samples (with and without UV irradiation) of pellets wood stoves emission. Analytical techniques HPLC-DAD and GC-MS were used to identify the phenols and Nitro-PAHs, respectively.

The ratios comparison shows the similar ratios transformation (90% of compounds) with except of 9-nitrophenol and 3-nitrophenol.

With these ratios you can estimate what happens in the atmosphere of these substances (phenol and nitro-PAHs) resulting from the combustion of biomass.

Introduction

The massive use of different types of stoves for residential heating in south of Chile, generated usually during the winter, severe air quality problems, due to this is essential study the real contribution of these air quality and potential health effects of the population and its contribution to climate change.

Methodology and Results

Photochemical Chamber (developed by Harvard T H Chan School of Public Health) is a Teflon bag, cubic shape of 14 m^3. In order to have a clean air prior to experiment, the chamber was flushed overnight using a Clean Air System (a set of 2 HEPA filters, activated carbon and acid and basic filters). Chamber clean air was verified using continuous monitors (NOx, CO and Particles).

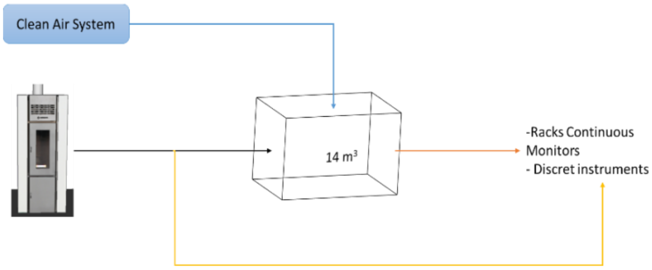

Fig 8: System set-up of experiment. Yellow line is a bypass to continuous monitors that allow to measure emission (upstream the photochemical chamber). Black line is the flow that fill the chamber with emission. Orange line is the line that measure photochemical concentration inside the chamber (downstream the chamber). Blue line represent the flushing line for clean the chamber.

In order to fill the Chamber with primary emission, a small amount of pollutants coming from pellet stove (Rika) was transported directly to the chamber during a period of 5 minutes, without any dilution. Throughout Chamber filling's process, continuous monitors and filters samples were also collected. Emission samples were taken using a by-pass line as shown in *Fig1*. After 5 minutes, the filling process was stopped and pollutants captured inside the chamber were leaved on darkness for 30 minutes (UV lights OFF), to have a homogeneous air inside the chamber (diffuse process). Only continuous monitors were operating taking a small amount of samples (flow less than 5 l/min).

After 30 minutes UV lamps were turned on to start the photochemical transformation inside the chamber. Continuous monitors were always measuring Chamber concentrations. After approximately two hours of UV lamps ON, secondary samples were taking for two hours. Two Harvard Impactor with quartz filters and two LiChrolut Si® (Merck) cartridge for phenols were installed in parallel in order to have duplicated for primary and secondary samples.

The results are shown in Table 1

Table 1: Transformation ratios of phenols and nitro-PAHs generated by pellets stove emission.

Type	Ratio secondary/primary	Type	Ratio secondary/primary	Type	Ratio secondary/primary
9-Nitroanthr	1.29	2-Nitropyr	20.50	Catechol	7.96
9-Nitrophen	228.47	1-Nitropyr	6.00	Phenol	29.68
3-Nitrophen	131.86	4-Nitropyr	14.58	4-Methoxyphenol	17.86
2-Nitrophen	9.90	7-Nitrob(a)Anth	17.10	2-Methoxyphenol	19.65
2-Nitroanthr	19.68	6-Nitrochr	12.04	p-Cresol	20.09
3-Nitrofluor	14.20	3-Nitrobenzanthr	1.44	2,5 Dinitrophenol	24.83
2-Nitrofluor	15.16	6-Nitrob(a)pyr	2.90	4-Nitrophenol	11.92

Conclusions

Primary vs secondary comparison shows secondary particles formation due to photochemical activity inside the chamber but this formation is around twenty times more for all pollutants analysed (phenols and Nitro-PAHs) with except of 9-nitrophenol and 3-nitrophenol analysed.

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DEVELOPMENT APPLICATION EVALUATION OF AIR QUALITY AND RELATED MODELS

EVALUATION OF AEROSOL OPTICAL PROPERTIES USING THE CAMX-AODEM MODELLING SYSTEM

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Summary
This work aims at evaluating the skill of the AODEM-CAMx modelling system in reconstructing the aerosol optical properties in the polluted area of Milan. Results were compared to both ground-based and vertical profile measurements collected in the city of Milan. Our analysis pointed out that the modelling system captures the AOD555 spatial patters, as well as the aerosol distribution along the vertical profile.

Introduction
The lack of a detailed knowledge on aerosol optical properties is one of the major sources of uncertainties in climate forcing assessment. Aerosol particles play a key role in determining Earth's climate by both interacting with solar radiation (direct effect) and acting as cloud condensation nuclei (indirect effect). Generally, such effects are investigated by means of modelling tools. However, accurate quantification of direct aerosol forcing is strongly related to the ability of global and regional models to describe physical and chemical properties of atmospheric pollutants. In order to assess the model skills in reproducing the spatio-temporal variability of aerosol optical properties, the AODEM – CAMx modelling system has been applied over the urban area of Milan and compared to ground-based and experimental vertical profiles collected during field campaigns (Ferrero et al., 2014).

Methodology and Results
High-resolution simulations (i.e. horizontal grid size of 1.7 km) of aerosol mass concentrations and aerosols optical properties were carried out for February 2010 by applying the AODEM-CAMx integrated modelling system over the urban area of Milan.
The chemical and transport model (CTM) CAMx (ENVIRON, 2011), driven by the meteorological model WRF and the local emission inventories (INEMAR; http://www.inemar.eu), was used for this experiment. Such modelling system allows an estimation of gaseous and aerosol concentrations in the polluted environment.
Given the CTM outputs, aerosol optical properties at three different wavelengths (470, 555 and 675 nm) were calculated by the AODEM post-processing tool (Aerosol Optical DEpth Module; Landi, 2013).

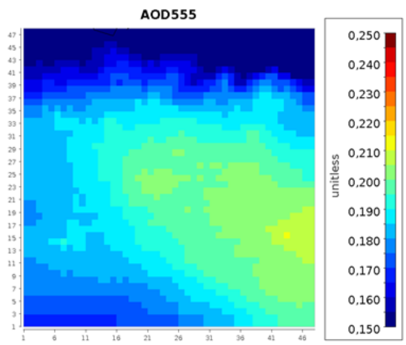

Fig.1 Monthly mean of Aerosol Optical Depth at 555nm estimated by AODEM.

Modelled data were compared to measurements both in terms of ground concentrations and vertical profiles. Ground-based observations were retrivered from AirBase network; while aerosol profile measurements were registered at the Torre Sarca sampling site, in the Milano Bicocca University Campus, by means of a helium-filled tethered balloon. Using these collected experimental data, calculations of scattering and extinction coefficients were performed along the vertical profiles (Ferrero et al., 2014).
As an example, Figure 1 shows the monthly mean of Aerosol Optical Depth at the wavelength of 555 nm estimated by AODEM. Besides, Figure 2 shows the vertical profiles of PM2.5 concentrations performed by CAMx over the city of Milan.
Our findings suggest that the model can reproduce the AOD555 spatial patters, as well as the aerosol distribution along the vertical profile.

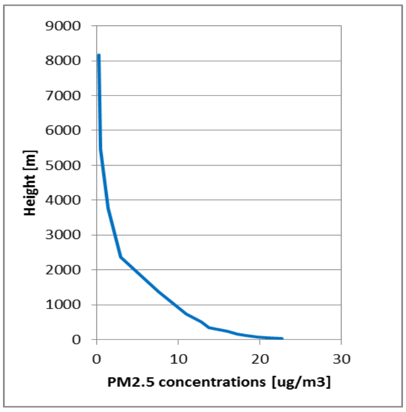

Fig.2 vertical profiles of PM2.5 concentrations estimated by CAMx in the city of Milan (Torre Sarca site).

Acknowledgement
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RECENT CFD MODELLING AND EXPERIMENTAL STUDIES OF AIR QUALITY AND THERMAL COMFORT IN URBAN AREAS

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Introduction

Six billion dwellers are projected to live in cities by 2050, implying that over 65% of world's population will be concentrated in urban areas. The consequence of increasing urbanization by means of replacement of natural land surfaces by buildings and pavement (i.e. concrete jungles) extensively modifies the climate at local, regional and global scales. The parallel growth in traffic, industrialisation, and anthropogenic heat emissions within cities continues to cause concerns about levels of air pollution and health risks associated with periods with elevated ozone, NOx or particulate matter concentrations and unusually high temperatures (e.g., during heat waves), resulting in alarming rates of mortality.

Over the years, there have been numerous investigations on the dispersion of pollutants in built-up areas. Due to complex city-atmosphere interactions, the understanding of flow and turbulence processes is limited requiring more investigations, as well as the assessment of efficient mitigation strategies to improve urban air quality and thermal comfort.

The importance and extent of this multi-disciplinary problem necessitates an integrated multiscale approach taking into account field measurements, laboratory experiments, and numerical modelling.

Methodology and Results

The paper reviews the most recent studies on air quality and thermal comfort in urban areas, with particular attention to new and novel measurement techniques and research methodology, and developments in urban meteorology (including thermal effects) and air quality.

We present latest advances in Computational Fluid Dynamics (CFD) simulation complemented by experimental data from new field and laboratory campaigns, paying particular attention to the presence and implication of vegetation on urban climate and air pollution, thermal consequences of urban surfaces and the urban heat island effect, and traffic-induced turbulence. This is in addition to the coupling of mesoscale and microscale models for meteorological and air pollution applications and urban canopy parameterizations.

Finally, latest urban air quality application studies are visited, with focus on spatial representativeness of air quality measurements, air quality issues related with legislation and population exposure to air pollutants and thermal comfort. Mitigation strategies of urban air pollution and thermal stress, employing urban greening, photocatalytic materials, and urban planning are also introduced and discussed.

Conclusions

This review attempts to summarise recent advances in CFD simulations, mesoscale modelling and experimentation of air quality and thermal comfort in urban areas. The dynamics of the urban atmosphere is influenced by a number of factors including building geometry and packing density, presence of trees and other urban vegetation, buoyancy effects as a result of thermal exchanges between urban fabrics and the atmospheric boundary layer flow, and traffic-induced turbulence.

At microscale these effects are analysed using different modelling approaches to account for the turbulent dynamics: 1) Reynolds-Averaged Navier-Stokes (RANS) models solves the flow and pollutant dispersion around the buildings but parameterizes all the turbulent motions. 2) Large Eddy Simulation (LES) models provide more reliable and accurate representation of the turbulent dynamics that dictates the mass and momentum transfers in the urban canopy. LES models show promise despite its high computational demand and sensitivity to boundary conditions. On the other hand, RANS models are the cheapest CFD models in terms of computational burden, hence they are frequently used in day to day applications like urban air quality assessment.

It's also worth noting that the aforementioned effects have been separately investigated and reported, and the review will bring them together to enable an appreciation of their relative influences and how they interact with one another. The most recent advances in urban canopy parameterizations for mesoscale models permit to evaluate the efficiency of commonly proposed urban adaptation strategies (such as green and cool roofs, solar photovoltaic panels, hybrid approaches, etc) to improve air quality, thermal comfort, and reduce urban energy demand. Within this context, the use of regional atmospheric models is crucial because potential tradeoffs between different adaptation strategies can show geographic and seasonal dependence, showing the need for geographically appropriate strategies rather than one strategy fit all solution.

EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF A CUBIC BUILDING ON THE WIND EROSION OF A MIXING OF ERODIBLE AND NON-ERODIBLE PARTICLES

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Summary

In the present paper, we carried out wind tunnel tests of sand particles in an oblong stockpile shape. The sand stockpile is a mixing of erodible and non-erodible particles due to their size distribution. The main objectives were to determine which case (concerning the presence of a building upstream) is the most critical to air pollution events and how the non-erodible particles indicate zones of high erosion in the case of placing an obstacle upstream to the pile. Several papers also reported and it is very well settled in the literature, that the flow becomes very complex due to the interaction with obstacles even with the simplest forms. The aims of the present study are to quantify the amount of emitted mass after wind tunnel exposure and to comprehend the association between high erosion potential zones and non-erodible particles behaviour.

Introduction

Wind erosion of granular material stockpiles has been already studied by means of both numerical and experimental approaches as shown by several works found in literature [Kok and Renno, 2009; Gousseau et al., 2013]. The non-erodible particles have enormous influence on the temporal evolution of emissions and consequently on the total amount of particles taken-off. Still many studies in a wind tunnel are required for a better understanding of the influence of these non-erodible particles for different configurations. In the present study one observed an improvement in the previously published methodology [Furieri et al., 2013]: the visual difference between black and white particles representing, respectively, erodible and non-erodible particles is a new approach found in the present paper. A very remarkable qualitative analysis was carried out for the visualization of the main areas of erosion on the stockpiles.

Methodology and Results

The experimental scaled-down model is placed at the test section located approximately 6.20 m downstream the entrance of the wind-tunnel enabling the development of a turbulent boundary layer. High quality photographs were taken each 30 seconds until the final covering of the stockpile surface. The emitted mass from the stockpile considerably increases due to the presence of the upstream cubic obstacle. For the velocity of 7 m/s, we found out an increase of approximately 83% of emitted mass due to presence of the building. It takes place by the formation of complex structures of the modified flow. Two main vortices are formed downstream of a cubic building and directly affect the pile (Figure 1). The effect of the main vortices generated due to the cubic obstacle are clearly seen since the first thirty seconds of exposure. The windward wall of the upstream stockpile is not normally affected by the incoming wind flow (perpendicular).

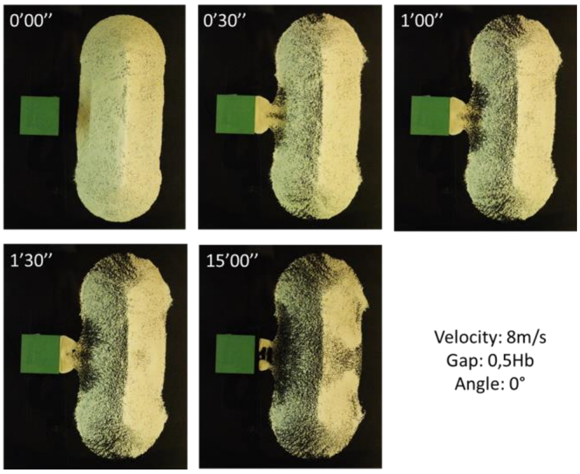

Fig. 1 Wind erosion of a sand stockpile: influence of a cubic building

Conclusions

We have noticed an increase of emitted mass if there is a building modifying the incoming wind flow. The qualitative analysis have helped us to identify on the stockpile surface the most eroded zones and their temporal evolution. The authors are developing numerical simulations of the shear distribution on the surface of the stockpile to complement information obtained experimentally. Required simulations were also never realized due to the fact that simulates the actual dimensions of a sand stockpile (instead of coal stockpiles already investigated) and consider the existing rounded the crest.

Acknowledgement

FAPES, CNPq and CAPES/COFECUB financially supported this work.

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MATHEMATICAL MODELLING OF EMISSIONS FROM A BED OF GRANULAR MATERIAL EXPOSED TO A TURBULENT FLOW

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Summary

A model was developed to estimate diffuse dust emissions due to wind erosion from a bed of particles with a wide particle size distribution. The non-erodible particles, treated as roughness elements, create a protection to the erosion. To accurately estimations it is important taking into account the influence of these larger particles. The model uses previous numerical simulations that relate the mean friction velocity of an erodible surface with some parameters of the roughness element.

Introduction

Dust emissions from fugitive sources on industrial sites can represent a significant contribution on airborne particle pollution. At several industrial sites, granular materials present a wide range of particle size distribution. The presence of coarse particles creates a temporal decrease of the emitted mass flux. Their presence diminishes the wind erosion because they protect surrounding erodible particles by covering a part of the surface or creating wake zones of low wind speed, leading to a decrease of the shear stress on the erodible surface. As the surface is eroded, the coarser particles accumulate and protect the bed surface from erosion, which is known as pavement phenomenon. Considering this, a computational program was built in order to estimate the mass emitted, taking into account these effects.

Methodology and Results

To assess the shear stress partition between the roughness elements and the erodible surface underlying we analyze the parameter R_{fric}, defined by $R_{fric} = u_R^*/u_S^*$ where u_R^* is the mean friction velocity in the erodible area of a surface with roughness and u_S^* is the mean friction velocity on a smooth surface. By means of numerical simulations with roughness arrays of varying density, Turpin et al. (2010) proposed:

$$1 - R_{fric} = A.(CR)^M.\left(S_{frontal}/S_{floor}\right)^N \qquad Eq.1$$

where CR is the cover rate of non-erodible particles, $S_{frontal}$ and S_{floor} are the roughness element frontal and floor surface, respectively, and A, M and N are constants. The program was built using Python language and a synthesis of the algorithm is shown in Fig. 1. For each size range, the amount of particles and the number of layers including into the height of the bed is calculated. Thereby is possible to characterize the progress of wind erosion following the evolution of the parameter R_{fric}. In each iteration, a layer of certain range of particles is eroded according to the criterion obtained by Foucaut (1996). The criterion determines the diameters D_{crit1} and D_{crit2} which limits the granulometric slice liable to take-off. As the take-off occur, the roughness augments due to the increase of CR and the parameter $S_{frontal}/S_{floor}$. The model accounts emissions for each size range until the friction velocity reaches the threshold friction velocity ($R_{fric} = R_{lim}$). To validate, the experimental data of Descamps (2004) were used. Although the model slightly overestimates the emissions, an overall good agreement was noticed, with a high correlation coefficient ($R^2 = 0.98$).

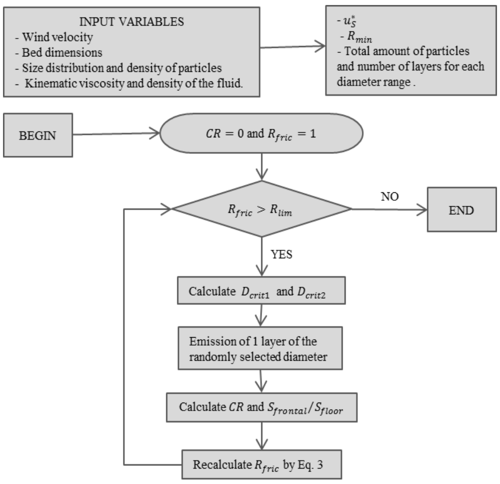

Fig. 1 Algorithm of the program

Conclusions

In this study, it was developed a model that estimates the total emitted mass from a particle bed exposed to turbulent flow. The influence of the non-erodible particles was modelled analysing the partition of shear stress between the roughness elements and adjacent erodible surface, previously obtained by numerical simulations. The increase of roughness characterizes the pavement phenomenon. Comparisons with experimental data have shown a good agreement. The results clearly show the protective effect of non-erodible elements on the entrainment of finer particles in the flow. The program demands little computational resources and could be a useful contribution for practical situations found in industrial sites.

Acknowledgement

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IMPROVED REGRESSION METHODS FOR MAPPING TRAFFIC RELATED AIR QUALITY

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Summary
Maps of air quality are regularly used for health studies to determine long term home address concentrations. With pollutants such as NO_2, that are often dominated by traffic emissions, such maps must be provided at high resolution in order to capture near road gradients. The heath community tends to favour the use of measurement data and spatial interpolation using land use regression for producing such maps. The air quality modelling community, on the other hand, would prefer the use of high resolution air quality modelling. In this paper a regression methodology using passive sampler measurements and a predictor variable based on aggregated inverse distance from traffic sources, mimicking the dispersion process, is used to produce high resolution spatial maps of annual mean NO_2 concentrations in the city of Bergen, Norway. Concentration, uncertainty and probability of exceedance maps are produced and home address exposures are calculated.

Introduction
Health and exposure studies investigating long term exposure to air pollution often use estimates of concentrations at home addresses. Whilst air quality modelling can provide such spatial information the health community tends to favour the use of land use regression (LUR), fitting measured concentrations to a range of predictor variables based on geographically distributed data. Such methods have been shown in many cases to 'over fit' the observational data resulting in unrealistic and noisy maps, particularly when a large number of predictor variables are 'offered' to the model (Denby, 2014). If regression methods are to be used then the data needs to be represented by far fewer predictors and these predictors should be physically based so that the resulting maps provide realistic fields. Whilst air quality models offer this information, they are not always available and may require substantial efforts for their implementation. In this paper we apply a regression method that is more physically based, when traffic emissions dominate, and requires far fewer fitting parameters than are usually made available for LUR models.

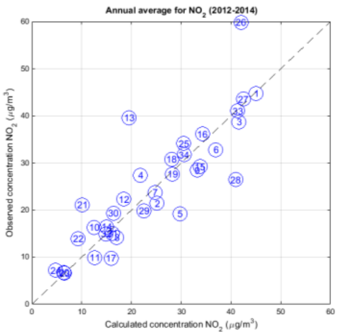

Figure 1. Scatter plots of calculated and observed NO_2 concentrations

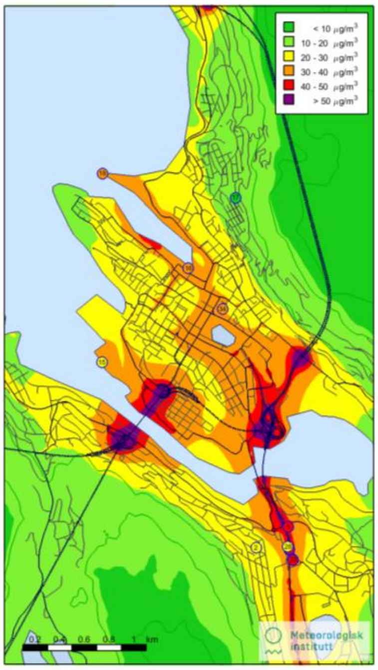

Figure 2. Calculated NO_2 concentration fields for Bergen

Methodology and results
The method uses the Annual Daily Traffic (ADT) multiplied by the road link lengths (ADT.L) as proxy for traffic emissions. This emission proxy is aggregated in 25 x 25 m^2 grids and is then distributed in space using a physically based pseudo dispersion function (inverse distance to the power of -1.5). The validity of this function was derived previously from high resolution air quality modelling (Denby, 2014). At each grid the contribution at all the other grids is summed using the pseudo dispersion algorithm to obtain the total contribution. The influence of terrain, based on change of height from source, is included in the algorithm. Contributions from shipping emissions are also included and these are calculated in a similar way based on 100 x 100 m^2 shipping emissions obtained from AIS data. Multiple linear regression of the model with observed annual mean concentrations of NO_2, obtained from 34 passive samplers distributed in the city, is then applied to these two sources to obtain regression parameters. The resultant regression (Figure 1) is based on only two proxy data fields and has an R^2 of 0.74. Ensemble methods are used to determine the uncertainty of the regression parameters and of the resulting concentrations fields. Maps are visualised as concentration fields (Figure 2), concentration uncertainty fields and probability of exceedance fields. Home address exposure, and its uncertainty, is also calculated (Denby, 2015).

Conclusions
The study shows that even simple, but more physically based, traffic proxy data can be effectively used for regression model mapping applications, removing the need for non-physical multiple traffic predictors often used in land use regression. Even so, the use of air quality models, combined with monitoring data, should provide the best mapping results.

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DEVELOPMENT OF AIR QUALITY FORECASTING SYSTEM IN THE EASTERN MEDITERRANEAN USING THE WRF-CHEM MODEL

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Summary
A regional air quality forecasting system is being established for Cyprus and the Eastern Mediterranean with a focus on Cyprus. To that end, the WRF-Chem atmospheric chemistry model is configured to forecast the hourly atmospheric concentrations of ozone (O_3), Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Sulphate (SO_4^{2-}) and particulate mater (PM_{10} & $PM_{2.5}$). The model performance was evaluated by comparing model calculations to measurements from the CYPHEX campaign, performed during Summer 2014. Initial results indicate that the calculated day-to-day and diurnal variations of the aforementioned species show good agreement with observations.

Introduction
The island of Cyprus is located in the north-eastern part of the Mediterranean Sea which is affected by dust transport primarily from the Sahara and the Middle Eastern deserts (Pey et al., 2013). In addition, north and north-westerly winds result in transport of air masses rich in ozone and/or its precursors from Middle East and Central/Eastern Europe towards Cyprus (Kleanthous et al., 2014). For the purposes of this study we have employed the Weather Research and Forecasting (WRF) model coupled online with chemistry (WRF-Chem).

Methodology and Results
Atmospheric chemistry observational data from the CYPHEX campaign near Inia village in Paphos, Cyprus (July 07-31, 2014) were used to test the model. The model was set up with three nested grids (of 45km, 15km, and 5km resolutions respectively; Fig.1). The meteorological boundary conditions were updated every three hours throughout the simulation using the Global Forecast System (GFS), while chemical boundary conditions were updated every 6 hours using the MOZART global chemical transport model. The gas-phase chemistry and aerosol modules used in this configuration are the Regional Acid Deposition Model, version 2 (RADM2) and the Modal Aerosol Dynamics Model for Europe – Secondary Organic Aerosol Model (MADE – SORGAM). No anthropogenic or biogenic emissions were included in the simulation yet, but will be considered at a later stage. First results suggest that the WRF-Chem model captures the daily and diurnal evolution of ozone relative concentrations (Fig.2) with similar results for the other modelled trace gases.

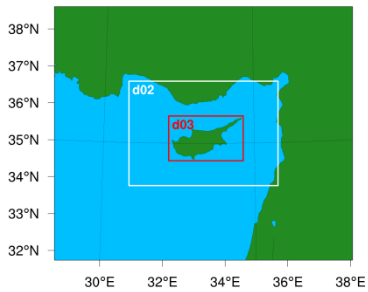

Fig.1 Model domains

Conclusions
Preliminary results show good agreement of the WRF-Chem air quality model with observations for the region of Cyprus. Some discrepancies between the model outcome and measurements can be attributed to the local emissions (biogenic & anthropogenic), not currently included in the simulation. Various combinations of chemistry and aerosol modules are still to be tested and local emission inventories will be included in future simulations.

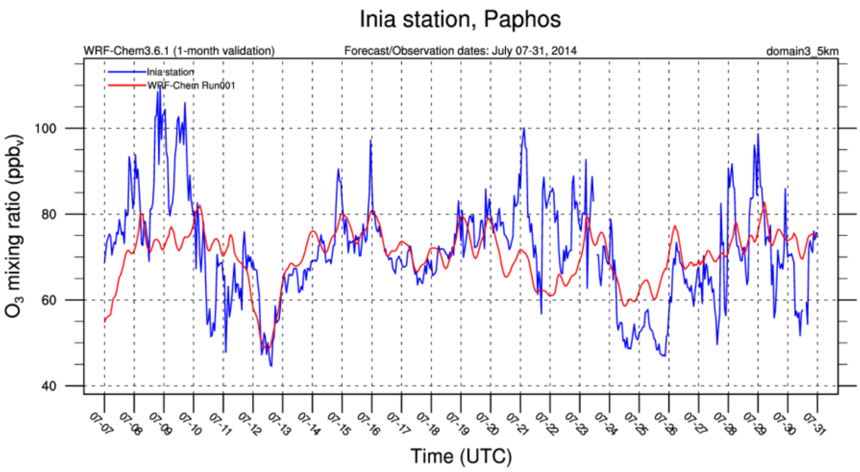

Fig.2 Observed (blue line) and simulated (red line) O_3 relative concentrations

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DEVELOPMENT OF ANFIS MODEL WITH OPTIMISED INPUTS TO REDUCE THE COMPUTATIONAL COST AND TIME FOR GROUND LEVEL OZONE FORECASTING

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Summary
This study aims to develop adaptive neuro-fuzzy inference system (ANFIS) for forecasting of daily ozone (O_3) concentrations in the atmosphere of a mega city. The ANFIS model predictor considers the value of seven meteorological factors (pressure, temperature, relative humidity, dew point, visibility, wind speed, and precipitation), NO_2 concentration, and previous day's ozone concentration in different combinations as the inputs to predict the 1-day advance and same day ozone concentration. Collinearity tests were conducted to eliminate the redundant input variables. A forward selection (FS) method is used for selecting the different subsets of input variables. The method reduces the computational cost and time. The performances of the models were evaluated on the basis of four statistical indices [(coefficient of determination (R^2), normalized mean square error (NMSE), index of agreement (IOA), and fractional bias (FB)].

Introduction
Environmental data are typically very complex to model due to the underlying correlation among several variables of different type which yields an intricate mesh of relationships (Marino et al, 2001). Standard statistical techniques may fail to adequately model complex non-linear phenomena (Moussiopoulos et al., 1995). In contrast, expert knowledge is becoming widely used because they showed ability to model non-linear data and their non-reliance on previously assumed equations (Marino et al., 2001).

Methodology and Results
A flowchart of ANFIS model development is presented is Fig. 1. The multi-collinearity test result shown in Table 1 clearly indicates that the VIF values exceeded the recommended value (10) for both the temperature and humidity before removing one of the variables. Also, the tolerance level of temperature and humidity are below the recommended limit (0.2) in each case. After removing of redundant variables, the VIF values and tolerance level are well within the recommended limit for each variable. Applying FS algorithm, all the explanatory variables (input variables) are ordered according to their correlation with the dependent variable (from the most to the least correlated variable). The statistical indices shown in Table 2 indicate that there is no significant influence of the number of input variables on different statistical indices (IOA, FB, NMSE, and R^2). There was a very slight change observed in the output in different input conditions in both the cases (same day and 1-day advance forecasting). Thus, the best model can be selected on the basis of training error and testing error levels. M4 showed the transition or stable input conditions where the error level is stable and thus suitable for forecasting the ozone concentration.

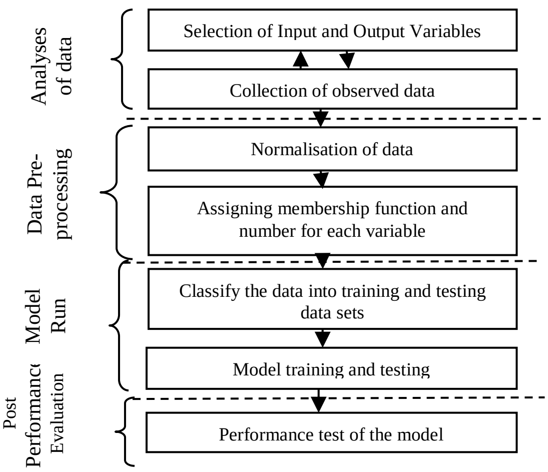

Fig. 1: Flowchart of ANFIS model development

Table 1: Collinearity Statistics

Before Removal of variables			**After removal of variables**		
Variables	**Signif.**	**VIF**	**Variables**	**Signif.**	**VIF**
P- O_3	0.847	1.180	P-O_3	0.861	1.161
NO_2	0.363	2.753	NO_2	0.365	2.740
PRESS	0.404	2.472	PRESS	0.415	2.411
RH	0.015	65.55	RH	0.486	2.058
TEMP	0.005	197.35	TEMP	0.329	3.036
DP	0.003	299.23	VISI	0.717	1.395
VISI	0.711	1.407	WS	0.856	1.169
WS	0.853	1.173	PRECI	0.809	1.237
PRECI	0.764	1.309			

Note: Variables Information
PRESS- Pressure, TEMP- Temperature, RH-Relative Humidity, DP-Dew point, VISI-Visibility, WS-Wind speed, PRECI-Precipitation, P-O_3- Previous day Ozone.

Table 2: ANFIS model results

Model	R^2	NMSE	FB	IOA	R^2	NMSE	FB	IOA
	Same day forecasting				1-day advance forecasting			
M1	0.80	0.02	0.014	0.95	0.68	0.08	0.012	0.91
M2	0.80	0.01	0.013	0.95	0.68	0.09	0.011	0.92
M3	0.81	0.01	0.014	0.95	0.68	0.07	0.010	0.91
M4	0.79	0.05	0.020	0.95	0.72	0.07	0.015	0.92
M5	0.82	0.05	0.017	0.95	0.73	0.07	0.019	0.92
M6	0.82	0.05	0.017	0.95	0.72	0.08	0.017	0.92
M7	0.82	0.05	0.016	0.95	0.72	0.08	0.014	0.92
M8	0.82	0.05	0.006	0.95	0.72	0.08	0.007	0.92

Note: Input combination of models
M1: P-O_3, WS, Visi, RH, Temp, Preci, Press, NO_2; **M2**: P-O_3, WS, Visi, RH, Temp, Preci, Press; **M3**: P-O_3, WS, Visi, RH, Temp, Preci; **M4**: P-O_3, WS, Visi, RH, Temp; **M5**: P-O_3, WS, Visi, RH; **M6**: P-O_3,WS,Visi; **M7**: P-O_3,WS; **M8**: P-O_3

Conclusions
Neuro-fuzzy logic is a stochastic approach which is used in the present study for forecasting of ozone concentrations. It was seen that the statistical performance was good for all the models, indicating that a lesser number of input variables can be considered in order to forecast the model. The IOA ranges from 91% to 95% indicating a good model, and closer to ideal value. The present study helps in finding out the input combination which would lower the computational cost.

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HIGH-RESOLUTION MODELING OF URBAN AIR QUALITY IN THE BERLIN-BRANDENBURG REGION WITH WRF-CHEM: A MODEL EVALUATION

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Summary
The WRF-Chem model was set up with high horizontal resolution (1kmx1km) and evaluated against observations for the Berlin-Brandenburg area. First results show a reasonably good performance for the meteorology, and a reasonable skill in reproducing observed chemistry and aerosols. This study focuses on urban areas, for which the model performs similarly well as for non-urban areas. Still, it was more challenging to simulate the heat wave in 2006 for the urban stations. Sensitivity studies include a new set of parameters for the urban scheme optimized for European cities as well as the implementation of new high-resolution anthropogenic emissions. The model setup is then applied for air quality studies in Berlin and Brandenburg.

Introduction
Air pollution is the number one environmental cause of premature deaths in Europe. Despite extensive regulations, air pollution remains a challenging issue, especially in urban areas. With the aim of studying air quality in the Berlin-Brandenburg region of Germany, the Weather Research and Forecasting Model with Chemistry (WRF-Chem, Skamarock et al., 2008; Grell et al., 2005; Fast et al., 2006) is set up and optimized for this application. This study presents its evaluation against meteorological and air quality observations from monitoring stations as well as from a field campaign ("BAERLIN") conducted in and around Berlin in summer 2014, which includes for example measurements of black carbon, VOCs, particle size distribution, particle mass, NO_x and O_3. This evaluation provides a basis for future studies such as how heat waves affect emissions of biogenic volatile organic compounds from urban vegetation and the impact of selected traffic measures, such as replacing a share of car trips with bicycle trips, on air quality in the Berlin-Brandenburg area.

Methodology and Results
The model setup includes three nested domains with horizontal resolutions of 15km, 3km, and 1km, online biogenic emissions (MEGAN 2.0), and anthropogenic emissions from the TNO-MACC_III inventory (Kuenen et al., 2014). The MADE/SORGAM aerosol scheme and RADM2 chemistry are used. Urban areas are represented with the 3-category urban canopy model. Simulations are done for the summers of 2006 and 2014. Preliminary results show that the model reproduces the observed meteorology in the region reasonably well in both periods. An exception is the heat wave period in 2006, during which the air temperature simulated at 3km and 1km resolutions is underestimated by 2°C at urban stations. WRF-Chem simulates the mean concentrations of O_3 in good agreement with observations. However, the 8-hr maxima are underestimated, and the minima are overestimated. Mean NO_x concentrations are modeled reasonably well at stations located in green areas of the city, but underestimated compared to observations at urban background stations. This can partly be explained with the coarser resolution of the emission input data compared to the model resolution. PM_{10} concentrations are underestimated by the model by around 50%. Typically, simulated O_3, NO_x, and PM_{10} from the 1-km domain do not show a significant improvement compared with the 3-km domain.

Conclusions
The performance of the WRF-Chem setup for Berlin and Brandenburg is similar to that from previously published WRF-Chem studies for the European domain and has clearly some room for improvement. As an example, the default input parameters for the urban scheme developed for application in the U.S. will be adapted for Berlin. In order to assess whether a horizontal resolution of 1km is superior to a setup with 3km for air quality studies with this model we will include an updated high-resolution emission inventory for Berlin and compare the performance of the different horizontal resolutions. The model will then be applied to several studies on different aspects of air pollution in the Berlin-Brandenburg region.

Acknowledgement
We acknowledge TNO for the provision and advice on the use of the TNO-MACC emission inventory version 3. We thank all participants of the BAERLIN measurement campaign for making the data available for the model evaluation.

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EVALUATION OF THE DISPERSION OF ODOUR IN ITALY: MODELLING STUDIES COMPLYING WITH THE NATIONAL REFERENCE GUIDELINE

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Summary
This work aims to introduce odour dispersion modelling in Italy. The main legal reference in Italy so far, the "Guideline of the Lombardy Region" standardized the procedure for modelling olfactive impact, enhancing the use of models as an evaluation tool. Non-stationary Gaussian puff models (eg. Calpuff) are now widely used, as they give good results in most cases: they can represent non-stationary conditions, such as variable emissions and variable meteorological conditions (calm wind, wind gust, atmospheric turbulence), and they can represent the effect of orography. But Gaussian models have some limitations: their dispersion algorithms can't simulate the dispersion of odour in areas dense with obstacles. However, Gaussian models are often improperly applied in urban areas or in very complex orography (eg. narrow valleys), thus calculating unrealistic results or not useful results. For this reason, we decided to test a Lagrangian model: we evaluated the olfactive impact in a complex area, with the atmospheric dispersion model MicroSpray (of Arianet Ltd.). The model gave realistic results, even around obstacles. The evaluation was carried out in compliance with the mentioned "Guideline".

Introduction
The Guideline of the Lombardy Region concerns the evaluation of olfactive impact and the characterization of odour emission (sampling of sources, odour measurement in ou_E/m^3 with olfactometry, calculation of odour emission rate in ou_E/s). The Annex 1 of the Guideline defines all requirements of the modelling studies for evaluation of the olfactive impact: every detail is defined, such as which emissions have to be simulated, and which models should be used.
The olfactive impact both depends on the odour concentration at ground level and on the frequency of annoying events (when concentration of odour exceed the tolerance threshold). Moreover, the odour concentration at ground changes quickly, because it is driven by short-scale weather phenomena (calm winds wind gust, atmospheric turbulence) and by odour emission rate, which typically is not steady. Thus, the olfactive impact is not represented by annual mean concentration: it must be assessed in terms of the annual 98th percentile of hourly peak concentration of odour (ref. Guideline of the Lombardy Region). The hourly peak concentration includes the fluctuations of hourly mean concentration due to meteorological conditions. In the maps of 98th percentile calculated by the model, the contour lines of three "annoying levels" 1 ou_E/m^3, 3 ou_E/m^3, 5 ou_E/m^3 include areas exposed to different olfactive impact (concentration > 5 ou_E/m^3 can be perceived by 95% of people).

Methodology and Results
The Guidelines require to apply Gaussian models or Lagrangian models or Eulerian models. Gaussian models allow to calculate the annual 98th percentile, but can't simulate the buildings effects and urban canopy in a realistic way. Thus, we decided to test the Lagrangian model MicroSpray: this model is designed to simulate the effect of obstacles with a good accuracy, but the increased complexity of calculation of MicroSpray penalizes the runtime, the elaboration of annual statistics (98th percentile) requires hours of computational time. To solve this issue, because the frequency of annoying events is the criteria for assessing the olfactive impact, we applied the model MicroSpray to calculate the olfactive impact in relation to most frequent weather conditions: we defined the worst meteorological conditions (calm wind, neutral atmosphere, wind blowing toward receptors) and we ran some short scenarios (1 hour-long).

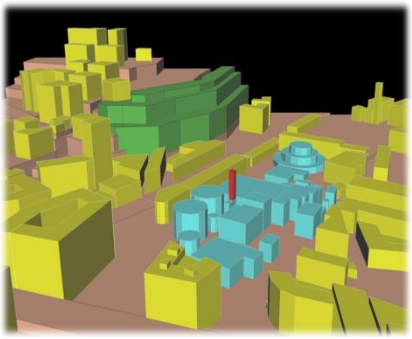

Fig.1 Domain of application of the model MicroSpray: complex orography, urban area

Conclusions
The model MicroSpray (of Arianet Ltd.) turned out as an excellent tool, for its sensitivity and flexibility: it can calculate the odour concentration at many heights from the ground, allowing to assess the impact at the houses at various floors, and representing the effect of mountain slopes and the effect of barriers (trees, buildings,...). Plus, the model can simulate many hourly meteorological conditions and emission scenarios within a short runtime.

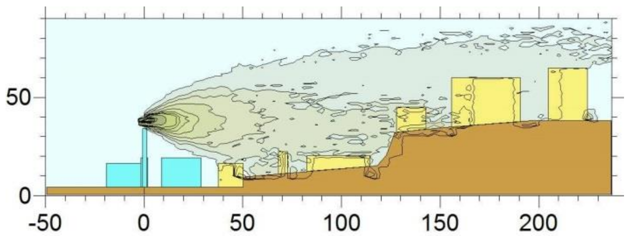

Fig.2 Map of the hourly peak concentration of odour, calculated with the model MicroSpray in the domain of fig.1

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MODELLING OF ARSENIC AEROSOL IN SOUTH-WEST SPAIN

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Summary

Concentrations of arsenic (As) in PM_{10} have been measured and simulated for an urban site in south-west Spain. The daily variation at this site was captured reasonably well, although in general the model underestimated the concentrations. As arsenic anthropogenic emissions continue to be reduced in Europe, the parallel measurement and modelling of Arsenic in particulate matter constitutes a useful tool to monitor these emission changes and the consequent improvement in ambient air concentrations.

Introduction

Arsenic is known to have adverse effects on human health and in January 2013 a mean annual target level of 6 ng m^{-3} of As in PM_{10} was introduced by the European Directive (2004/107/CE). Anthropogenic emissions constitute the largest source of As and Cu-smeltering is one of the largest anthropogenic contributions. The second largest Cu-smelter in Europe is located in Huelva (south-west Spain) and consequently a measurement and modelling program was initiated to characterise the behaviour of this species.

Methodology and Results

Concentrations of arsenic in PM_{10} were measured at an urban site (University Campus) in the city of Huelva at a distance of about 5 km northeast of the Cu-smelter. Daily measurements of PM_{10} were conducted with a high volume sampler (68 m^3 h^{-1}) on Munktell quartz filters which were subsequently analysed for As content in the laboratory by Inductively Coupled Plasma-Optical Emission Spectrometry (see Sánchez de la Campa et al., 2011). The daily measurements were conducted for intensive periods of 14 days at a time, followed by periods without measurement; this resulted in 196 measurement days. Arsenic in PM_{10} concentrations were simulated using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Stein et al., 2015) driven by the MM5 meteorological model with three nested domains of 18, 6 and 2 km horizontal resolution. Emissions of As were provided for five stacks at the Cu smelter. Results of the measured and simulated PM_{10} As concentrations for 2014 are shown in Fig. 1. This demonstrates that the modelling system was capable of capturing the daily temporal variation reasonably well, although in general the model underestimated the concentrations. The mean and maximum observed PM_{10} As concentrations were 2.6 ng m^{-3} and 23.0 ng m^{-3}, while the mean and maximum modelled PM_{10} As concentrations were 0.8 ng m^{-3} and 11.1 ng m^{-3}, resulting in a mean bias of -1.8 ng m^{-3}.

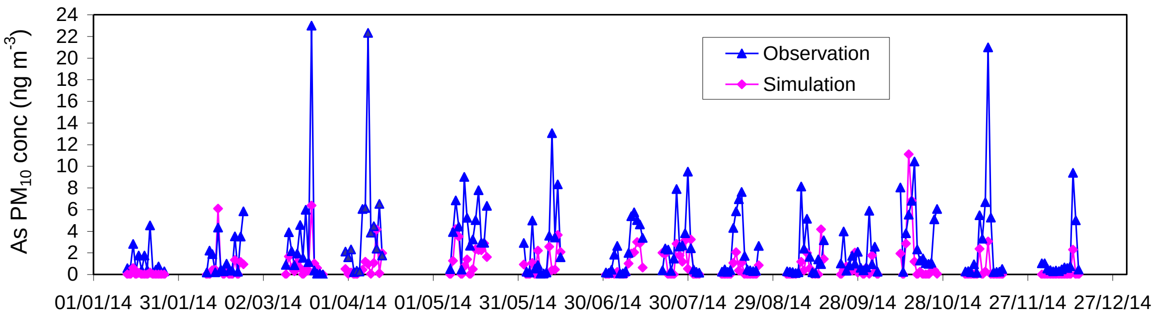

Fig.1 Observed and simulated PM_{10} As concentrations at University Campus, Huelva, 2014.

Conclusions

Concentrations of As in PM_{10} were measured and simulated for an urban site in south-west Spain for 2014. The parallel measurement and modelling of Arsenic in particulate matter constitutes a useful tool to monitor emission changes and the consequent improvement in ambient air concentrations.

Acknowledgement

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RELATIONSHIP BETWEEN MODELLED POLLUTION OF NITROGEN DIOXIDE AND TRAFFIC FLOW

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Summary
The aim of this research was to assess the relationship between modelled concentration of nitrogen dioxide (NO_2) in streets with different traffic intensity and composition and to estimate the air pollution of NO_2. ADMS-Urban dispersion model was used to estimate a level of nitrogen dioxide in streets of Kėdainiai city. Strong positive correlation was observed between the traffic flow and the concentration of NO_2. The linear relationship between the heavy traffic flow and NO_2 level was stronger than between the light traffic flow and NO_2. The median concentration of NO_2 in streets with high, medium and low traffic intensity was 14.27µg/m^3, 10.34µg/m^3 and 7.9 µg/m^3, respectively. This study has shown that the level of nitrogen dioxide is directly related with traffic flow, especially high traffic flow.

Introduction
The largest sources of air pollution in the cities are motor vehicle and industry (Levy et al., 2014). Road transport is one of the biggest emitter of NO_2. Increased concentration of NO_2 irritates breathing system, reduces lungs immunity to infections, can cause adverse health effects (Latza et al., 2009). In many Lithuanian cities the pollution of nitrogen dioxide is increasing every year due to the increasing number of vehicles that are older than 10 years and their emissions have significant impacts on local air quality. One method, which is widely used for estimating air pollution in the urban areas, is mathematical modelling. Atmospheric dispersion modelling enables the assessment of air pollution dispersion in areas where air quality measurements are not carried out.

Methodology and Results
The dispersion of NO_2 was determined by ADMS-Urban modelling software, which was developed by CERC (CERC, 2014).
Model requires the following input parameters: roads, stationary and grid sources, meteorological and background concentrations data. We created street network map, collected the data of traffic flow and composition in the main streets, stationary sources and their characteristics that have been entered to the model. For the analysis of the modelling results we grouped traffic flows into three categories: < 4000, 4000-6000 and > 6000 vehicles per day. ArcGIS software was used to enter air pollution data, for their visualization and to crate air pollution of NO_2 map. The average annual concentration of NO_2 was modelled using ADMS-Urban model in Kėdainiai city (see Fig.1). The results of this study showed that the highest concentration of NO_2 was assessed in the central part of the city, near the main streets and intersections where the traffic flow is intensive. The average annual NO_2 concentration in the main city streets varied between 15.8–19.8 µg/m^3. The median concentration of NO_2 in streets with high, medium and low traffic intensity was 14.27 µg/m^3, 10.34 µg/m^3 and 7.9 µg/m^3, respectively (see Fig. 2). The relationship between the concentration of nitrogen dioxide and traffic flows was assessed. Strong positive correlation was observed between the level of NO_2 and total traffic flow ($r = 0.77$; $p < 0.01$). The highest correlation coefficient was calculated between NO_2 and high traffic flow ($r = 0.84$; $p < 0.01$).
This study has shown that the level of nitrogen dioxide is directly related with traffic flow, especially high traffic flow.

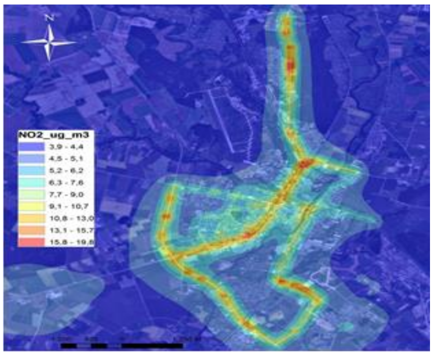

Fig.1 The average annual modelled concentration of nitrogen dioxide (µg/m^3) in Kėdainiai city

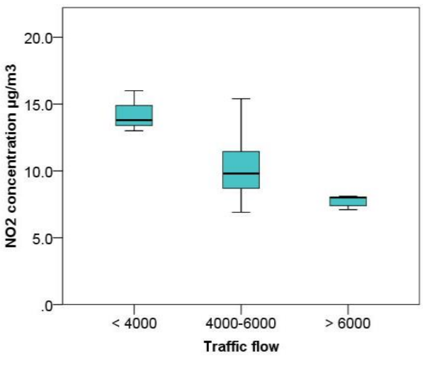

Fig.2 The median concentration of NO_2 (µg/m^3) in streets with different traffic flow

Conclusions
The traffic growth rates in the main streets contribute significantly to the total nitrogen dioxide pollution in the city. Motor vehicle exhaust emissions of NO_2 pose a threat to the environment and public health. Finding effective ways to reduce air pollution arising from the use of vehicles therefore remains important.

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USE OF COMPLEMENTARY METRICS TO IMPROVE DATA ASSIMILATION PERFORMANCES

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Summary

This study goes through an innovative methodology for combining information from air quality models and monitoring networks. The Successive Correction Method (SCM) has been modified by introducing, in addition to the distance-based metric, the geometric distribution of proxy variables (such as land use, built-up, emissions, etc.). The results obtained considering these complementary metrics have been compared with those provided by the original SCM implementation confirming the possible benefits coming from the adoption of this approach.

Introduction

A key requirement of the Directive 2008/50/CE on ambient air quality and cleaner air for Europe is the harmonization of data, coming from air quality (AQ) models and monitoring networks, to have a coherent picture of AQ status over a given area. Usually, the integration of AQ measurements and modelling fields is performed by means of data assimilation/fusion techniques (SCM, Optimal Interpolation –OI-, …) that consider the error variances of measurements and predictions and the location of monitoring sites and grid points. In their original formulations these techniques, derived from the meteorological field, do not take into account other information (as inhomogeneities in territory use or pollution sources location) which strongly affect the spatial distribution of pollutants. An example is given by so-called Land Use Regression (LUR) techniques, often used by air pollution epidemiologists to enhance spatial details of available satellite Aerosol Optical Depth (AOD) observations. In this perspective, the potential of different complementary metrics in improving the performance of data fusion techniques has been explored. Yearly average concentration fields provided by an AQ model, over a portion of Tuscany (Central Italy), have been combined with the observations coming from 44 monitoring stations and complementary territorial and emission information.

Methodology and Results

SCM is based on the Bratseth technique (Bratseth, 1986) and is still useful because of its low computational demands and its convergences to OI method due to the inclusion of background and observation error statistics. SCM is initialized by a background field (first guess modelled field) which is then iteratively modified by the analysis of local data on the model grid. This method has been revised by including a further metric, representing above mentioned inhomogenities, in terms of an additional 2D theme. The themes considered were densities of built-up areas, road network and population and pollutants emissions distribution on the target grid. The results obtained by the application of the original and modified version of SCM have been compared with raw model results. Figure 1 show an example of the results obtained by the application of this version of SCM considering built up areas used as a complementary metric. Several tests have been performed and NO_2 and PM_{10} results have been evaluated considering six cross-validation sets of stations, randomly selected, including 20%, 50% and 80% of the original dataset. Normalised Mean Square Error (NMSE) and Fractional Bias (FB) have been considered as performance evaluation indicators. This procedure evidenced that the use of the considered complementary metrics improves the results provided by the original SCM implementation. Small differences among the tested metrics have been found depending on the selected pollutant and the considered air quality standard. The tests also confirmed the strong influence played by the de-correlation horizontal length scale, used in the error spatial correlation functions, and provided indications about the better values to be used for this parameter.

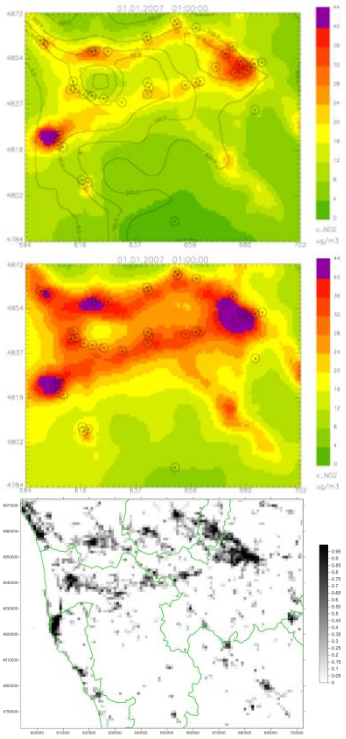

Fig.1 NO_2 annual average concentration field provided by the AQ model (upper) and the modified version of SCM (central) using built up areas used as complementary metric (lower). Circles: monitoring stations.

Conclusions

Adopting complementary metrics, associated with factors influencing AQ may lead to significant improvements in the geographical mapping of the pollutants and in the estimation of the health risk. The application of data assimilation/fusion techniques may also provide many other positive outcomes, like for example insights about the optimal location of monitoring stations.

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A HYBRID MODELING SYSTEM FOR THE EVALUATION OF URBAN CONCENTRATIONS: CASE STUDY FOR MILAN AREA

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Summary
This study aims at reconstructing the spatial variability of concentration levels of pollutants within Milan urban area by means of an integrated urban air quality hybrid modelling system (HMS) that integrates a Chemical and Transport Model (CTM) and a Local Scale Model (LSM). The Comprehensive Air Quality Models (CAMx) (ENVIRON, 2011) was the eulerian CTM model applied to consider chemical reactions and physical phenomena at basin scale; AUSTAL2000 (Janicke Consulting, 2002) was the lagrangian LSM model applied to compute dispersion of pollutants at the urban local scale. The HMS provided a detailed spatial reconstruction of pollutant concentrations that can be used to properly assess exposition levels within the urban area

Introduction
CTMs are generally not able to reproduce the spatial gradient of pollutants within urban areas; conversely LSMs enable to account for the features of the urban environment affecting pollutant transport and for the actual distributions of the emission sources (e.g.: high emission roads). Coupling a CTM model with a LSM model in a HMS exploits their strength allowing a more accurate reconstruction of the concentration pattern that points out the areas more exposed to pollution.

Methodology and Results
CAMx was applied to 3 nested domains downscaling from Italy to Milan urban area. The last domain covered 85x85 km^2 with a grid step size of 1.7 km. PSAT (Yarwood, 2008), a source apportionment algorithm implemented into CAMx, was able to distinguish background contribution from local sources contribution; however, this latter was specifically accounted by means of the AUSTAL2000, which can handle different types of emission sources (point, area, linear or volumetric) and the effect of the built environment, thus being able to properly describe the complex urban pattern. As an example, Figure 1 shows the NOx January mean, that describes the spatial variability computed by AUSTAL2000. HMS output was then composed by the sum of background concentration, computed by CAMx, and of local contribution, computed by AUSTAL2000. Both models were driven by the same meteorological input, outcomes of the WRF meteorological model. HMS model was applied over a portion of Milan city centre, covering roughly the same area of one CAMx cell, 1.6x1.6 km^2 with a 20m grid step size. HMS results were compared with observations at two air quality stations in Milan city centre. Figure 2 shows the comparison between NOx modelled (HMS and total CAMx, i.e.: background and local contribution) and observed hourly time series in January 2010. A good agreement between measurements and both modelled time series was observed, except some episodes (11-13/01, 19-21/01) due to particular meteorological conditions. Particularly, statistics (not shown) pointed out a slight increase in model performance when HMS is applied.

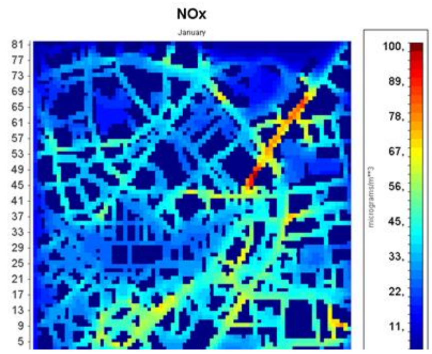

Fig.1 AUSTAL2000 - NOx January mean

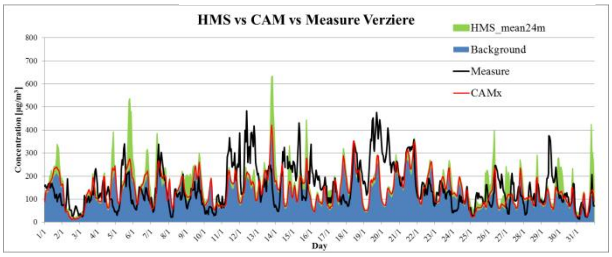

Fig.2 NOx Measured and modelled time series at Verziere site. Black and red lines represent observations and total CAMx estimation. Blue area indicates background contribution, that added to AUSTAL outcome (green area) generates HMS result.

Conclusions
HMS model allows reproducing the spatial variability of pollutants within the urban area, not feasible by CTM alone. This permits to compute a more accurate quantification of pollutants exposition levels. The HMS application to Milan city centre also highlighted that background contribution can be prevailing even in highly emitting areas, confirming that the evaluation of air quality in urban areas, as well as the definition of proper strategies for air quality management, cannot be limited only to the urban local scale.

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AIR POLLUTION FORECASTS COMPARED WITH DAILY MEASUREMENT AT THE ISLAND OF LAMPEDUSA

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Summary
The impact of several pollution sources onto the environment was investigated through determining a list of air toxicants at Lampedusa island, located in the South of the Sicily channel. Two advanced sensors systems were developed, one to measure on site the suspended particulate matter (PM_{10}), and the second to detect several regulated pollutants (nitrogen dioxide, ozone, carbon monoxide, hydrogen sulphide and sulfur dioxide). The experimental measurements of suspended particulate matter, nitrogen oxide and carbon monoxide were used to calibrate and validate the proposed model.

Methodology and Results
The system for the particulate monitoring was based on a QCM (Quartz Crystal Microbalance) sensor having 10 MHz of fundamental resonating frequency and coated with a suitable high sticking trapping material. While the gas system used low cost, low power, small dimensions and high performances electrochemical sensors.
Two in-field campaigns were carried out in spring and summer 2015. The pollution sources monitored were the i) one diesel power plant, ii) vehicular traffic in Lampedusa city center, iii) airport and iv) two ports (commercial and touristic).
The pollution sources that resulted to have the greatest impact on air quality of Lampedusa island were touristic and commercial ports in August (e.g., NO_X, 28,7 ppb vs. 19,4 ppb at diesel power plant; SO_2 107,4 ppb vs 97 ppb in the airport area). In fact shipping emissions impact the levels and composition of all particulate and gaseous pollutants monitored. By contrast, vehicular traffic in Lampedusa city center resulted to have the greatest emission of the suspended particulate matter in August (eg. PM_{10}, 47 ug/m^3 vs. 14.5 ug/m^3 in the touristic port.). The diesel power plants emissions resulted to have the greatest impact on the air quality only for hydrogen suphide (80.40 ppb vs 50.5 ppb in the touristic port).
In this study a Gaussian air dispersion mathematical model has been used to simulate and forecast the air pollution episodes in Lampedusa island. The model contains the main sources on the island: diesel power plant, airport, port and vehicular traffic; the 'EMEP Guide' on air pollutants and all available information about sources (vehicular traffic, phase modulations of the diesel power plant, arrivals and departures timetable and engine property of airplane and main ships) has been used to assign emission rates to the sources. The meteorological conditions of measurement campaigns have been reproduced in the program (BREEZE - Trinity Consultants) and the results have been compared with the measured values in the same places. Once the model has reached a good agreement with the measures, various kind of different scenarios have been investigated, altering sources and meteorological conditions parameters.

Conclusions
Two prototypes sensors systems were developed to monitorate gas (nitrogen dioxide, ozone, carbon monoxide, hydrogen sulphide, sulfur dioxide) and particulate pollutants (and PM_{10}) in different pollution sources in Lampedusa island. A mathematical model was applied to simulate pollulant dispersion in different scenarios altering sources and meteorological conditions parameters.

Acknowledgement
This work was supported by the Italian Ministry of Education, University and Research

INFLUENCE OF ATMOSPHERIC STABILITY ON THE ESTIMATION OF TRACE METALS CONCENTRATIONS BY MEANS OF LINEAR STATISTICAL MODELS

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Summary
Atmospheric stability is a key attribute that influences the dispersion processes of pollutants in the atmosphere. The aim of this work is to determine the influence of atmospheric stability related input variables on the performance of linear statistical models - Multiple Linear Regression (MLR) and Partial Least Squares Regression (PLSR)- to estimate levels of lead (Pb), arsenic (As), cadmium (Cd) and nickel (Ni) in ambient air. Four variables have been proposed to evaluate the atmospheric stability: (i) quantitatively, mixing height and the Richardson number, and (ii) qualitatively, inversion and Pasquill-Gifford stability classes.

Introduction
Air quality statistical models establish an empirical relationship between observed values of certain atmospheric variables and pollutants immission concentrations and, therefore, are simpler than deterministic models, which require information regarding emissions sources and dispersion/transformation of pollutants. Statistical models are usually developed for major pollutants, but they are sometimes applied to minor pollutants, such as trace metals; thus, Arruti et al. (2011) successfully developed a MLR model to estimate levels of Pb, As, Cd and Ni in three urban areas of Cantabria (Spain), based on major atmospheric pollutants immission concentrations and basic meteorological data monitored by local air quality networks. In particular, the performance of MLR models in Santander site was poor. Taking into account the availability of atmospheric sounding data at Santander and the role that atmospheric stability plays in deterministic air quality models, this work aims at including atmospheric stability related input variables in statistical linear models to improve their performance.

Methodology and Results
Mixing height (*MH*) was determined based on the Holzworth method from vertical temperature profiles of atmospheric soundings. In addition, those cases where inversion (*I*) occurred (i.e. temperature increased with height) were also identified (1: no inversion, 2: moderate inversion; 3: complete inversion). The dimensionless Richardson number (*Ri*) was calculated for the air layer between the ground level and that corresponding to the mixing height. Subsequently, the corresponding Pasquill-Gifford atmospheric stability class (*PG*) was determined according to the equivalence between these classes and *Ri* values, as proposed by Woodward (1998), and coded as 1-6, where 1 is very unstable and 6, stable. Because two soundings a day (at 0h and 12h) were available in Santander, two values of the atmospheric stability related input variables were calculated: one in the morning and one in the evening.
The correlation matrix between the all the independent variables used (the former input variables - major pollutant concentrations and meteorological parameters - and the new variables related to atmospheric stability) and metal concentrations was calculated, so that the more significant inputs may be identified. For every pollutant in the period 2008-2009, at least one of the four considered new input variables was among those statistically significant (90% confidence level): *I* for Pb, *I* and *PG* for Ni, *Ri* for As and *MH* for Cd.
Results show that the consideration of these variables yield a better performance of MLR and PLSR estimation models for As and Cd as they produced an increased correlation coefficient (from 0.5 to 0.6 for As and from 0.3 to 0.4 for Cd) and a slight decrease in the uncertainty indices. Nevertheless, no significant improvements were found for Pb and Ni.

Conclusions
Atmospheric stability may be an important aspect to take into account for the development of linear statistical estimation models of air pollutants. In this work, MLR and PLSR models that include meteorological variables related to atmospheric stability as additional inputs exhibited better performances than those of previous models for the estimation of the As and Cd levels. However, it has been proven not to be an equally effective strategy for the estimation of Pb and Ni levels.

Acknowledgement
This work was supported by the Spanish Ministry of Economy and Competitiveness (MINECO) through the Projects CTM2010-16068 and CTM2013-43904R. The authors also acknowledge the Spanish State Meteorology Agency (AEMET) for providing atmospheric sounding data for the period of study.

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ERROR APPORTIONMENT FOR AIR QUALITY MODELLING: ADVANCEMENTS IN MODEL EVALUTION

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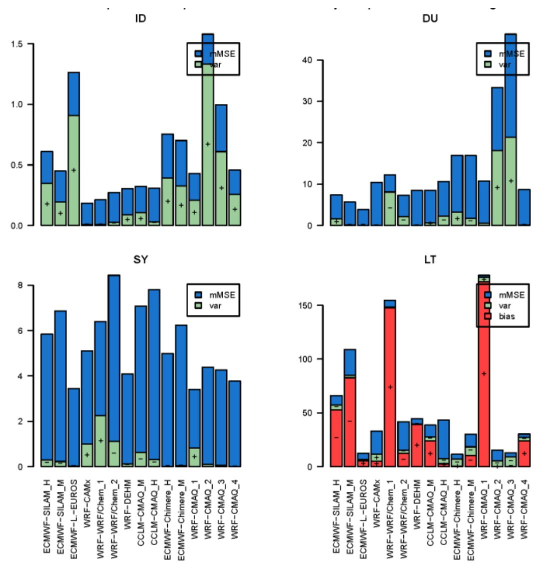
Summary
Scope of this investigation is to introduce methods for the diagnostic of the error originated in air quality (AQ) modelling systems, for the sake of model evaluation and development. In this study we investigate the nature of the error through the mean square error (MSE) of modelled time-series of ozone concentration. The MSE is decomposed into its components, the bias, the variance, and the covariance. Each of the error components is analysed in isolation as function of the time scale of the resolved processed (long scale LT, synoptic SY, diurnal DU, and intra-day ID) and of model complexity.

Introduction
The novel methodology proposed here (see Solazzo and Galmarini, 2015 for details) tackles the issue of diagnostic evaluation from the angle of model/data signals spectral decomposition and error decomposition. When the analytical decomposition of the error into bias, variance and covariance (and its re-organization into the so-called Theil's coefficients) is applied to the decomposition of the signals, into long-term, synoptic, inter diurnal and diurnal components revealing information can be gathered that allow to reduce the spectrum of possible sources of errors, and knowing the list of processes that are most active at a particular scale, pin point the latter that need attention and improvement. The procedure is denoted here as *error apportionment* as it provides an improved and more powerful capacity of identifying the nature of the error and associate it to specific part of the spectrum of the model/measurement signal. The AQMEII (Air Quality Model Evaluation International Initiative) set of models and measurements have been used to exercise the evaluation procedure.

Methodology and Results
The time-series of hourly ozone mixing ratios produced by over fisteen modelling systems over Europa and North America have been spectrally decomposed and the error (respect to surface observations) of each component broken-down to its parts: bias (accuracy), variance (precision) and covariance (associativity) (Figure 1). We conclude that:

- The bias component of the error is by far the most important source of error and is associated to LT processes and/or input fields (emissions or boundary conditions). From the model application viewpoint, any effort to improve the current capabilities of AQ modelling systems might have little practical impact if this primary issue is not tackled and solved;
- Most relevant to model development, the variance is prevalently associated to the DU component. At time scale of ~1-2 days the complexity of modelling systems increases exponentially and the variance error (the discrepancy between modelled and observed variance) drops dramatically, indicating that efforts of model developments and this time scale are paying off;
- There is little variation in the SY and LT signal and this is the reason why the error due to variance is little for these components and becomes predominant only when the bias is negligible or the total MSE is small;
- The ID component has little weight into the overall model performance balance and ID time-scale need not to be the priority for model improvements.

Fig.1. Apportionment of error by spectral components and by error break-down for fifteen modelling systems applied to European ozone for the year 2010



Conclusions
The new method outlined here is a breakthrough in the field of model evaluation as it allows to diagnose the quality of the error and its originating time-scale, thus returning important information to modellers, restricting the analysis to the processes in that specific time-scale. Analysis of the modelling results for the third phase of AQMEII will be built on the aforementioned considerations and will be devoted to the diagnosis of the error of the LT component with respect to external forcing (emissions and boundary conditions) and of the DU component with respect to the variance error. The collaboration with the modelling groups, the design of specific sensitivity studies and the use if the error apportionment and its sensitivity to model or input data modification, should provide, after the diagnosis more precise information on possible cures.

Acknowledgments
The community of modellers and data providers of the third phase of AQMEII are thankfully acknowledged.

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EVALUATION OF OZONE LEVELS FROM A GLOBAL MODEL IN EASTERN MEDITERRANEAN SEA - THE INFLUENCE OF ETESIAN WINDS

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Summary
The aim of this work is to study the impact of local northerly winds over Aegean Sea on surface ozone in Eastern Mediterranean Sea. For this reason, the performance of a global model from the atmospheric service MACC (Monitoring Atmospheric Composition and Climate) is examined. The predicted ozone concentrations are evaluated against surface measurements from three background stations, located in Malta, Greece (island of Crete) and Cyprus for a three year period (2010-2012).

Introduction
Summertime ozone concentrations in Eastern Mediterranean Sea, an area with high ozone levels, are affected by photochemistry due to increased solar radiation and meteorological factors (Kalabokas et al., 2008) such as the Etesian winds, northerly strong winds, which blow over the Aegean Sea during summer and early autumn. Another important factor contributing to high O_3 values is the stratosphere-troposphere transport (Zanis et al., 2014). This paper focuses on the comparison of the results of a global model with ozone observations over the Eastern Mediterranean Sea that is under the influence of Etesian winds.

Methodology and Results
The Etesian winds are characterized by a wind direction of Northwest to Northeast and a wind speed that takes values greater than or equal to 5 m/s (Poupkou et al., 2011). Based on the ERA-Interim wind data from the European Centre for Medium-Range Weather Forecasts (ECMWF), two groups of days are identified in Central Aegean Sea i.e., the Etesian and non-Etesian days. The global MACC Reanalysis data are based on the ECMWF Integrated Forecast System (IFS). The evaluation has been done separately for the Etesian and the non-Etesian days for both models. High ozone values are found in Eastern Mediterranean Sea. These values become more pronounced during Etesian days. Finokalia (Crete) station presents the highest influence of Etesian winds. The global model underpredicts O_3 concentrations for Ag. Marina (Cyprus) and Finokalia stations (Fig. 1). These results are in agreement with the findings of Katragkou et al. (2015) that reported a similar underprediction on average for the summer period. A relatively good agreement with observations is found at Gharb (Malta) station (Fig. 1). Correlation coefficients are higher for the non-Etesian days compared to the Etesian days.

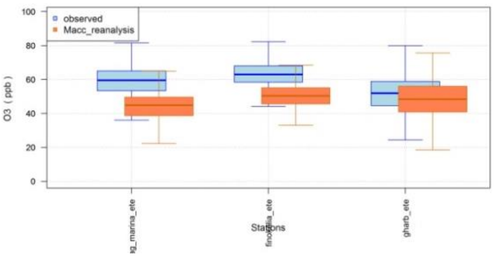

Fig. 1 Box and Whisker Plot of observed and global modeled hourly mean O_3 concentrations for the

Conclusions
The results suggest that there is a strong variation of ozone concentrations in Eastern Mediterranean during Etesian days. Performance metrics show that the global model better captures O_3 levels during non-Etesian days. The best agreement between model results and observations is obtained for Malta station.

Acknowledgement
This study is supported by the State Scholarships Foundation of Greece in the context of the "IKY Fellowships of Excellence for Postgraduate studies in Greece – Siemens Program".
We would like to acknowledge the EU Horizon2020 project MACC III (Monitoring Atmospheric Composition and Climate - Interim Implementation).

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MODELLING EXERCISES IN COST ACTION ES1006: LOCAL-SCALE MODELS FOR ACCIDENTAL RELEASES IN BUILT ENVIRONMENTS

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Summary

Evaluating available local-scale models in built environments by model inter-comparison, as well as by comparison against test data from qualified field and laboratory experiments was a main research task of COST Action ES1006. Assuming that a typical emergency response model has already been validated with regard to local-scale dispersion modelling, the existing model evaluation and validation strategies were extended towards task- and application-specific measures for accidental release scenarios, such as extreme value prediction and exposure assessment. Both continuous and puff releases were taken into account during the exercise. The model evaluation, here described, focuses on the output obtained by the different model categories considered during the action.

Introduction

Three case studies were carried out as modelling exercises: (a) the Michelstadt case (see Fig. 1 for an example of concentration output), based on flow and dispersion data gathered in a wind-tunnel experiment where an idealized urban environment was modelled and both continuous and puff releases were reproduced; (b) a real-field campaign with continuous and puff releases in a European harbour, named as CUTE 1 case, which was also reproduced in the wind tunnel, named as CUTE 3, and (c) a real industrial accident occurred in a European Country, named as AGREE case. In all cases, 'blind tests' were conducted, that is only the minimum flow information and no information about measured concentrations was provided to the modellers.

Methodology

The design of the experiment takes into account that hazardous releases may occur in very different locations in an urban or industrialized area: in open squares, small or wide streets, perpendicular or parallel to the prevailing large-scale flow or even in court yards. Given the varying airborne hazards flow and dispersion modelling approaches which were used, models can be grouped to the following three types according to their flow and dispersion approach characteristics: models that do not resolve the flow between buildings; models that resolve the flow diagnostically or empirically, although not resolving the flow between buildings; models that resolve the flow between buildings. The applied models ranged from Gaussian type, to Lagrangian and advanced Eulerian CFD. It was observed that, in case of continuous releases, maximum concentrations, dosages and the area affected by values above a relevant threshold are usually the information expected from an emergency response model. In case of puff releases, also the arrival time of the puff at given locations, the duration of the puff passage and the peak concentration values are of interest.

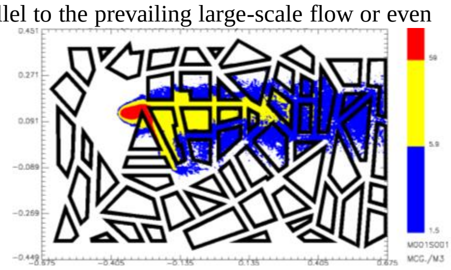

Fig.1 Example of concentration map in the Michelstadt exercise for source S2

Results and conclusions

In general, both from the Michelstadt and CUTE wind-tunnel experiments it can be concluded that the model performance increases with increasing model complexity, as expected. Model performances are often influenced significantly by the location of sources and receptor points. In a relative open space, the dispersion near the source can be well captured by all models. When the release is located inside a complex building structure, an appropriate and accurate description of the geometry in the model becomes fundamental for reproducing, for example, plume splitting and the resulting concentration pattern. Puff releases are found to be far more complex than for continuous releases. In this case, specific test parameters have been introduced to be considered as well. Also in such scenario more advanced models are clearly preferable.

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GRAMM/GRAL: A COUPLED MODEL SYSTEM TO SIMULATE AIR POLLUTION AT THE CITY SCALE

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Summary
We simulate air pollution at a very high resolution at the urban scale for two Swiss cities, Lausanne and Zurich. Combining a very detailed emission inventory with high-resolution dispersion simulations, we compute air quality maps at an hourly resolution. Contributions from different source categories such as traffic or heating are calculated separately to allow source apportionment in each grid cell.

Introduction
Air pollution is one of the major issues that have to be dealt with in urban areas. Air pollutant concentrations vary strongly within the city depending on the proximity to emission sources, meteorology, local dispersion, as well as on the background air pollution. To accurately assess air pollution exposure of citizens it is necessary to provide maps of air quality in different parts of the city at a very high horizontal resolution. Such maps can be used by policy makers for designing effective mitigation measures or by sensitive persons to reduce their personal exposure. To date, models capable of simulating the dispersion of air pollutants are usually one of two types: (1) Coarse mesoscale meteorological models where the concentrations are averaged over the city. (2) Highly resolved CFD models that are too costly to be run on a regular basis for long time-periods.
Within the Nano-Tera project OpenSense2 we aim to assess the impact of air pollution on the health of citizens living and working in urban areas by combining dense sensor networks with high-resolution models. Using the model system GRAMM/GRAL, we are bridging the gap between the two types of models by combining the strengths of each of them. The final model product is a catalogue of air pollution maps for the two Swiss cities that can be used to provide hourly information on air quality at a resolution of 5 m. These will be used for health studies by our partners in the OpenSense2 project.

Methodology and Results
We are using the mesoscale model GRAMM (Graz meteorological model; Almbauer et al., 2009) to simulate wind fields for the greater regions around the two cities. These wind fields are then modified by the CFD model GRAL (Graz Lagrangian model; Oettl and Uhrner, 2010) to represent the flow at the building-resolving scale. The same model GRAL is used to simulate the dispersion of primary emitted pollutants such as NO_x or PM. As the temporal and spatial variability of emissions has a profound impact on the variability of the air quality in urban areas, a detailed emission inventory is as important as the dispersion model. A newly developed inventory for the city of Zurich specifies the yearly amount of emitted air pollutants for 60 different source categories (e.g. traffic, heating, industry) which are described as point, line and area sources. The temporal variability of the emissions (e.g. traffic hours, heating days) is accounted for using specified time functions. The map in Fig. 1 is the output of a high-resolution dispersion simulation using the detailed information from the inventory. By computing separate maps for different source categories, we can assess the sensitivity of the air quality to different emission sources at specific locations.

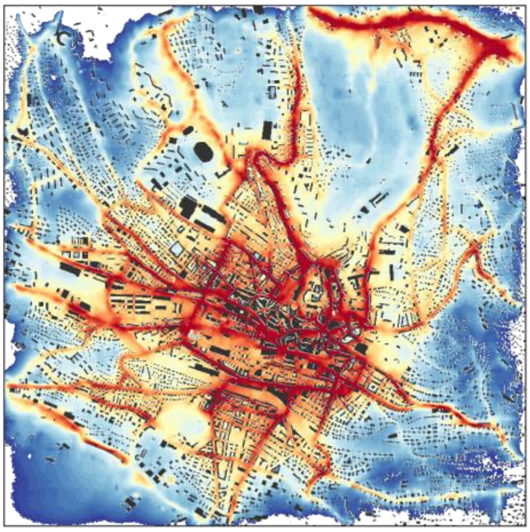

Fig.1 NO_x concentration map for Lausanne (example)

Conclusions
Based on our extensive catalogue of fine-scale distribution maps for the two Swiss cities, we produce time series and spatial plots of the air quality at an hourly resolution. We can identify the source groups that are mainly contributing to the concentrations of air pollutants at a specific time and location. Using this tool, it is possible to assess the individual exposure of people moving in the area or to give advice to policy makers regarding control measures or urban planning.

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ENVIRONMENTAL AND HEALTH IMPACT RESULTING FROM AIR POLLUTION

DISTRIBUTION OF PARTICULATE MASS CONCENTRATIONS IN A COMPLEX TRAFFIC HOT SPOT

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Summary

Two field campaigns were performed in 2015 during winter and summer in a complex traffic hotspot in Madrid. Apart from gaseous species, the ambient particulate mass concentration levels (PM10, PM2.5 and PM1) were measured at different atmospheric conditions. Several Optical Particle Counter instruments were deployed in the study area, two of them installed at two points in the North –South axis. A DustTrak DRX measured the particle levels around the experimental area following a dynamic measurement pattern. These instruments were previously intercompared against the reference gravimetric method and against a TEOM instrument. Particle measurements were complemented with meteorological and microturbulence parameters (friction velocity, sensible heat flux and turbulent kinetic energy) from two stations located in the study area (0.42 km^2). The pedestrian flows were also characterized to obtain their exposure to ambient particles.

Introduction

The TECNAIRE project (Técnicas innovadoras para la evaluación y mejora de la calidad del aire urbano) aims to diagnose the problems of air quality in urban environments by developing new measuring and modelling techniques able to evaluate strategies for their resolution. Within this framework, two campaigns were designed and performed during the winter period 13 February-2 March and the summer period 25 June-20 July 2015 in a complex traffic hot spot (Plaza de Fernández Ladreda) in Madrid. This spot frequently experiences the highest pollution levels for particles and gases of the city caused by traffic influence. It is a site of enormous complexity in terms of sources, urban geometry and intense pedestrian activities.

Methodology and Results

Several Optical Particle Counters (Grimm and Eatough, 2009) were deployed in the study area. A Grimm 1107 instrument was installed at 2.5 m high stand in the South of the square, next to a transport station, and a Grimm 365 at the roof of a 5 m high building in the North side. Meteorological stations were installed at both locations, one of them providing microturbulence parameters (measured by sonic anemometers). A TSI DustTrak DRX instrument (Tasić et al., 2012) measured the particulate mass levels at 14 points around the experimental area in a dynamic pattern by moving the instrument around the square and measuring at a mean adult height respiration level. Additional measurements in specific spots such as bus stops and traffic lights were made. Local features variations (e.g. traffic lights changes) were recorded at these locations to analyse their influence on the observed concentration values. Additionally, the traffic and pedestrian flows were also measured.

During the winter monitoring campaign, local meteorological conditions varied giving well defined periods of strong to moderate winds, in occasions accompanied by showers, alternating with wind calm periods which favoured pollutant stagnant and accumulation. The most important episode lasted from 19^{th} to 21^{st} February and the highest concentrations of pollutants were recorded at the air quality monitoring station. During this episode a daily cycle with two peaks linked to traffic rush hours could be detected for the main pollutants. The nocturnal values remained high due to the atmospheric stability associated with temperature inversion conditions. Turbulent kinetic energy was less than 1 m^2s^{-2} during 19 and 20 February, with nocturnal values below 0.1 pointing out the low turbulence associates to these days, even during the diurnal time. PM10 hourly concentrations higher than 50 μgm^{-3} were reached in occasions, as it was measured by the Grimm 365. Measurements during the fast rounds confirmed that the maximum concentration values correspond to crosswalks, especially during the car accumulation. This situation was studied in further detail in a bus stop where the highest concentrations were measured when diesel buses were waiting during the red lights.

Conclusions

Local emissions had a great influence in the concentration field, which, even under higher wind speeds and turbulence, did not follow a clear pattern dominated by the atmospheric dynamics. Most of the particulate matter mass was in the smaller fraction, PM1, pointing to traffic as the main source in this hot spot. Nevertheless, the high complexity of this urban scenario requires further studies to categorize the different impacts of local sources and activities under a wider range of conditions.

Acknowledgement

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CHILDREN EXPOSURE TO AIR POLLUTANTS IN INDOOR OF PRIMARY SCHOOLS

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Summary
This work intends to contribute to the understanding of the impact on children's health of the exposure to indoor air in primary schools in the municipality of Coimbra. This study evaluated the concentration of carbon monoxide (CO), carbon dioxide (CO_2), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), volatile organic compounds (VOCs), formaldehyde (CH_2O) and particulate matter ($PM_{2,5}$ and PM_{10}), temperature (T°) and relative humidity (Hr) in order to characterize the IAQ of classrooms in primary schools of the Municipality of Coimbra and the ambient air quality, to estimate the current health situation of students and to propose mitigation measures.

Introduction
The modern and growing pattern of consumption has environmental consequences which will inevitably reflect on human health. Daily, air quality affects our well-being and may affect our future, which is why the indoor air quality (IAQ) has been identified as a major environmental risk to public health. In Europe, air pollution is regarded as a pressing environmental issue because it has a major impact on the health of citizens. Among these, children are considered to be a particularly vulnerable group. The level of indoor air pollution can reach values 2 to 5 times higher than outdoor air. The levels of contamination of indoor air become even more important when one considers that in modern society people spend about 80-90% of their time inside buildings. Despite the existence of some epidemiological studies concerning IAQ in schools, little is known about the IAQ in Portuguese schools. The perception of IAQ problems is relevant to assess the risks to the health and performance of students and to propose measures to reduce exposure to unwanted pollutants.

Methodology and Results
We classified the study as a level II, of observational type and of cross-sectional nature. The sample was non probabilistic as to the type and of convenience in what concerns the technique. To carry out this study, we assessed the air quality in 51 schools belonging to parishes moderately and predominantly urban and predominantly rural parishes, and we also assessed the respiratory capacity of children in the 1st and 4th year of these schools in autumn/winter and spring/summer. Parents/guardians were also asked about the signs, symptoms and pathologies of their children. The sample consisted of 82 classrooms and 1019 students, with an average age of 7 (standard deviation=1.54). The data collected were then processed using the SPSS version 19.0 statistical software. The interpretation of statistical tests was based on a significance level of p=0.05, with a confidence interval of 95%. We found that the average concentrations of pollutants in indoor air were higher than the average concentrations recorded outside, which demonstrates the important contribution of indoor sources in schools. Levels of CO_2, VOCs, PM_{10}, $PM_{2,5}$, CH_2O, Hr and Tº in several classrooms exceeded the maximum acceptable levels for the health and comfort of occupants stated in the Portuguese legislation. These results have shown that poor ventilation conditions were responsible for the accumulation of indoor air pollutants in various classrooms. However, also the occupation and school activities were identified as determinants of IAQ. We also acknowledged that, from the parameters that revealed concerning results and above the legislated value, CO_2, VOCs and CH_2O showed the highest average concentrations outside predominantly in urban areas, whereas PM_{10}, $PM_{2,5}$ showed higher concentrations predominantly in rural areas. We found that in classrooms with wooden flooring the average PM_{10} concentrations were higher than in classrooms with a different type of flooring, which shows that the characteristics of the type of coating material of the floor are related to a greater difficulty to clean, thereby causing an accumulation of dust between the material.

Conclusions
We found associations between some analyzed environmental parameters and signs, symptoms and diseases, as well as changes in respiratory function in students. The results of the study reinforce the benefit of the study of the binomial environment/health, namely in the area concerning the relationship between indoor air pollutants and the impact on children's health. Effectively an increased risk occurrence of environmental problems can lead to an increased incidence of several diseases. These results show the opportunity to take corrective measures, including reducing the emission sources and promoting greater ventilation. It is crucial: the development of an investigation which is applied and integrated into the causes, mechanisms and effects in all aspects of the binomial environment/health; the dissemination of results and conclusions obtained in order to promote information, awareness, training and education; the establishing of guidelines for the prevention, control and reduction of inherent risks.

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POLLUTANT DATA MAPPING AT MUNICIPALITY LEVEL FOR EXPOSURE ASSESSMENT ON EUROPEAN COUNTRIES

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Summary
This study aims to provide annual air pollution maps at municipality scale for exposure assessment on national basis. Maps have been produced for each country involved in the European Union LIFE+ project MEDiterranean Health Interview Survey Study (MED HISS) and for the main atmospheric pollutants (PM_{10}, PM_{25} and NO_2), combining two sources of information: observed data and concentration fields from Chemical Transport Models (CTMs). In order to improve not already assimilated CTMs output, we have post-processed them through Kriging with External Drift (KED). Then we have up-scaled pollutant concentration data in order to obtain exposure assessment at municipality level, particularly useful for epidemiological studies on air pollution health effects.

Introduction
Within the MED HISS project, in order to evaluate health effects of long-term exposure to air pollution for the entire population of countries involved in the project, it was necessary to provide an annual pollutant value at municipality level. Available air quality data were observations from monitoring stations and CTMs concentrations fields. CTMs data were output of the subsequent modeling systems running at national scale: for Italy, the National Integrated Modeling system for International Negotiation on atmospheric pollution (MINNI[1]), for Spain, the CALIdad del aire Operacional Para España (CALIOPE[2]), and for Slovenia the Comprehensive Air Quality Model with Extensions (CAMx)[3]. All the CTMs data are available at a spatial resolutions representative of urban background pollution levels.

Methodology and Results
In order to reduce model uncertainty CALIOPE includes assimilation of observed data. Thus, to conform Italian results to Spanish ones and to provide a more realistic representation of pollutant spatial distribution, a KED procedure has been used to account for the observed data into MINNI concentration fields. Specifically, the kriging is applied on the observed data and the external drift is constituted by the MINNI model output for years 2003, 2005, 2007 and 2010. Observations were interpreted as realizations of a Gaussian spatial process following this structure: $Y(s) = \mu(s) + w(s) + \varepsilon(s)$, where in the trend component we introduce the MINNI model output, $w(s)$ is a stationary Gaussian random process and $\varepsilon(s)$ is the error term. Only background stations have been used in the KED procedure. We have carried out a leave-one-out cross-validation analysis in order to evaluate KED performance: a comparison between observations and KED output at monitoring station locations showed a good agreement, also where the spatial coverage of monitoring stations was low (as example, see the Taylor diagram in Fig. 1). Following this data fusion approach, the exposure assessment was carried out for all the MED HISS countries by up-scaling the gridded data at the municipality level[4]. Using a weighted block averaging procedure accounting for built-up surface percentages, annual exposure maps at municipality level for the three countries were obtained. Looking at resulting maps, concentrations levels and main spatial patterns are well preserved.

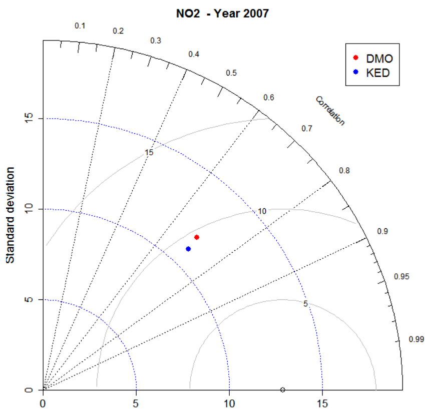

Fig.1 NO_2 Taylor diagram for year 2007 where DMO (direct model output) is MINNI output, KED is the assimilated output

Conclusions
The adopted data fusion tecnique produced satisfactory results. Also the up-scaling provided consistent exposure estimates at municipality level that account for the areas where people really live.

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ASSESSMENT BY MODELING OF THE ATMOSPHERIC DISPERSION THE EMISSIONS OF A THERMAL POWER STATION IN DOUALA (CAMEROON)

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Summary
Air quality in the vicinity of the thermal power station of Logbaba in the town of Douala was investigated in this study using data collected in a 5 year period (2008-2012).The distribution of molecules such as SO2, NOx, CO and the particle matter PM2.5 was analyzedusing numerical modeling, basedon physical andthermal characteristics,as well as the operating periods of the power station. TheAERMOD was used for simulation, and wind rose and other NOAA in-situ data were used for validation of the model. The pollutants distribution was evaluated at two locations: at the exit of the power station,considered as reference point, and 330m away from the exit where the first houses exist. The results show that, at the exit of the power station, the relative concentration for each contaminant is: 7.2% for the PM2.5 during 24 hours of emission, 45.96% for CO over 8 hours of emission, and 17.5% for SO2 over one hour. The NOx is the highest pollutant with an emission of 259.1% over an hour from emission and 51% over one year. After 330 m of the power station, only the NOx keeps a polluting character with a relative rate of 100%. These results show that the pollution level of the power station is beyond the threshold for air quality set by the World Health Organization (donner un chiffre si possible).Moreover, among all pollutants investigated, NOx appears to be the most critical for the populations in the vicinity of the Logbaba thermal power station. Therefore, this information is important for policyand decision markers in preventing the vulnerability of the population to air pollutants from industrial settings.

THE METHODOLOGY OF DETAILED LINKING BETWEEN THE AIR POLLUTION MODELLING OVER A COMPLEX TERRAIN AND RESPIRATORY DISEASES IN CHILDREN – THE ZASAVJE REGION, SLOVENIA, CASE

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Summary
One of the important objectives of air pollution dispersion modelling is to support the public health interventions. Effective measures cannot be implemented without proper understanding of the association between **air pollution and health phenomena**. To establish the relationship correctly, numerous methodological problems must be solved. Among them possible deviations related to the modelling, as well as to the health data collection. The key steps of the detailed **methodology** of linking the air pollution modelling over a complex terrain in the Zasavje Region, Slovenia, and respiratory diseases in children, will be presented.

Introduction
One of the most polluted areas in Slovenia is the Zasavje region, located in the central part of the country. It is characterized by three narrow valleys with more or less steep surrounding hills, where three urban and numerous rural settlements are located. Consequently, there are specific meteorological conditions. In the region various different kinds of heavy industry is placed. The complex terrain of the region complicates the assessment of the relationship between air pollution and health phenomena. Methods for linkage health and environmental data at the population level were recommended by the World Health Organization (Briggs et al., 1996; Corvalan et al., 1997).

Methodology and Results
To establish the relationship properly, firstly, the annual air pollution for the main pollutants in the best possible temporal and geographical resolution (good enough to enable to separately examine the areas, where due to the complex terrain varied pollution was expected and was confirmed by the measurements) had to be modelled, taking into consideration also structure of the settlements. In the next step the basic spatial units had to be combined in observed **small geographical units** proper for the analysis. Afterwards, the modelled data aggregated on the level of observed **small geographical units** had to be linked to the georefferentiated health data, also aggregated on the level of observed **small geographical units**. In both, environmental and health data, critical deficiencies had to be evaluated in order to minimize the possibility of wrong conclusions. The results of our spatial analysis in Zasavje region of the association between respiratory diseases in children and modelling air pollution showed a statistically significant positive relationship in the effect of the **average annual SO_2** concentration. The association with this pollutant in the athmosphere has been expected, because the input data in the modelling system were relatively complete only for SO_2. The moste important results of our study can be seen in the presented methodology of linkage health and environmental data on a **complex terrain**. **Small geographical units** on the complex terrain in fine resolution with urban and rural cases has been defined. Additionally, the **metodology** for spatial analysis on **complex terrains in fine resolution** was improved and in **the case of SO_2 it was comfirmed**.

Conclusions
We can conclude that the present study is in several ways important for the environmental health. An important benefit can be seen in the presented **methodology** of establishing small spatial units with models of the air pollution dispersion for linking to health data on a **complex terrain** in **fine resolution**. The presented methodology could be useful in creation and management of health policy related to environmental health. In the future is necessary to improving the data quality, firstly to change the system of collecting and reporting health and environmental data.

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HAVOC OF OUTDOOR AIR CONTAMINANTS - A CASE STUDY FROM INDIA

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Summary

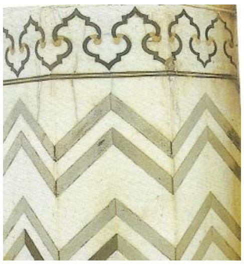
Due to excessive industrialization and unwarranted automobile growth the air resource has come under the catastrophic range of pollution specially due the oxides of sulphur (SO_2) and nitrogen (NO_2) concentrations in the air, the effects of which is devastating. One of the finest mausoleum, the Taj Mahal in Agra is surrounded by the number of smelters, foundries and thermal power plants. Furthermore, the Mathura Oil Refinery established in its vicinity in 1972, is merely 40 Km away. All these industries together with burning of fossil fuels by the vehicular circulation is emitting 25-30 tons of SO_2 and NO_2 gases. These pollutants are transported in the atmosphere over distances of hundreds of kilometres and eventually combine with water vapour to form sulphuric acid (H_2SO_4) and nitric acid (HNO_3) which washed down during rains to reach to the earth surface as acid rain having a pH value of 4.0 or less which is effecting the monuments as well as the human health of local people.

Introduction

Air pollution in India is a serious issue with the major sources being industries, fuel-wood and biomass burning, fuel adulteration, vehicle emission and traffic congestion. India has a low per capita emissions of greenhouse and other gasses but the country as a whole is the third largest after China and the United States. The Air (Prevention and Control of Pollution) Act was passed in 1981 to regulate air pollution and there have been some measurable improvements. However, the 2012 Environmental Performance Index ranked India as having the poorest relative air quality out of 132 countries.

Methodology and Results

The monitoring of sulphur dioxide (SO_2) and oxides of nitrogen as NO_2 is carried out for 24 hours (4-hourly sampling) in Agra with a frequency of twice a week, to have one hundred and four (104) observations in a year. Last year, the 24 hours average concentration of the sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) levels was recorded at 269µg/m^3 and 217µg/m^3 respectively as against WHO Guidelines for Ambient Air Concentrations of maximum 150µg/m^3. These elevated concentration of air contaminants are causing neurological, digestive disorders, eyes, throat and respiratory tract problems in local human populations. Studies indicate that long-term exposure to NO_2 levels currently observed in and around Agra has decreased lung function and increase the risk of respiratory symptoms such as acute bronchitis and cough and phlegm, particularly in children (a large number of children work in foundries). The adverse effect is not limited to human beings but it is also effecting the monuments. The Taj Mahal which was constructed entirely in white marble in 1632, has four minaret besides the main mausoleum. The above left picture show that the pilasters of the Taj Mahal were once inlaid with white marble but now gone pale due to air pollutants as seen in the above right picture (air pollution industry in the background).



The SO_2 precipitation, together with humidity and low wind speeds has caused disfiguration of marble. The sulphuric acid reacts with the $CaCO_3$ in the marble to form $CaSO_4$ – which causes pitting in the mausoleum. Discoloration of the white marble has turned the Taj Mahal surface pale yellow, chipping and breaking of the edges of the marble slabs and formation of cracks in marble are clear indication of deterioration of the monument.

Conclusions

In order to mitigate the environmental air pollution problems, the Government of India introduced the Air (Pollution Prevention and Control of Pollution) Act, 1981 with an objective to provide prevention, control and abatement of air pollution. The government has set up the Taj Trapezium Zone (TTZ), around the monument where strict emissions standards are in place and closed down two thermal power stations at Agra, The government is also encouraging the electric or human driven transport from the city to reach the monument instead of using the petrol/diesel vehicles. This would not only save the Taj Mahal from further damage but would also help in restoring human health of local people and plants.

Acknowledgement

This work was supported by the Carman School and the Central Pollution Control Board helped in sampling and analysis.

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SEASONAL DISTRIBUTION OF VIABLE BACTERIAL AEROSOL IN BENGALURU URBAN, KARNATAKA, INDIA

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Summary

Microbial air pollution causes major allergic respiratory disorders, in particular asthma, infections are increasing which is a global phenomenon. Bacterial aerosol sampling was carried out during the year of 2010 to 2013. The microbial air quality data of Bangalore urban recorded highest during the year 2011 and the minimum annual number was recorded during the year 2010. Bacterial aerosol for the year of 2010, 2011,2012 and 2013 crossed the tolerance limit prescribed by Institut de recherché Robert-Sauvé en santé et en sécurité du travail, Occupational Health and Safety Research Institute Robert-Sauvé (IRSST, 2007). Bacterial aerosol was dominated during Pre-monsoon season. Majority of bacterial aerosols recorded were genera of *Aerococcus* , *Staphylococcus* , *Streptococcus*, *Corynobacterium*, *Bacillus*, *Enterococcus* , *Pseudomonas*, *Neisseria*, *Actinomyces*, *Mycobacterium* and *E.coli*. In Winter *Bacillus sp*., and *Staphylococcus sp*., dominated during winter season.

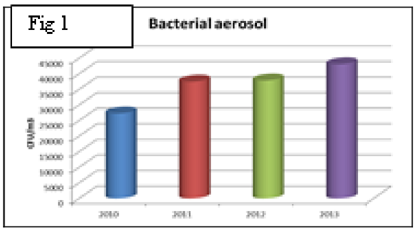
Atmospheric pollutants supported the bacterial aerosols as a platform, as nutrient for survival and transport. Bacterial aerosols correlated with air pollutants like particulate matter and SOx. Bacterial aerosol had significant correlation with ($r= 0.3266$) with respirable suspended particulate matter size ≤10µm and less correlation with SOx ($r= 0.1266$). Aerosols of fine particle size 0.4µm to 0.14µm correlated($r=0.441$) with bacterial aerosol which indicates that bacterial aerosol prefers the fine particle as a platform. Polluted water bodies, municipal solid waste dumping sites, open sewage drains and unscientific disposal of garbage are major sources of bioaerosols perhaps harmful for the residents of Bengaluru Urban.

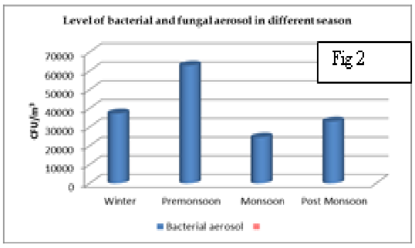
Introduction

Developing countries like India, the affluent urban population following Western lifestyle appears to be more prone to allergic risk, resulting in increased incidence of allergic manifestations like asthma and adverse manifestation (Sneller 1984 and Jindal 2010) . In a study conducted as a part of the European Community Respiratory Survey, the prevalence of asthma in adults aged 20 to 44 years in Mumbai was reported to be 3.5% using clinician diagnosis and 17% by a physician diagnosis and broncho-provocation test. A recent study5 in school children from Delhi reported asthma prevalence of 10–13% (Agarwal et al., 2010 and Ritesh 2011). Prevalence of asthma and bacterial pneumonia in Bangalore, hospital based study on 20,000 children under the age of 18 years in 2 decades from 1979,1984,1989,1992 and 1999 in the metropolitan city showed 9%, 10.5%, 18.5%, 24.5% and 29.5% respectively (Paramesh, 2000). The present bacterial aerosol study was carried to fulfil the scientific reason behind the steady rise of airborne bacterial adverse effect on human.

Methodology and Results

The Aerobiological study was carried out at Municipal solid waste dump sites, Polluted water bodies. Krishnarajendra market (K.R.Market), LalBagh botanical garden and the Department of Environmental Science, Bangalore University, Jnanabharathi campus. Air samples were collected using single stage impactor operating at about 100 L/minute for 1 min, with a frequency of about twice in a week during day light hours for all season, usually between 06.00 and 18.00 hrs at about 1.5 m above the surface, to simulate the human breathing zone. Nutrient agar media was used for cultivation of a wide variety of bacterial aerosol. Selective isolation media for isolation of organisms belongs to the genus *Aerococcus, staphylococcus, streptococcus, Corynobacterium, Bacillus, Enterococcus, Pseudomonas, Neisseria, Actinomyces, Mycobacterium and E.coli* species were prepared according to directions as per the manufacturer manual of HiMedia laboratory, Mumbai, India. The average bacterial aerosol recorded during the year 2010 as 27,209 CFU/m^3, for the year 2011 as 37, 435 CFU/m^3, for the year 2012 as 37, 795 CFU/m^3 and for the year 2013 was recorded as 43, 009 CFU/m^3 (Fig.1). Premonson and winter recorded maximum bacterial aerosol perhaps the risk of bacteria related adverse effect on humans during these seasons (Fig 2).





Conclusions

The bioaerosol number revealed that 2013 recorded the highest bacterial aerosol pollution and minimum during the year 2010. The air quality during the year of 2012 and 2013 are moderately polluted by bacterial aerosol. The seasonal bioaerosol records proved that maximum bacterial pollution occurred during premonsoon (summer) season. Bacterial aerosol namely *Streptococcus sp., Bacillus sp., Staphylococcus sp., and Escherichia coli* were dominated during premonsoon. Minimum bioaerosol pollution was recorded in monsoon season. It was discovered that polluted water bodies, municipal solid waste dumping sites, open sewage drains and unscientific disposal of garbage in Krishnarajendra market are significant sources of bioaerosol in Bengaluru urban.

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AIR POLLUTION, HEALTH AND SOCIAL DEPRIVATION ASSESSMENT IN MUMBAI

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Summary
The prime objective of this study is to investigate the relationship between the long and short term air pollution exposures and measures of health and the effect of social deprivation on this relationship in the city of Mumbai. Our preliminary results show a high coefficient of correlation i.e. 0.75 and 0.82 in the relationship between NOx concentration and socioeconomic status in terms of HDI for the years 2013 and 2014 respectively.

Introduction
Several studies have indicated that more deprived population tend to live in the areas with higher levels of environmental pollution, yet, time trends and geographical pattern of disproportionate distribution of environmental burden remains poorly assessed particularly in a country like India. The prime objective of this study is to investigate the relationship between the long and short term air pollution exposures and measures of health and the effect of social deprivation on this relationship in the city of Mumbai.

Methodology and Results
Air quality data was taken from three regulatory agencies for the period January 2013 to December 2014. Respiratory illness was chosen as the health end point and the monthly data of number of cases of upper respiratory tract infection (URTI) were obtained from an NGO working in Mumbai. Socioeconomic status of people living in various wards of Mumbai was considered in terms of Human Development Index (HDI) score as well as other parameters such as literacy attainment and percent slum population in each ward. Data processing and analysis was conducted using statistical software, R. First, univariate analysis was conducted to see the relationships between NOx concentrations, URTI cases and HDI. With the use of GIS mapping, layers of information on pollutant concentration, HDI, URTI cases were overlaid and spatially analysed to develop composite effect. Multi variate linear regression model has been to assess the relationship between air pollution and health effects with the variable for socio economic status kept as a modifier. Our preliminary results show a high coefficient of correlation i.e. 0.75 and 0.82 in the relationship between NOx concentration and socioeconomic status in terms of HDI for the years 2013 and 2014 respectively. This shows that wards with lower HDI experience higher NOx concentrations.

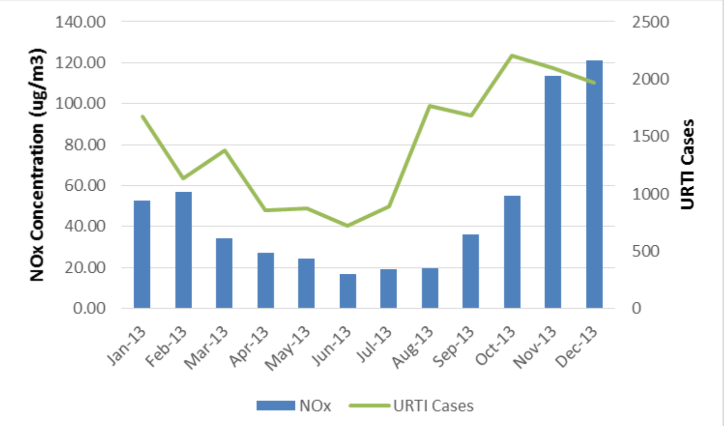

Fig.1 Relationship between NOx and URTI cases

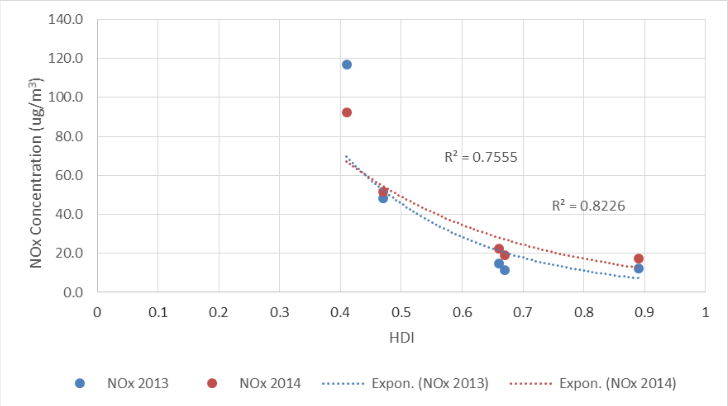

Fig.2 Relationship between NOx and HDI

Conclusions
Our study indicated that in Mumbai there is a high correlation between socioeconomic status, health and air quality levels. The study has found that population groups with lower socioeconomic status have exposure to higher level of pollution and their also suffer from poor health.

Acknowledgement
This work was supported by British Council UK India Education and Research Initiative (UKIERI).

SPATIAL DISTRIBUTION OF NON-REGULATED BIOGENIC AIR POLLUTANTS (ALLERGENIC POLLEN) ACROSS BERLIN, GERMANY

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Summary

To gain information about distribution of allergenic pollen in towns a network of pollen traps was established at 14 localities across Berlin, Germany. The measurements of airborne pollen (birch, grasses, mugwort) were running from March until October 2014 using gravimetric traps of Durham type. The results show remarkable spatial variations of pollen sedimentation across the town. In case of birch and grasses were the highest pollen sedimentations mostly observed closer to the outside of the town. Substantial proportions of mugwort pollen in traps were influenced by nearby vegetation with mugwort plants. The difference between the traps with the highest and the lowest amount of pollen was for birch 245%, for grasses 306% and for mugwort 1.962%. These differences can probably lead to different health impacts on allergy sufferers in one city. Therefore, pollen situation in big cities should be monitored as part of the natural air quality in different places.

Introduction

Between 10% to 30% of adults and 40% of children worldwide suffer from allergic rhinitis and/or asthma; one of the most common causes is pollen (Pawankar et al., 2013). Half of the world´s population lives in towns where pollen allergies can be aggravated because of mostly higher living standards, air pollution or inappropriate management of urban vegetation. Few studies investigated spatial variation of pollen in cities. To gain insight into the distribution of pollen across towns it is necessary to observe airborne pollen by more pollen traps per town.

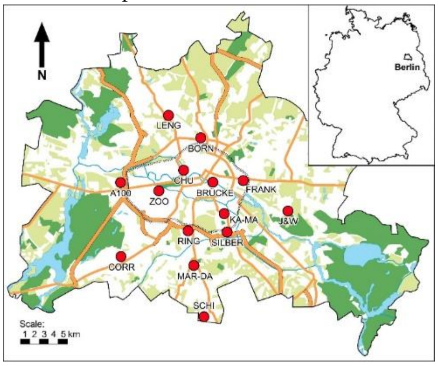

Fig.1 Map of Berlin with locations of gravimetric pollen traps. White color: built-up areas; light green: meadows and fields; dark green: forests; blue: water bodies.

Methodology and Results

Berlin (3.4 million inhabitants, size 892 km²) lies in the northeastern German lowlands and has a maritime temperate climate (Cfb). 14 gravimetric pollen traps – similar to Durham trap (Durham, 1946) – were placed across the town (see Fig. 1) on exposed rooftops of small houses or containers in heights between 2 and 2.5 m above ground level. Pollen sedimentations were measured weekly from 11th of March till 28th of October 2014 (33 weeks). Betula (birch): The highest amounts of birch pollen were observed in traps situated closer to outside of Berlin, the smallest amounts were found near the inner city (see Fig. 2). The difference of birch pollen counts between the traps with the highest and lowest amount was around 245%. During the peak pollen week the difference reached 283%. Poaceae (grasses): The highest overall grass pollen count was measured in a station situated in the southern periphery of Berlin. The difference between the station with the highest and lowest count in total grass pollen sum was 306%. Artemisia (mugwort): The highest mugwort pollen sum was found at an inner city trap, where a rich vegetation with mugwort plants was in close proximity. Overall difference between the trap with the highest and lowest mugwort pollen sum was 1.962%.

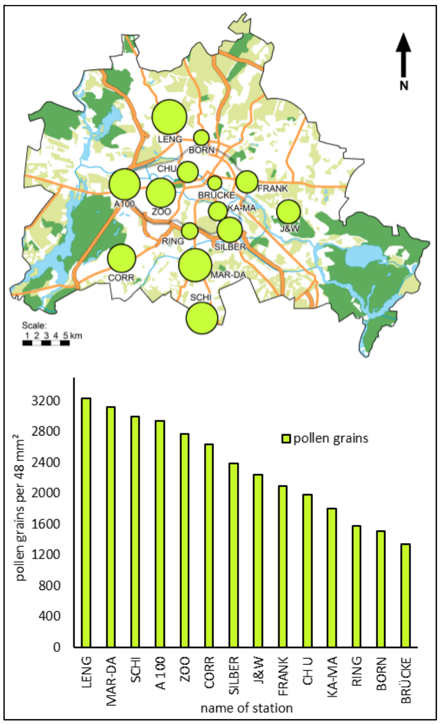

Fig.2 Total sum of Betula pollen during 11th March to 28th October 2014. The circle size corresponds with the pollen sum.

Conclusions

Within the city of Berlin there are big differences in the amount of airborne allergenic pollen of birch, grasses and mugwort. Therefore, a net of pollen traps is necessary to assess the impact of health. Allergenic pollen should be accepted as an important factor for air quality needing the introduction of suitable legislation to regulate measurement of allergenic pollen.

Acknowledgement

This work was supported by the Federal Environment Agency of Germany.

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REGIONAL SCALE AMINE CHEMISTRY DISPERSION MODELLING WITH COSMO-MUSCAT

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Summary

The present air pollution study focuses mainly on the regional scale modelling of the tropospheric fate and deposition of monoethanolamine (MEA) and its oxidation products using the modelling system COSMO-MUSCAT. Both detailed chemical process model studies are performed and complex 3-dimensional dispersion model investigations were carried out focusing mainly on the multiphase chemical fate and lifetime of MEA and its reaction products such as amides, nitramines and nitrosamines in the troposphere. The performed simulations were attended by extensive sensitivity and process studies to evaluate the associated uncertainties. For this study, realistic concentrations of reactants (OH, NO3, NO2) for MEA chemistry were provided by applying the RACM chemistry and anthropogenic emission inventories The physical loss processes of dry and wet deposition are described in dependence on meteorological conditions and land use properties..

Introduction

CO_2 capture and store (CCS) technologies, for example amine-based post-combustion CO_2 capture techniques, are designed to reduce anthropogenic CO_2 emissions into the atmosphere and are thus an attempt to mitigate the climate change. At present, amine-based post-combustion CO_2 capture techniques of power plants will release discharged air into the environment, which will contain a small but still significant amount of amines and their oxidation products. Moreover, it is known that the atmospheric oxidations of amines can lead to the formation of harmful (potentially carcinogenic) compounds such as nitramines and nitrosamines. Thus, an improved knowledge on the tropospheric chemical fate and physical removal processes of released amines and its oxidation products is required in order to assess the environmental impact and risks resulting from amine-based capturing operations. Recent box model studies performed at TROPOS have implicated the importance of multiphase chemical interactions for the tropospheric processing of emitted amines from CCS techniques

Methodology and Results

The modelling department of the TROPOS has developed the state-of-the-art multiscale model system COSMO-MUSCAT (Wolke et al., 2012). Driven by the meteorological model, the chemistry transport model MUSCAT treats the atmospheric transport as well as chemical transformations for several gas phase species and particle populations. The transport processes include advection, turbulent diffusion, sedimentation, dry and wet deposition.

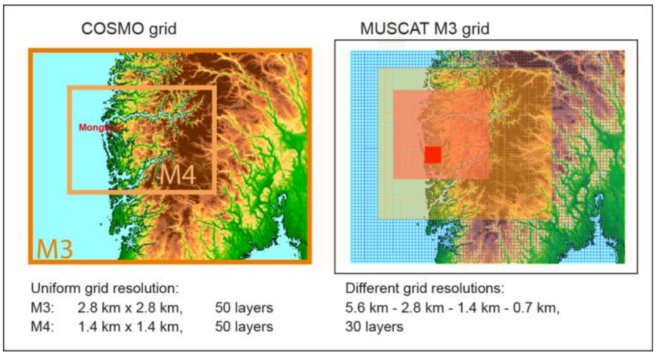

Fig.1 COSMO and MUSCAT grids for the M3 model simulations.

The dynamics of the plume was analysed for different situations, where rotating, alternating, retrograde, and fast variable wind leads to very complex structures like evasion of the mountains, advance into the fjords, transport of former plume fractions, and oscillating plumes. Not only the spatial resolution plays an important role in a realistic simulation of the plumes, but also the (fast) temporal development of the meteorological situation. Such changes, e.g. of the dynamic stability of the atmosphere, can occur abruptly, which necessarily affords an online-coupled combined treatment of all processes as is implemented in the applied model system.

The nitramine concentrations modelled by the explicit MEA chemistry mechanism were compared with two simplified schemes, which provide upper limits for the nitramine concentrations. In the first approach, the product of the OH-reaction (see Figure 1) gives an upper limit. In the second approach, the branching by the NOx and O2 reaction pathways of the product is also taken into account. As expected, the explicit mechanism produces the smallest concentrations.

Conclusions

The present dispersion model study has revealed that based on the available emissions and the meteorological, the proposed guidelines for long-term exposure in air for MEA and also the total amount of nitrosamines and nitramines should be not exceeded. The results might allow future evaluations of possible environmental impacts and human health effects of pollutants emitted from CCS processes

Acknowledgement

This project was gratefully funded by the Technology Centre Mongstad (TCM, http://www.tcmda.com). Furthermore, the ZIH Dresden and the NIC Jülich supported this work. We gratefully acknowledge the DWD Offenbach for good cooperation.

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MEASUREMENT OF AIR POLLUTANTS AND PROCESS STUDIES

A TWO-YEAR STUDY ON URBAN PARTICLE NUMBER (0.3-10 µM) AND MASS CONCENTRATIONS (<10 µM): LEVELS IN TIME AND WEEKLY VARIATION

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Summary
This work presents measurements of particle number (size range 0.3-10 µm) and particle mass (PM_{10}, $PM_{2.5}$, PM_1), in a site near a major highway at the Metropolitan Area of Porto Alegre, south Brazil. Measurements were carried out during two years: 2012 and 2013. Particle number and mass concentrations were measured using an optical counter with a PM_{10} analyzer. Results showed that concentrations of $N_{0.3-1}$ (0.3-1 µm) were the highest, although similar to $N_{1-2.5}$ (1-2.5 µm). Daily variability of the analyzed pollutants followed the traffic pattern. Moreover, particle number was higher during the day, whereas particle matter showed higher concentrations during nighttime. Traffic influence was evidenced by the mean concentrations of weekends and weekdays, being higher for the latter.

Introduction
Emissions from gasoline and diesel fuelled vehicles remain the dominant source of atmospheric particle number in polluted urban environments, and heavy duty vehicles contribute more than 50% of particle number and PM_1 emissions (Keogh et al., 2009). Current ambient air quality standards for controlling particulate matter pollution are mass-bases and restricted to $PM_{2.5}$ and PM_{10}, but may be ineffective for controlling fine particles from mobile sources, which are very numerous in terms of their numbers, but have little mass (weight) (Tittarelli et al., 2008). For this reason, this work is part of an attempt to investigate the variability of particle number in size ranges $N_{0.3-1}$ (0.3-1 µm), $N_{1-2.5}$ (1-2.5 µm), and $N_{2.5-10}$ (2.5-10 µm) and mass concentrations (PM_{10}, $PM_{2.5}$, PM_1).

Methodology and Results
Sampling site was located in the Metropolitan Area of Porto Alegre near the BR-116 and BR-290 highways, which are characterized by heavy traffic. Particles were measured using a PM_{10} analyzer model MP101M (Environnement) with an optical particle counter. Particle number and particulate matter were measured continuously at an average of 15-min interval during two years: 2012 and 2013. Means of daily concentrations of particle number $N_{0.3-1}$, $N_{1-2.5}$, and $N_{2.5-10}$ may be observed in Figure 1. Particle number concentrations were higher for the fine fraction: $N_{0.3-1}$ and $N_{1-2.5}$. Probably because number concentration generally increases as the radius decreases, thus the lower radius limit is of great importance in specifying the total number concentration.

Table 1 shows the mean particle number and particle matter during weekdays (Monday–Friday) and weekends (Saturday-Sunday). In weekdays, particle number reached the highest concentrations principally in $N_{0.3-1}$ reflecting increased levels of vehicular emissions in rush hours. Higher weekday/weekend ratio for particle number concentrations were obtained for finer particle fractions, revealing that during weekdays, higher concentrations of fine particles characterized by their smaller diameter occurred due to primary emissions from motor vehicles.

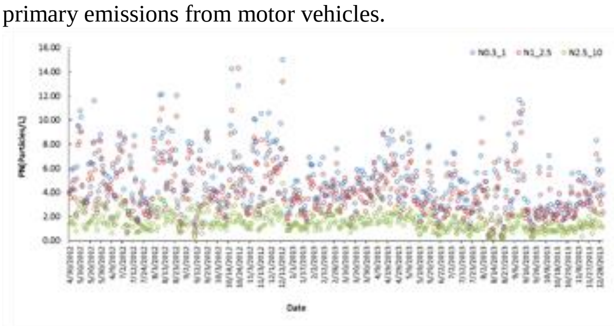

Fig. 1. Time series of particle number ($N_{0.3-1}$, $N_{1-2.5}$, $N_{2.5-10}$) daily concentrations in the studied period.

Table 1. Means of particle number and mass concentration (PM_1, $PM_{2.5}$, PM_{10}) during weekdays (Monday–Friday) and weekends, (Saturday-Sunday).

	PM_{10}	$PM_{2.5}$	PM_1	$N_{0.3-1}$	$N_{1-2.5}$	$N_{2.5-10}$
	($\mu g \cdot m^{-3}$)			($Particles \cdot L^{-1}$)		
Weekday	44.83	15.36	1.49	4.95	4.21	1.64
Weekend	40.36	13.38	1.33	4.09	3.60	1.49
Ratio	1.11	1.15	1.12	1.21	1.17	1.10

Conclusions
The evaluation and study of the two-year data set of measurements at an urban site highly impacted by traffic confirmed that traffic is the main source to particle number, especially of fine particles: $N_{0.3-1}$ followed by $N_{1-2.5}$. Traffic influence was also confirmed by the weekday/weekend ratio, which was > 1 for all analyzed pollutants.

Acknowledgement
We would like to thank FAPERGS and CNPq for financial support

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ASSESSMENT OF IMPACTS OF COARSE AND FINE PARTICLES FROM BUILDING DEMOLITION WORKS ON SURROUNDING AREAS

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Summary

A series of fixed-site and mobile measurements of PM_{10} (≤10 µm), $PM_{2.5}$ (≤2.5 µm) and PM_1 (≤1 µm) around a building demolition site were carried out during 54 hours over 7 days to assess their impact on the air quality in surrounding areas. The objectives were to understand the emission characteristics of PM emissions from the demolition activities, their physical and chemical characteristics along with estimating the occupational exposure of site workers during the activities. The increase in PM concentrations at the downwind monitoring stations suggested a need to design more appropriate risk mitigation strategies to limit exposures to onsite workers and people who live in the surrounding areas.

Introduction

Building demolition in both developing and developed world is a common activity. However, impact of particulate matter (PM) emitted in coarse, fine and very fine particle size range from such activities, which contains a wide variety of toxic organic substances and may adversely affect the respiratory health of nearby residents, is yet poorly understood (Kumar et al., 2012; Azarmi et al., 2014). Considering this, we determined the impact of PM_{10}, $PM_{2.5}$ and PM_1 arising from a range of outdoor demolition activities works in the UK.

Methodology and Results

Measurements were made at a fixed-site in the downwind of the demolition site in the UK. Also were made mobile monitoring around a building demolition site and at different distances (sequentially) in downwind of the demolition site to assess the PM decay. A GRIMM (model 1.107E) particle monitor was used to measure PM_{10}, $PM_{2.5}$ and PM_1 fractions in the 0.1–10 µm size range along with a portable weather station (KESTREL 4500) for measuring the meteorological data. The results show that $PM_{2.5\text{-}10}$ contributed about 89, 83 and 78% of total particle mass concentration during activity periods at fixed-site, mobile and at different distances over the values obtained during the background (pre-activity) values (see Fig.1). The findings for demolition activity present that exposure to PM_{10}, $PM_{2.5}$ and PM_1 inside the building excavator cabin were up to 37-, 8- and 37-times higher for than those during the local background exposure level, respectively. Moreover, the monitoring station in downwind direction illustrated a logarithmic decrease in the distances away from the construction and demolition site, with R^2 about 0.9 in PM_{10}, $PM_{2.5}$ and PM_1 concentrations (see Fig. 2). Energy-dispersive X-ray spectroscopy (EDS) and scanning electron microscopy (SEM) were used also to find physicochemical features of particles and attribute these species to their likely sources. These analyses showed the existence of the elements such as Ca, Si, Cu, K, S, Zn and Al on the collected samples.

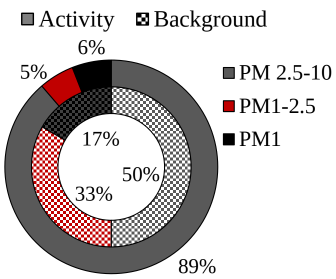

Fig.1 The concentrations of coarse, fine and very fine particles at fixed site during demolition activity.

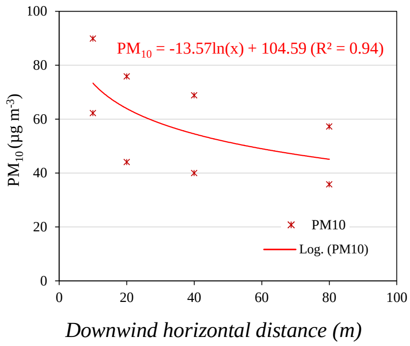

Fig.2 Decay of PM_{10} concentrations with the distance (in meter) in the downwind direction of demolition site.

Conclusions

Our findings clearly suggest an increase in PM concentrations in the nearby downwind areas and that these concentrations follow a logarithmic decay profile in the downwind of the demolition site. The results also highlight a much greater contributions of coarse particles (i.e., $PM_{2.5\text{-}10}$) compared with fine particles ($PM_{2.5}$) from demolition works. Further analysis of the data is currently in-progress.

Acknowledgement

The authors thank the University of the Surrey and CARA for supporting this work.

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EVALUATION OF ARTIFACTS AFFECTING COLLECTION OF AIRBORNE PAHS

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Summary

Extensive laboratory experiments have been carried out aimed at determining the aftermaths of volatilization and oxidation on atmospheric PAHs during the sampling phase. Eleven congeners were investigated, and implemented procedures allowed to assess losses distinctly associated to each of the two processes. Results show that the good practices application during the sampling phase is mandatory to assess the real PAH impact on health as well as emission sources affecting the study areas.

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds whose structure is formed by two or more condensed aromatic rings and are produced by every combustion process. Due to the ascertained carcinogenicity of many congeners, Directive 2008/50/EC regulates the PAH atmospheric concentrations. In particular, the concentration limit of benzo[a]pyrene (BaP) in PM_{10} is fixed to 1 ng m^{-3} **(**mean over a calendar year) and six other congeners must be monitored in order to assess the respective importance with regards to ambient air toxicity. The PAH determination in PM is affected by biases up from the collection step. In fact, being semi-volatile they can evaporate from the filter, stripped by the air flow. Moreover, PAHs can be decomposed by atmospheric oxidants such as ozone. These phenomena can result into significant losses that undermine the representativeness of collected PAHs with regards to air composition. In the framework of the implementing collection devices and procedures able to minimize the PAH sampling artifacts, important laboratory experiments have been carried out in order to evaluate distinctly the effects of volatilization and oxidation on each of PAH compounds.

Methodology and Results

Twin pairs of samples were obtained by using a Hydra dual sampler modified for the purpose. Filters for the particulate collection were simultaneously exposed over 48 hours at a flow rate equal to 2.3 m^3/h, during the winter season. After sampling one filter of each pair was analyzed, the latter was treated to investigate oxidative degradation or volatilization suffered by PAHs. To determine oxidative degradation (ageing), filters were tested with an air flow spiked with known concentrations of ozone; in this case, the losses due to volatilization were minimized through using flow rates one order of magnitude lower than those used in in-field tests and the time of exposure was reduced to one hour. Three ozone levels were chosen, i.e. 0.4 0.8 and 1.2 ppm*h. To assess volatilization from filters, the second filter was exposed to another sampling cycle (48h, 2.3 m^3/h) at 19±2 °C. An absolute filter was located upstream of the PM-loaded filter in order to allow zero air crossing the sample and, by consequence, putting in the evidence the neat effects of PAH stripping and evaporation.

Volatilization generated losses from negligible (e.g., indeno[1,2,3-cd] pyrene) up to 55% (benzo[a]anthracene), while the benzo[a]pyrene losses associated to oxidative degradation could exceed 50%.

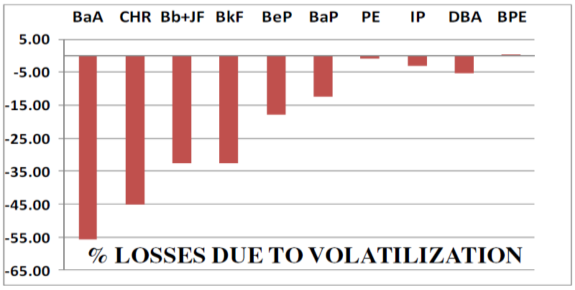

Fig.1 Effects of volatilization on PAHs sampling

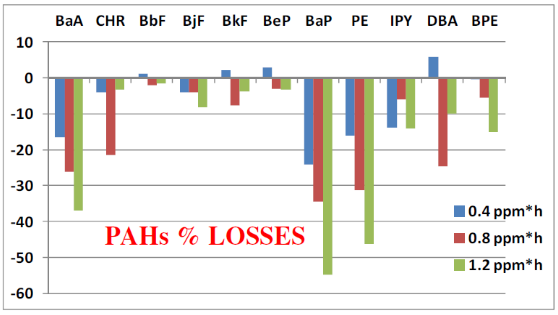

Fig.2 Effects of oxidative degradation on PAHs sampling

Conclusions

Concerning the oxidative degradation, especially the BaP losses can lead to underestimate the environmental toxicity associated to PAHs, while differences between the congeners in the volatilization or in the reactivity to ozone can originate differences between the real distribution pattern of PAHs in the atmosphere and those in the collected samples. This phenomenon must be adequately taken in account whereas the statistical multivariate approach is applied to determine the emission sources affecting any study area.

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CFD-URANS PREDICTION OF DOSAGE-BASED PARAMETERS FROM SHORT-TERM RELEASES (PUFFS) OF HAZARDOUS AIRBORNE MATERIALS

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Summary

One of the key issues of recent research on the dispersion inside complex urban areas is the ability to predict dosage-based parameters of an airborne material which is released many times and consecutively under short time durations (puffs) from a point source. The present work addresses the question whether the Computational Fluid Dynamics (CFD) - Unsteady Reynolds Averaged Navier Stokes (URANS) methodology can be used to simulate such a complex phenomenon. The whole effort is focused on the prediction of various key dosage-based parameters inside a complex real urban area. The capabilities of the proposed methodology are validated against wind tunnel data. Sensitivity analysis for the turbulence closure modeling is also performed. The reference data set was compiled by members of COST Action ES1006. The provision of reference data is gratefully acknowledged.

CUSTOM MADE DUST MONITOR EQQUIPED WITH FAST GPS MODULE AND INTERNET CONNECTION

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Summary
In Krakow city, where the air pollution is the common problem there is a dire need to evaluate the sources of air polluting dust particles. A lot of remedial programs are implemented. To optimise investment of social funds, precise information about pollution sources are required. To meet this needs, custom made particulate matter monitor was build basing on commercially available analyser. System capabilities allow to made mobile dust air pollution measurements with precise positioning.

Introduction
Krakow air quality belongs to one of the lowest in Europe (EEA Report No 5/2014). Mostly in winter months dust particles concentration in air exceed relevant norms indication several times. For many years there has been a debate about the sources of air pollution in the City. As the main source of dust particles some scientists indicate road traffic, other coal burning in households or industry. There are many analytical methods to identify dust sources, for example IRMS or PIXE. In this study it was decided to approach of the problem from a different angle. Campaigns with mobile equipment was designed to cover area of the Town centre, suburbs as well as a background of the City.

Methodology and Results
Custom made dust monitor was build based on TSI Dust Track II 8530 aerosol monitor (A) with analyser basing on measurement of scattered laser beam intensity. Additional equipment including fast GPS (5Hz) (B), GSM module (C), sample heater (D), external data logger (C) and power supply working with 230V AC and 12V DC (E) was combined to the full setup mobile device. Setup is able to work as a stationary monitor powered with 230V AC or it can be supplied with 12V DC car socket to be used in mobile campaigns. Fast GPS module was used to precise positioning of the measurement and subsequently to identify particulate matter source location. Received data can be continuously previewed online by the GSM data connection. To avoid interference of the liquid fraction of the aerosol sample inlet was heated to stabilise the temperature of intake line over the dew point. Setup was built on order and thanks to funding of Krakow Smog Alert (KSA)

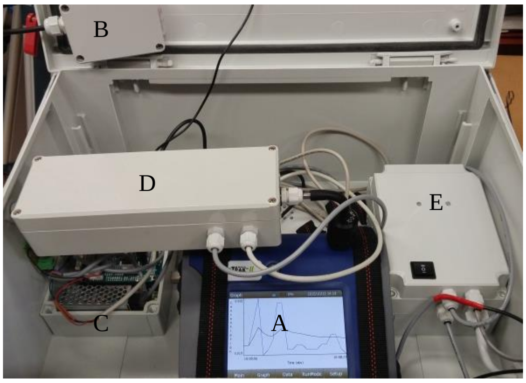

Fig. 1. Explanatory figure of dust monitoring custom made device.

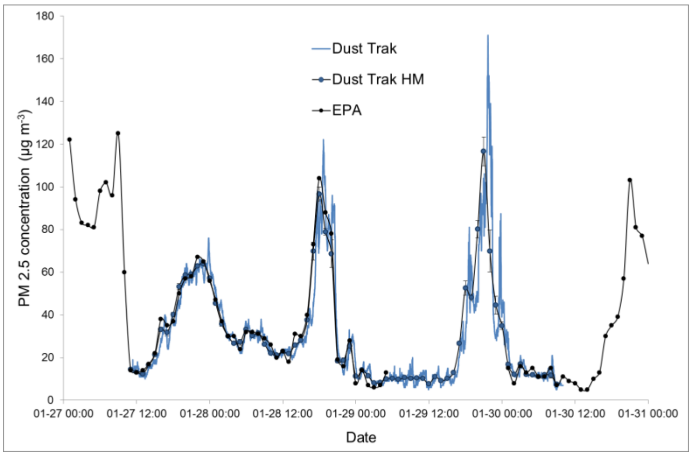

Fig. 2. Parallel measurement of PM2.5 at EPA (Inspectorate for Environmental Protection Agency) (in black) and Dust Trak monitor (in blue). Round points indicates hourly means. Solid lines connects individual values.

To justify the setup reliability and feasibility in different weather conditions after the gravimetric calibration the equipment was used in parallel measurement campaign with certified instrument according to PN-EN 14907 provided by the Voivodeship Inspectorate for Environmental Protection Agency. Typical test length was 72 hours, results were presented on figure 2. Hourly mean differences were not greater than 5% of measured value.

Conclusions
Precise, accurate and resistant to weather conditions dust measurement system was performed. Possibility to supply by 12V and fast response allow to use in mobile measurements. The comparisons performed with the reference methods allow to use mobile system to elaborate the map of dust pollution in the city of Krakow and to have a try to evaluate sources of the pollution.

Acknowledgement
Voivodeship Inspectorate for Environmental Protection [http://www.krakow.pios.gov.pl/]
Krakow Smog Alert [http://www.krakowskialarmsmogowy.pl/en/]
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DETERMINANTS OF PERSONAL EXPOSURE TO BLACK CARBON IN STOCKHOLM TRAFFIC

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Summary
This study aims to identify the role of traffic and travel mode on personal black carbon (BC) exposure in Stockholm. Personal BC was measured by a portable Aethalometer, on four busy streets in central Stockholm, in the morning, midday and late afternoon using various travel modes (bus, cycling, car and on foot). The study identified background pollutants, meteorology and travel mode to be the most important determinants of personal BC. Those travelling by bus were exposed to higher BC concentrations in the ambient air than those using other travel modes. The personal BC concentration was on average 3.4 times higher than urban background levels.

Introduction
Epidemiological studies have documented associations between BC exposure and various adverse health outcomes including arrhythmias (1) and decrease in lung function (2). Although BC and other carbonaceous fractions are minor components of PM2.5, studies have also shown that the carbonaceous fraction of PM is more strongly associated with adverse health effects than the total PM2.5 mass (3), yet BC is normally not monitored routinely. The transport microenvironment is a key contributor to total personal exposure4 and concentrations measured at background monitoring stations substantially underestimate personal exposure to BC and other traffic related pollutants (4). The aim of this study was to identify the role of traffic and travel mode on personal exposure to BC in Stockholm.

Methodology and Results
Personal BC was measured using a portable Aethalometer (MicroAeth Model AE51, AethLabs, San Francisco, CA, USA) in two measurement campaigns (Jan 21-May 8 and Sep 16-Oct 24, 2013). The campaigns were undertaken during XX weeks, along four inner-city streets during morning and afternoon traffic peak hours and at midday for 2 hours, respectively. The measurements were performed using four transport modes; walking, cycling, bus and car. A linear regression was applied using personal BC concentration as an outcome and predictors were pollutants from a background monitoring station (BC, PM2.5, coarse particles and NOX), weighted daily traffic, and meteorology (wind speed, wind direction, temperature, humidity, rain fall and global radiation). Average personal BC concentration during the study period was 2.29 µg/m3 (range: 0.03 to 37.19) while the background BC concentration averaged 0.67 µg/m3 (range: 0.07 to 6.09). Travelling by bus resulted in the highest personal BC levels in the ambient air (2.69 ng/m3), while walking had the lowest concentrations (1.70 µg /m3). BC concentrations were highest in the morning rush hours, followed by midday. Personal BC was moderately and positively correlated with PM2.5 and BC from central monitors and negatively correlated with wind speed. In the regression analysis, background pollutants (BC, PM2.5 and coarse PM), global radiation, temperature and humidity had significant positive relationships with personal BC while wind speed had a significant negative relationship.

Conclusion
The level of personal BC is more than 3 times higher than the background level in this study, which implies that the use of central monitors for traffic related pollutants is not fully representative of personal exposure. Background pollutants (especially BC, PM2.5 and coarse PM) and meteorological parameters were important determinants of personal BC.

Acknowledgement
The study was supported by the Stockholm County Council.

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PARTICULATE MATTER MEASUREMENTS AT KASPROWY WIERCH MOUNTAIN STATION AND ZAKOPANE CITY IN SOUTHERN POLAND – PRELIMINARY RESULTS

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Summary

In 2015 the particulate matter measurements was lunched at Kasprowy Wierch in Tatra Mountains. First, preliminary results were compared to similar measurements provided by the Voivodeship Inspectorate for Environmental Protection Agency in Zakopane City, located in the valley at the base of Tatra Mountains. Poster presents obtained results of this comparison.

Introduction

Kasprowy Wierch is a high-altitude meteorological station established in 1938 in north-western High Tatra mountain ridge, Western Carpathians (49°14'N, 19°59'E, 1989 m a.s.l.), named after the peak on which the laboratory building is located. As the station is situated in the convergence area of three large valleys, approximately 300m above the tree line, anabatic and katabatic wind events are frequently observed. Wind statistics available for the station indicate prevalence of southerly and north-easterly wind directions, caused by two of the valleys originating from Kasprowy Wierch summit (Gąsienicowa valley and Dolina Cichej valley) channelling the air masses in these directions.

The nearest town is Zakopane located 6km to the north and about one kilometer below Kasprowy Wierch. This is the most famous mountain holiday resort in Poland. Therefore the number of people residing in the Podhale region increases even several times during the summer and winter holidays. In Zakopane and surrounding villages dominates low housing construction, and homes in the vast majority are still heated by coal or wood stoves. Therefore, relatively large anthropogenic emissions of PM1, PM2.5 and PM10 occurs in this region, especially during the winter months.

Methodology and Results

DustTrak™ II Aerosol Monitor 8530 was used to measure size fraction of particulate matter using light-scattering laser photometry technique. The precision of this analytical method is on the level of ±1µg/m^3. Sample inlet system was modified to provide reliable measurements in extremely difficult conditions (frequent freezing drizzle, high humidity and high wind speed). Prior to measurement the sample is heated to eliminate liquid fraction interference in measurement chamber. Monitor was installed at Kasprowy Wierch station in June 2015 and it was settled to measure fraction PM2.5. It is first available record of particulate matter concentration measurements in the air of Polish Carpathians Mountains. Before installation DustTrak™ monitor was gravimetric calibrated and subsequently parallel measurements with normalized instrument according to PN-EN 14907 Polish National Standard was performed. Parallel to the measurements at Kasprowy Wierch, continues monitoring program was conducted at the center of Zakopane City. Data record was provided by the Voivodeship Inspectorate for Environmental Protection Agency.

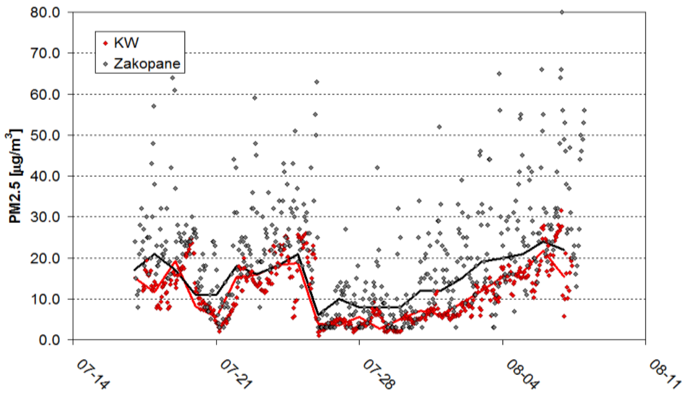

Fig.1. Parallel measurement of PM2.5 at Kasprowy Wierch (in red) station and in Zakopane city (in black). Individual points indicates hourly means. Solid lines connects daily mean values.

During the measurement period the highest PM2.5 concentration level at Kasprowy Wierch was 40µg/m^3, while in Zakopane City it exceeded 80µg/m^3. Relatively frequent temperature inversions and poor ventilation, observed inside this valley, can induce accumulation of particulate matter originating from the so-called low emission in the lower troposphere. Usually Kasprowy Wierch atmosphere is depleted in particulate matter (on average 25% less then in Zakopane city), however occasionally opposite vertical gradient is observed. An example of episode of parallel measurements is presented on fig.1.

Conclusions

During the period of observations mean daily average value of PM2.5 was significant higher in Zakopane city then at Kasprowy Wierch (15.2µg/m^3 compared to 11.4µg/m^3). Short time variability of PM2.5 at Kasprowy Wierch was at the level of 6µg/m^3 while Zakopane city record reviled 13µg/m^3.

Acknowledgment

Voivodeship Inspectorate for Environmental Protection [http://www.krakow.pios.gov.pl/]
Krakowski Alarm Smogowy [http://www.krakowskialarmsmogowy.pl/en//]
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AIR POLLUTION ANALYSIS AND DEPENDENCE ON METEOROLOGY IN KLAIPĖDA CITY

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Summary
The aim of this study was to analyze the changes of air quality in Klaipėda city and to assess the impact of meteorological factors to the dispersion of air pollutants in Klaipėda city. The data from two automatic air quality monitoring stations and the meteorological data from shore meteorological station were used in this study. The seasonal variation of nitrogen dioxide (NO_2), particulate matter (PM_{10}) and carbon monoxide (CO) was analysed. The assessment of meteorological factors on the dispersion of air pollutants showed a moderate, negative, statistically significant correlation between CO and temperature, NO_2 and wind speed and between PM_{10} and temperature.

Introduction
Air pollution is rapidly growing environmental problem in many countries and poses a threat not only to human health, but to the natural environment as well (Han, Naeher, 2006; Marshal et. al., 2005; Yanga et. al., 2015). Weather and ambient air quality synergistically influence human health and its condition. Therefore, it is important to observe, determine and predict the air quality and its variability in time in order to avoid and prevent health problems (Cakmak et al., 2006).

Methodology and Results
The object of this study was air pollution of NO_2, PM_{10} and CO in Klaipėda city. The data were obtained from two automated air quality monitoring stations, one of them is located in the city center and other is placed in Šilutė highway. The seasonal analysis of air pollutants was performed. In order to assess the influence of meteorological parameter on the dispersion of air pollutants, the data of wind speed, air temperature and relative humidity were used from Klaipėda Meteorological Station. The statistical analysis was performed using SPSS software. The results of this study showed that the highest concentration of NO_2 in Šilutė highway station was determined in the spring 27.2 µg/m³, while in Center station it was observed in the winter 18.5 µg/m³ (see Fig.1). The lowest concentration of NO_2 was observed in the summer in both monitoring stations. Šilutė highway station represents the air pollution arising mainly from traffic, while Central station represents the air pollution from residential households and industry. PM_{10} was observed in the spring (see Fig.2). The concentration of PM_{10} was 40.8 and 38.5 µg/m³ in Center station and in Šilutė highway station. The lowest concentration of PM_{10} was found in Central station 23.1 µg/m³, while in Šilutė highway station it was 26.6 µg/m³. The highest concentration of CO was observed in the winter; in Šilutė highway station it was 0.39 mg/m³ and in Center monitoring station it was 0.35 mg/m³ (see Fig.3). The lowest CO level of 0.23 and 0.16 mg/m³ was determined in summer season, respectively in Šilutė highway and in Central stations. The correlation analysis revealed that there is a moderate negative statistically significant relationship between CO and temperature ($r = -0.55$; $p = 0.00$), between NO_2 and wind speed ($r = -0.47$; $p = 0.00$), and between PM_{10} and temperature. ($r = -0.33$; $p = 0.00$).

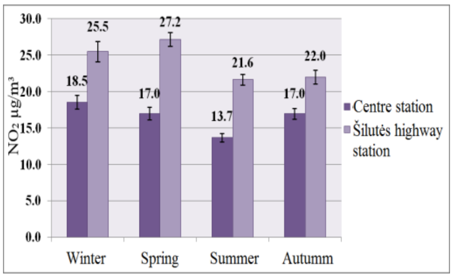

Fig.1 The seasonal variation of NO_2 concentration (µg/m^3) in Klaipėda city

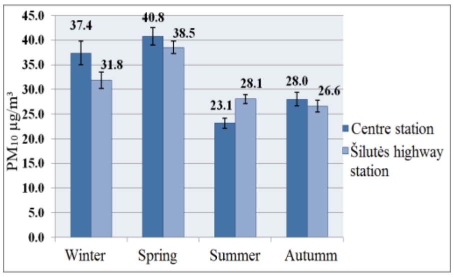

Fig.2 The seasonal variation of PM_{10} concentration (µg/m^3) in Klaipėda city

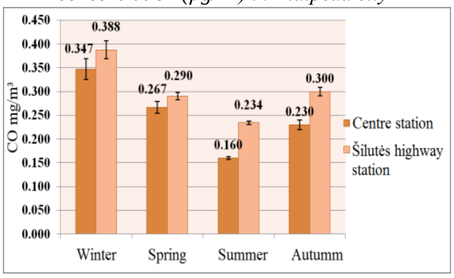

Fig.3 The seasonal variation of CO concentration (µg/m^3) in Klaipėda city

Conclusions
Air pollution is an important environmental issue in urban areas, which causes human health effects. Meteorological processes and conditions have the influence on the occurrence of high pollution episodes; therefore, understanding the effect of meteorological parameters on air pollution can help to predict the future concentrations of air pollutants and to reduce the air pollution in the cities.

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MODELLING HIGH RESOLUTION PM_1 INDOOR CONCENTRATIONS USING CONTAM MODEL

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Summary

This study aims to assess the ability of CONTAM multi zone model in reconstructing high-resolution PM_1 indoor concentrations in residence houses and to evaluate at what extent the deposition and penetration processes contribute to the overall reconstruction of the indoor particles number.

Introduction

Outdoor pollutants exhibits different abilities in penetrating into indoor depending of the type of pollutant (gaseous or aerosol), building characteristics and its ventilation mechanisms. Infiltration factors based on contemporary I/O measurements can estimate the penetration factors, but lack of information on key parameters such as air exchange rate, type and characteristic of air leakages in indoor environment, does not allow analysing their contribution to final indoor concentration. A modelling approach, able to simulate all the above impacts, is a possibility in the understanding of related phenomena.

Methodology and Results

A field campaign to measure PM_1 particles number concentrations in both outdoor and indoor environments has been carried out in a residential house located in Rome, Italy. Two TSI 3007 condensation particle counter were used for particles measurements. Windows and doors were kept close during the test experiment. As for meteorology, wind speed and direction were measured by means of a sonic anemometer located on the terrace of the hosting building. Both particles and meteorology data were collected at one-minute time resolution from 9am to 2pm. The multi-zone air movement and contaminant transport program CONTAM (Walton and Dols, 2005) was used for indoor modelling. CONTAM is an established simulation tool for predicting airflows and contaminant concentrations in multi-zone building airflow systems. The layout of the apartment was model reconstructed. The leakage values for the various building components were used as model inputs to represent the interconnectivity between outdoor and indoor spaces. The time-varying ambient weather data and outdoor PM_1 concentrations were also used as inputs to calculate the temporal airflow and indoor PM_1 concentrations in each of the building zones. Indoor concentrations were simulating by including deposition and penetration factors. Figure 1 shows a time series of observed and modelled indoor PM_1 concentrations including or excluding deposition and penetration processes. In can be seen that without the inclusion of these processes the model is far to reproduce the observed indoor particles concentration. It is worth to notice the strong variability of observed outdoor concentration, the attenuated and delayed indoor one and the model inability to reproduce these indoor variations, although the baseline behaviour is well reconstructed.

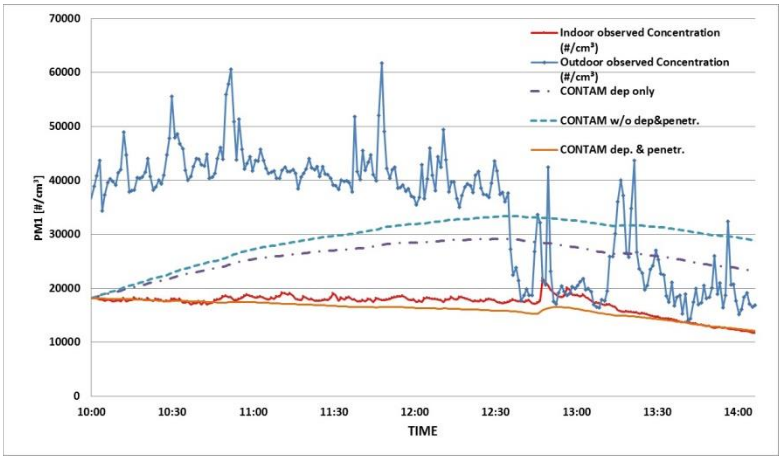

Fig.1 Time series of observed and modelled indoor PM_1 concentrations

Conclusions

CONTAM simulations and experimental studies were performed for a residential test apartment. The results show that the model needs to consider both size-resolved deposition and penetration to predict accurately the time-varying particle concentrations in buildings. Particle deposition and penetration have significant effects in the model prediction. The model validation indicates that CONTAM model can provide insight into the general trend of PM_1 entry into buildings.

Acknowledgement

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MODELLING THE OZONE CONCENTRATION OVER MEDITERRANEAN MBL: ESTIMATION OF SHIP EMISSIONS IMPACT

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Summary
Ozone concentrations in the Mediterranean area regularly exceed the maximum levels set by the EU Air Quality Directive (2008/50/CE, a maximum 8-h mean of 120 µg·m−3) in the summer, with consequences for both human health and agriculture. The particular geographical and meteorological conditions in the Mediterranean influences these high values, as do anthropogenic ozone precursor emissions from around the Mediterranean and continental Europe. The WRF/Chem model has been used to simulate tropospheric chemistry during the periods of the measurement campaigns in order to estimate the contribution of maritime traffic in the Mediterranean to the anthropogenic emissions inventory. The differences in the model output suggest that, in large parts of the coastal zone of the Mediterranean, ship emissions contribute to 5% and 15% to ground level daily average ozone concentrations.

Introduction
The Mediterranean Basin has a number of characteristics that favor Boundary Layer (BL) ozone formation, especially in the summer. During the summer, the Mediterranean is under the descending arm of the Hadley circulation and, therefore, enjoys long periods of anticyclonic weather, with high temperatures and intense sunshine. These conditions favor both ozone formation and the natural production of VOC. The presence of major urban and industrial centers on the coasts and the general north to south BL flow mean that anthropogenic ozone precursors are abundant. Elevated concentrations of ozone have been observed at inland sites, coastal sites and during intensive field campaigns, as during measurements over the sea, performed on-board the Italian Research Council's R. V. Urania (Gencarelli et al., 2014).

Methodology and Results
Measurements from six oceanographic campaigns (Med-Oceanor, Sprovieri et al., 2003) and from EMEP network monitoring stations have been used for validate the modeled ozone concentrations.
Three model domains were used to model each oceanographic campaign period to include the area covered by the oceanographic campaign. Anthropogenic emissions were obtained from the EMEP CEIP, considering their specificity to the European region and their availability for individual years. Versions of the emission inventory for the years of oceanographic campaigns were prepared in which all of the SNAP sector 8 emissions over the Mediterranean Sea were removed (*No_ships simulations*). Comparing these model values with *Tot_emiss* simulation it was possible estimate the influences of ship emissions on Mediterranean basin and surrounding areas (Fig. 1).

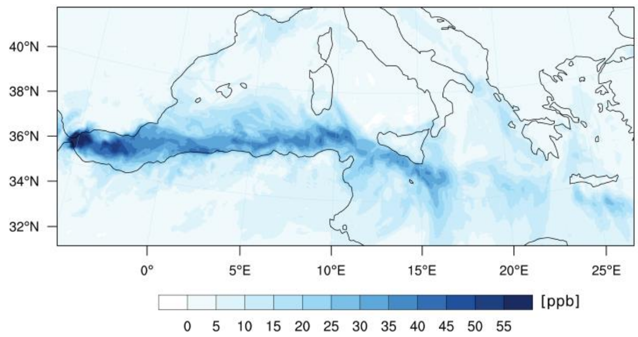

Fig.1 The difference (ppb) in the ozone concentrations between the Tot_emiss and No_ships simulations.

Conclusions
Ship emissions mostly influence marine and coastal areas as a result of the low summer time Mediterranean MBL height and the steepness of much of the Mediterranean coastline. However, the simulations with and without ship emissions showed differences in ozone tens and even hundreds of km inland over the flatter coastal areas of North Africa. This suggests that ship emissions could contribute to the ozone budget above the boundary layer, where, due to its role as a short-lived climate forcer, it may have an impact on the regional radiation budget. Along the routes taken by the R.V. Urania, the simulations indicate that ship emissions may contribute to the exceedance of the EU 8-h average concentration limit of 120 µg·m−3 .

Acknowledgement
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EXAMINATION OF THE SPATIAL DISTRIBUTION AND TEMPORAL VARIATION OF BLACK CARBON IN SANTIAGO DE CHILE

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Summary
In this study we have examined the black carbon (BC) data generated by a network of 6 stations in the years 2013 and 2014 in order to determine the spatial distribution and trends of this pollutant over a 6 month period each year. All but one station, show a peak in BC at 8:00 indicating that during the rush hour there is a strong influence from traffic, however, this influence is not seen during the rest of the day. In one section of the city, the BC concentration is related to transport from other sections, while in the other section, BC is mostly related to emission from local sources. Cluster analysis was applied to the data, and the results indicate that the city has four large sectors with similar pollution behaviour related to its location on the city and to the origin of BC.

Introduction
During winter, it is common to observe an increase in the number of children's hospitalizations due to respiratory diseases following pollution events (Ostro et al., 1999), even an increase in daily mortality was observed (Cakmak et al, 2009). Particle mass ($PM_{2.5}$) and BC concentration are very high the western part of Santiago (Pudahuel, Quilicura). However, it is very difficult to determine if these concentration levels are due to pollution transport from other parts of the city or local emissions. This information is needed so that for authorities can make better informed decisions regarding pollution control measurements. Considering this, an array of BC monitors was installed in order to determine BC temporal trends and its spatial distribution over the city.

Methodology and Results
The measurements were made from April to November of 2013 in five sites and from May to November in other five sites in 2014. The sampling sites are shown with an in Figure 1. Black carbon was measured with a low-cost instrument (SIMCA) instrument developed at the University of Santiago. The instrument measures the light absorption in a filter to obtain BC concentration every 15 min. The stations towards the east of the city (Huechuraba, Cerro and Puente Alto) show lower dependence on direct emissions from traffic and higher influence from transport of pollution from other parts of the city. The stations on the west (Pudahuel and Quilicura) show higher influence from local emissions and lower influence from transport. At the same time these stations have very high night level of BC. Cluster analysis of the data shows that the stations form groups related to its location on the city and to the origin of BC.

Fig.1 Measurement sites in Santiago

Conclusions
The results show one sector of the city with pronounced BC concentration located in the west of the city. BC in this sector is also related to local emissions rather than transport from other parts of the city. The eastern side of the city has lower BC levels which, in turn are related partly to transport from other parts of the city and partly to local emissions. These results indicate that in cities like Santiago, policies to reduce pollution have to consider local sources as well as transport from other parts of the city.

Acknowledgement
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HEAVY METAL EXPOSURE SOURCE IDENTIFICATION AND HEALTH IMPACT ASSOCIATED WITH INDOOR PARTICULATE MATTER (PM10 & PM2.5) -A STATISTICAL ANALYSIS

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Summary-
The study was conducted in Lucknow city which is the third most polluted city of India to assess Indoor Air Quality (IAQ) in urban houses by monitoring PM_{10} & $PM_{2.5}$ from March '13 – Feb'14. Sixteen houses were characterized in four different microenvironments i.e. Well planned, Densely populated, Roadside and Livestock. Particulate concentration was found to exceed than the WHO limit in each microenvironment. Fe, Zn, Cu, Pb, Mn, Ni and Cr were also analyzed in PM_{10} and $PM_{2.5}$ samples. Fe was most and Cd was least abundant metal found in indoor environment. Major source responsible for heavy metals indoors were house dust, fuel combustion and re-suspended outdoor dust. Occupants exposed to sudden elevated level of particulate concentration complained more respiratory problems.

Introduction-
In developing countries like India with the fast growing urbanization and development air quality is getting deteriorated at a fast pace. With the sharp rise in the number of vehicles more research awareness should be implemented to control pollution level, especially of the particulate pollutants, as increase in number of vehicles causes more emission of pollutants and also changes the composition ratio of the pollutants especially the particulate matter (Lawrence et. al., 2013), which includes fine and ultrafine particles. As In developing countries with warm climate ventilation is largely natural, the quality of indoor air largely depends on the quality of the external environment. Most of the researches are still focused on outdoor pollution management, lesser attention has been paid on indoor air quality specially in Northern India. The purpose of the study was to present a clear picture of indoor air quality in urban city houses.

Methodology and Results-
Sixteen urban houses were selected for monitoring. RSPM- PM_{10} & $PM_{2.5}$ were assessed through full day monitoring. PM_{10} and $PM_{2.5}$ were measured using APM-550 Fine particulate Sampler (Envirotech) at a flow rate of $1m^3$/hr controlled by critical orifice. The yearly average concentration ($\mu g/m^3$) of PM_{10} and $PM_{2.5}$ were 72 and 49 for well planned, 97 and 60 for densely populated, 112 and 76.4 for roadside and 68 and 52.42 for livestock microenvironments respectively. The values were higher than the WHO limits, highest for roadside houses. Fe, Zn, Cu, Pb, Mn, Ni and Cr were analyzed in PM_{10} and $PM_{2.5}$ samples. Fe was most and Cd was least abundant. A correlation was done among metals using SPSS 11 in order to find common sources of these metals. Pb with Mn, Fe with Cr, Zn with Ni and Cr, Ni with Cr, Mn with Fe and Cu with Cr showed significant positive correlation either at $p<0.05$ or $p<0.01$ level. Pb, Mn, Cr ($p<0.01$) and Cu ($p<0.05$) showed positive correlation with PM_{10}. Pb, Ni, Cr and Mn associated with PM2.5 samples showed positive correlation in roadside microenvironment. Source identification of heavy metals was done through varimax rotated factor analysis. Three main factors were analyzed in each sample representing the major sources of metals indoors. Major sources identified were house dust, fuel combustion and re-suspended outdoor. Occupants exposed to sudden elevation in PM_{10} concentration reaching up to 199 $\mu g\ m^3$ and 169 $\mu g\ m^3$ for $PM_{2.5}$ complained more respiratory problems. Irritation of eyes was a common symptom for concentration 148 $\mu g\ m^3$ for PM_{10} and 122 $\mu g\ m^3$ for $PM_{2.5}$.

Conclusions-
The conducted study gave a clear insight of the indoor air quality in urban houses of Lucknow city. Concentration of RSPM was found to be considerably making the exposed population more vulnerable for COPD, asthma, pulmonary tuberculosis, prenatal mortality, low birth weight and cataract. Most of the exposed population was unaware about the hazards associated with poor air quality. Government should conduct awareness programmes for the exposed population. The authors strongly recommend policy implementations.

Acknowledgements-
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SPATIAL DISTRIBUTION OF SIZE SEGREGATED PARTICULATE MATTER IN SLUMS SITUATED NEAR HEAVILY TRAVELED TRAFFIC ROADS IN MUMBAI, INDIA

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Summary
Since slums in Mumbai are primarily located near legal or illegal industries, near heavily travelled major traffic roads, they are exposed to air pollution from industrial and vehicular sources. The objective of this study is to understand spatial distribution of size segregated particulate matter (PM_{10}, $PM_{2.5}$ and $PM_{0.18}$) moving away from a major road in slums. Monitoring of size segregated PM is done using a multi-stage cascade impactor for the sizes $PM_{10-2.5}$ (coarse mode), $PM_{2.5-0.18}$ (accumulation mode) and $PM_{0.18}$ (ultrafine mode) during weekdays near a major road in Mumbai, India. At kerbside location, accumulation mode particles are about twice and four times than coarse and ultrafine mode PM, respectively during rush hours, while ~ 1.5 and 5 times than coarse and nucleation mode PM, respectively, during non–rush hours. At a location about 50 m away from kerbside, the concentration of PM in all size ranges is lower than at kerbside and a third location, ~100m away from kerbside. The first results suggest the traffic as well as within-slum activities as the major sources of outdoor PM concentrations in the slums.

Introduction
Slums in Mumbai are mainly situated near heavily traffic road. Also, there are many unknown sources present in these slums. Hence the people from these slums are exposed to air pollution not only from vehicular emissions but also from other outdoor sources.

Methodology and Results
Monitoring of size segregated particulate matter was done by using MOUDI (Micro-Orifice Uniform Deposit Impactor) for the sizes $PM_{10-2.5}$ (coarse mode), $PM_{2.5-1.8}$ (accumulation mode) and $PM_{0.18}$ (nucleation mode) during traffic peak (8-11am) and non-peak hours (12-4pm) on weekdays near a heavily travelled traffic road in Mumbai, India. This major road has traffic density of around 250,000 vehicles/day. Figure 1 shows that at kerbside location (S1), $PM_{2.5-0.18}$ was about thrice and four times than $PM_{10-2.5}$ and $PM_{0.18}$, respectively during peak hours, while ~ 1.5 and 5 times than $PM_{10-2.5}$ and $PM_{0.18}$, respectively during non–rush hours. But at location about 50m from kerbside (S2), $PM_{0.18}$ is ~ 1.5 times greater than $PM_{2.5-0.18}$ during peak hours and almost equal with $PM_{2.5-0.18}$ during non-peak hours. Moving further, at another location, ~100 m away from the road (S3), $PM_{0.18}$ and $PM_{2.5-0.18}$ are almost equal (about 30% during peak hours and 20% during non-peak hours). Detailed chemical characterization of the PM samples and additional measurements outside public housing schemes are currently underway.

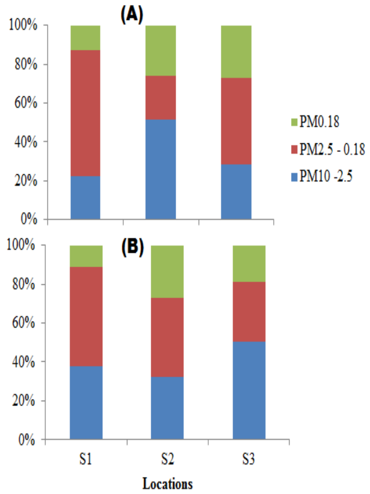

Fig.1 Percentage variation of size segregated particulate at three locations in Durga Nagar Slum, Mumbai during A) morning traffic rush hours, B) afternoon non-rush hours

Conclusions
Slum residents are likely exposed to high levels of airborne PM from traffic sources. At about 100 m away from the major road the impact is lesser and may be dominated by other household/industrial sources within the slums. There is a need to better identify the sources and assess their contribution to ambient air pollution in the slums.

“NO GAS” PROJECT: EXHAUSTED DUMP EMISSIONS

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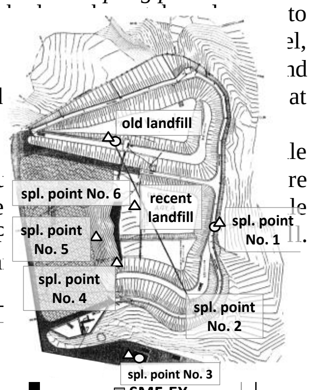
Summary
Two in-field campaigns have been carried out in Calabria region, Southern Italy, aimed at characterizing the release of volatile hydrocarbons (VOCs) from exhausted dumps. The former experiment was conducted at two landfills (San Giovanni in Fiore-SGF and San Martino di Finita-SMF), while the latter was performed at one only site (SGF). Volatile hydrocarbons were collected from air by means of both active and diffusive sampling methods. Nitrogen dioxide, ozone, ammonia and sulphur dioxide were collected in parallel. During the summer campaign, concentrations of NO_2, SO_2, and NH_3 ranging from 2 µg/m^3 to 6 µg/m^3 were detected both inside and outside of the two dumps, while O_3 reached ~120 µg/m^3. Unlike other toxicants, NO_2 was more in dumps than outside. As for VOCs, usually both benzene and toluene were more out of dumps whilst other substances were roughly equal or less; nevertheless, at one point inside SGF the concentrations of compounds apart from benzene were higher. Similarly at SMF most VOCs were higher at a location rich in H_2S release from soil. High levels of isoprene and chlorofluorocarbons were estimated at all locations.

Fig. 1. Map of SGF dump with sampling points



Introduction
A lot of air contaminants are released by dumps; in particular, important emission of volatile [...] to several years after their run off. This phenomenon is somewhere exploited for production [...]el, which allows reducing the global budget of green house gases emission. Nevertheless, the [...]nd after the dump life is mandatory to understand their long-term impact on environment and [...] at optimizing the landfill management and preventing pollution.
Two in-field campaigns were conducted at SGF and SMF landfills during 2015, in June and [...]le hydrocarbons VOCs, however regulated toxicants (i.e. NO_2, SO_2, O_3 and NH_3) were measu[...]re complete overview of air composition at the two sites. In SGF, diffusive sampling devices we[...]le active sampling (pump + cartridge) was applied occasionally at three further points (Fig. 1). F[...]l. In SMF two points were chosen inside and outside the site, and a third point rich of H_2S was a[...]

Methodology and Results
Air toxicants and VOCs were determined using *Analyst®* passive samplers, allowing to collect compounds over some weeks. Inorganic species were solvent extracted and analyzed through ion chromatography (IC). VOCs were extracted with benzyl alcohol and analyzed through gas chromatography coupled with mass spectrometry (GC-MS). Cartridges for active sampling were thermally desorbed and characterized through GC-MS.

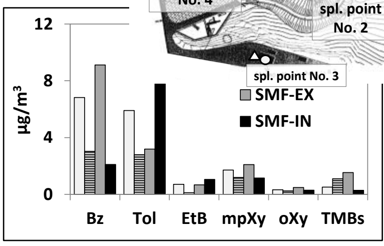


Fig. 2. Mean VOC concentrations at SGF and SMF landfills. EX = external locations; IN = internal locations (mean).

Figure 2 provides a synthesis of VOC measurements performed with active sampling during the first campaign (June 2015). Compounds were usually more abundant outside of dumps, the sole important exception consisting in toluene at SMF (H_2S rich location).
Toxic butadiene was ca. 3 times more outside of landfills than inside (~ 0.3-0.5 µg/m^3 vs. 0.1-0.2 µg/m^3, respectively).

As for the inorganic toxicants, the two landfills showed different trends. At SGF (still active with regards to biogas release) SO_2 and NH_3 were more inside (4.2 vs. 2.1 µg/m^3 and 6.0 vs. 3.5 µg/m^3, respectively), while the reverse was observed at SMF (1.7 vs. 2.3 µg/m^3 and 2.6 vs. 3.9 µg/m^3) in active for some 10 years now. NO_2 was everywhere more inside than outside of landfills (4.7 vs. 4.2 µg/m^3 at SGF and 3.6 vs. 2.5 µg/m^3 at SMF).

Conclusions
Two closed dumps were investigated for the release of VOCs and inorganic toxicants into the atmosphere in Calabria, Southern Italy. The emission of aromatic compounds could be identified at one landfill, that of SO_2 and NH_3 at the other one; NO_2 seemed to be released by both of them.

APPLICATION OF DIGITAL IMAGE PROCESSING TECHNIQUE IN DETERMINING VISUAL AIR QUALITY: A FEASIBILITY STUDY

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Introduction

Estimating the atmospheric visibility is of importance for air and ground transport safety, as well as for air quality. Visibility reduction due to air pollutant is particularly severe in polluted and populated urban areas with pollution sources and unfavorable meteorological condition. Atmospheric pollutants may cause visibility reduction by absorbing or scattering of visible light. Both gases and particles scatter and absorb radiation and contribute to the light extinction in the atmosphere. Several instruments have been developed to monitor visibility. However, in recent years the digital techniques on camera images are rapidly applied in visibility monitoring. Digital image data can be characterized by illumination and reflectance components and translated to specific brightness value.

Data and Methods

This paper an image processing technique has applied to estimate light extinction based on the visual content of images from a static camera and to investigate the influence of air pollutants on extinction for the selected cases. A series of images obtained by a digital camera from 2010 to 2011 in the urban area of Tehran. The approach to determining extinction includes three steps: 1) Selecting a target in the digital images, 2) Computing the difference between the brightness of the target and the background. 3) Calculating the inherent and apparent contrast ratios to determine image extinction for each image.

Measurements of air pollution concentration are also used for the selected cases, in order to find a mathematical modeling approach to relate the pollutant loading and extinction of each image. Air pollution data are sampled using instruments which are outlined in Table 1, consists of particulate matter and gaseous pollutants.

Table 1 Equipment used for pollutant sampling

Pollutant	Equipment model	Principle of operation
SO_2	AF22M	Fluorescence in ultraviolet
NO_2	AC32M	Chemiluminescence of NO in presence of highly oxidizing O_3
O_3	O342M	Absorption in ultraviolet light
PM_{10}	MP101M	Cyclic measurement by Beta gauge
CO	CO12M	Detection of the absorption in the infrared

Results

Clear days and polluted days were digitized and the extinction of each image is computed. The most polluted day with the visibility of less than 3 km has the lowest contrast of -0.154 and the highest extinction of about 1.11 km^{-1}that accompanied with a highest concentration of No_x of about 346ppb.

Comparison between the image extinction and pollutants concentration on clean and polluted days, shows that the light scattering by small particles that converted from gaseous air pollutants, is a major contributor to the extinction rather than by large particles. More case studies should be investigated for a long-time period to propose the visual air quality indicator based on image processing, to be use as a tool for an emission control program.

Keywords: extinction coefficient, visual air quality, image processing.

DETERMINATION OF 19 PAHS IN AIR SAMPLES USING GAS CHROMATOGRAPHY - MASS SPECTROMETRY

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Summary
The aim of our study was to develop an efficient and selective method for the determination and quantification of 19 PAH compounds in the atmosphere of the Thessaloniki in Greece. Air samples were collected in two sampling sites during the cold period, in year 2013. Nineteen PAHs were analysed using gas chromatography/mass spectrometry. The calibration curves were estimated using the internal standard calibration method. For the quality assurance and control, laboratory blanks and field blanks were extracted and analyzed in the same way as the samples. The method detection limit (for an air volume of 55 m^3) ranged from 0.008 to 0.27 ng/m^3, depending on the PAH compound considered. Validation of the analytical procedure was carried out by analyzing a standard reference material of urban particulate matter (NIST, SRM 1649b). This analysis was in good agreement to the certified values (i.e. PAH recoveries above 80%). PAHs concentrations were higher in the urban background station, due to the increase in biomass combustion.

Introduction
Over the last years, as a result of the economic crisis, there was an evident increase in biomass, which deteriorated the air quality during the winter in the area of Thessaloniki, Greece (Sarigiannis et al, 2014). Biomass burning has been associated to emissions of smaller fractions of PM. Moreover, PAHs of higher molecular weight, hence more toxic, are mostly adsorbed to finer PM. Under this scope, it would be of particular interest the analysis of PAHs in an area significantly polluted by biomass emitted PM.

Methodology and Results
A campaign of PM measurements in air was conducted between January and mid April of 2013 in Thessaloniki, Greece. PM1.0, PM2.5 and PM10 particles were collected in an urban background site and a traffic site. PAHs were extracted using dichloromethane in an ultrasonic bath. Hexane was added and the extract was filtered and cleaned in a chromatography column. The extract was concentrated to 0.4 ml and a known amount of internal standard solution was added. Nineteen PAHs were analyzed by a gas chromatography/mass spectrometer system (GC/MS) operated in the SIM mode. Total run time was 60 min. The calibration curves were estimated using the internal standard calibration method. Chromatographic peak areas were fitted by linear regression. All calibration curves showed good linearity (over 0.995). For the quality assurance and control, laboratory blanks and field blanks were extracted and analyzed in the same way as the samples. The method detection limit (for a volume of air of 55 m^3) ranged from 0.004 to 0.27 ng/m^3, depending on the specific PAH. The validation of the analytical procedure was carried out by analyzing a standard reference material of urban particulate matter (NIST, SRM 1649b). This method showed good agreement to the NIST certified values with PAH recoveries ranging from 83.2 to 109.3%, depending on the specific PAH compound. The values found in this study indicate that the analytic protocol presented good accuracy. Concentrations in samples from the two monitoring stations showed variations both in PM fractions and PAH compounds. PAHs concentrations were higher in the urban background station, due to the increase in biomass combustion.

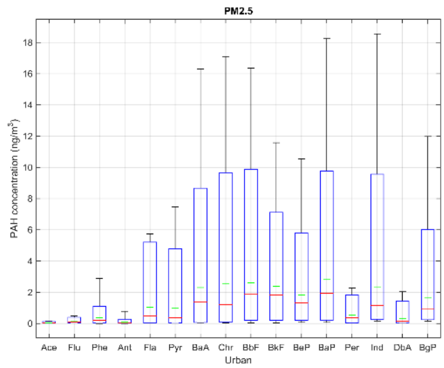

Fig.1 PAH concentrations in the urban station

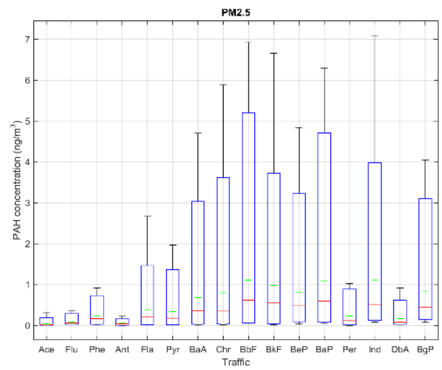

Fig.2 PAH concentrations in the traffic station

Conclusions
The method developed showed good precision and accuracy and is able to detect and quantify PAH compounds at very low concentration in the air. Estimated concentrations in the urban background station found to be higher than the concentrations of the traffic background station due to the increase in biomass burning.

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MICROBIAL AIR QUALITY AND SURFACE CONTAMINATION IN HOSPITAL AMBULANCE SERVICES – AN EXPLORATION

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Introduction
Healthcare personnel working in the ambulances may be at risk to blood-borne, airborne, droplet, and direct contact infections due to medical and health care practices administered to the patient in a closed air ventilation system and limited air space. The objective of the study was to assess microbial air quality and bacterial surface contamination on medical instruments and the surrounding areas among 15 ambulance runs during service.

Methods
A cross-sectional study of 53 air samples collected from 15 ambulances before patient services and 111 air samples collected during patient services to assess the bacterial and fungal counts at the two time points. Additionally, 113 surface swab samples were collected from medical instrument surfaces and the surrounding areas before and after ambulance runs. Groups or genus of isolated bacteria and fungi were preliminarily identified by Gram's stain and lactophenol cotton blue. Data were analyzed using descriptive statistics, t-test, and Pearson's correlation coefficient with a p-value of less than 0.050 considered significant.

Results
The mean and standard deviation of bacterial and fungal counts at the start of ambulance runs were 318±485cfu/m3 and 522±581cfu/m3, respectively. Bacterial counts during patient services were 468±607cfu/m3 and fungal counts were 656±612cfu/m3. Mean bacterial and fungal counts during patient services were significantly higher than those at the start of ambulance runs, $p=0.005$ and $p=0.030$, respectively. The predominant isolated bacteria and fungi were Staphylococcus spp. and Aspergillus spp., respectively. Additionally, there was a significantly positive correlation between bacterial ($r=0.3$, $p<0.010$) and fungal counts ($r=0.2$, $p=0.020$) in air samples and bacterial counts on medical instruments and allocated areas.

Conclusions
The study revealed high microbial contamination (bacterial and fungal) in ambulance air during services and higher bacterial contamination on medical instrument surfaces and allocated areas after ambulance services compared to the start of ambulance runs. Additionally, bacterial and fungal counts in ambulance air showed a significantly positive correlation with the bacterial surface contamination on medical instruments and allocated areas.

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NANOPARTICLES ASSESSMENT IN SAPIRANGA CITY, SOUTHERN BRAZIL

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Summary

The aim of this study was to evaluate the nanoparticles number concentration (PNC) and size distribution at two locations of Sapiranga city, Southern Brazil. An average concentration of $3.14 \times 10^4 \pm 1.89 \times 10^4$ particles/cm³ was obtained in the city center (site T), an area under traffic influence and residential biomass combustion. The background in this city (site B) presented $1.00 \times 10^4 \pm 0.67 \times 10^4$ particles/cm³. Furthermore, the results indicated that nanoparticles, probably from biomass combustion, increases especially on weekends, impacting in greater concentration than on weekdays and with larger particle diameters.

Introduction

Atmospheric nanoparticles, especially those with a diameter <300 nm, can cause health effects because they can penetrate more deeply into the human respiratory system and increase damaging toxicological effects. These particles are mainly emitted by vehicles, but in certain conditions, biomass combustion can be an important anthropogenic source (Wardoyo et al., 2006). Thus, the objective of this work was to study the concentration and size distribution of nanoparticles in an area in southern Brazil that is under the influence of these two sources.

Methodology and Results

Atmospheric nanoparticles (10 to 420 nm) were measured during the winter of 2014 in 2 locations of Sapiranga, Southern Brazil, with a Scanning Mobility Particle Sizer model 3910 (TSI Inc. Manufacturer). The area in the city center (site T) was under traffic and domestic biomass combustion influence and presented an average concentration of $3.14 \times 10^4 \pm 1.89 \times 10^4$ particles/cm³, whereas the background location in this city (site B) presented $1.00 \times 10^4 \pm 0.67 \times 10^4$ particles/cm³. At site T, daily variation shoes two well defined peak concentrations at 9 h and 19 h, corresponding to periods when many vehicles are in circulation. For the weekend stands out the maximum PNC at 21 h.

Both locations (B and T) presented a trimodal size distribution for the average nanoparticles concentrations. Mode 1, centered on ~14 nm, can be attributed to the particles formed in the atmosphere through the gas-to-particle conversion from the vehicle exhaust gases. The mode 2, centered between 32 and 36 nm, and mode 3, centered on ~ 99 nm, may be attributed to particles formed in the vehicle combustion chamber (or shortly thereafter) or be associated with biomass combustion or other source not related to vehicles emissions. If we consider the measurements only made on weekends in the T site, when little influence of vehicle traffic is expected, it can be observed that the particles from modes 2 and 3 are still in high concentration and the mode is observed at larger diameters. Although the emissions of nanoparticles from biomass combustion are not well characterized and they depend on biomass type and combustion temperature (Wardoyo et al. 2006), higher nanoparticles on weekends could be related to biomass combustion for residential purposes, or wood and charcoal combustion for barbecue, which is quite common in the study area. This is consistent with another study developed in this region which indicated that at site T biomass combustion contribute to about 22% of the $PM_{2.5}$ level observed (annual average of 18.6 µg/m^3) and local traffic exhaust for 9%.

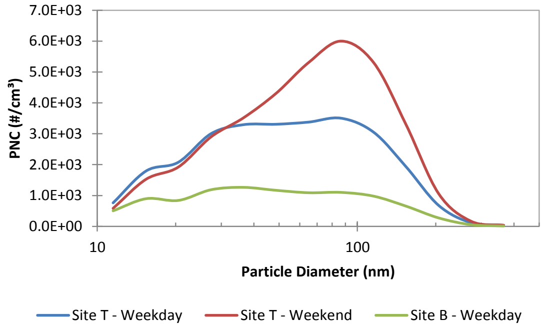

Fig 1. Mean nanoparticles size distribution.

Conclusions

In this study were evaluated the concentrations and size distribution of nanoparticles in two locations of Sapiranga, southern Brazil. The city center presented an average concentration about 3 times higher than the background, probably due to vehicle emission and biomass combustion. Higher concentrations of nanoparticles were obtained at site T at the weekend than during the week, which was mainly related to the contribution of biomass combustion. This is confirmed by the fact of being observed more particles with larger diameters.

Acknowledgement

We are grateful to CAPES, FEPAM, and the Swedish Meteorological and Hydrological Institute for cooperation in this study.

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THE IMPACT OF SPEED AND CONGESTION ON TRAFFIC EMISSIONS WITH SPECIFIC ATTENTION TO DATA ANALYSIS

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Summary
Traffic maximum speed and congestion have an impact on traffic emissions. Often these relations are established under test conditions. However, in practice the mutual effects of a reduced speed limit and its impact on congestion are site dependent and hard to estimate. We assessed the impact of a change of speed limit (80 and 100 km/h) on traffic emissions, combined with its secondary effect on congestion. The data were derived from a routine monitoring network and not from a dedicated research monitoring set-up. Specific attention was given to data-analysis aspects of air quality time series data.

Introduction
An urban motorway had its speed limit changed from 80 to 100 km/h (and back again). The effect of the lower speed limit was twofold: lower emissions and a more homogenous traffic flow and less congestion, which led to further emission reduction. We studied the impacts of speed limits and congestion on the traffic emissions using a roadside monitoring site at this urban motorway. Two routine city monitoring stations served as background. The data analysis specifically focused on (a) the selection of an appropriate model that minimises the impact of changes in background concentrations that could hamper the interpretation of the results; (b) testing regression techniques that account for the time-series nature of the air quality data (data with autocorrelation).

Materials and Methods
Hourly air quality data (NO, NO_2, Black Carbon) from two urban background and one roadside monitoring station were used. Hourly traffic intensity and vehicle speed on the urban motorway as well as hourly local meteo data were obtained. The average city background was calculated as a proxy for the precise local background, and subtracted from the hourly roadside measurements to estimate traffic contribution. Hours with wind perpendicular to the road were used to study the traffic contribution measured on the roadside station.
The model that was used, tested the change of the traffic contribution *per unit of traffic* rather than the change in concentration as such: TrafficConcentration= $\alpha+\beta1\cdot$TrafficIntensity+ $\beta2\cdot$TrafficIntensity$\cdot\Delta$ (where Δ=0 default speed and Δ=1 during the change). This is preferred over a simple model like TrafficConcentration= $\alpha+\beta1\cdot$TrafficIntensity+ $\beta2\cdot\Delta$. The first model corrects (to some extent) for errors in the assumed background (α) and is less sensitive to other changes than the traffic contribution whereas the second model might test positively for any change in concentrations, irrespective if it is due to traffic or not. Congestion was defined as the difference between the observed vehicle speed and the maximum vehicle speed (during quiet hours). This provided a continuous variable to test the impact of congestion on vehicle emissions.
Linear regression assumes the absence of autocorrelation. We tested several techniques (Newey-West standard errors, block-bootstrapping) to correct for autocorrelation, leading to higher standard errors of the regression parameters.

Results and Conclusions
Speed limit reduction has a significant positive effect on the traffic emissions. We found that the speed limit increase from 80 to 100 km/h led to 20% and 17% increase in traffic concentration contribution of NOx and BC respectively. Our results indicated that this effect mainly occurred during hours with congestion (see Willers et al. 2013, Fig.4) and were partly due to the increased congestion. Table 1 shows that at a higher maximum speed, the drop in actual average speed during the rush hours is higher, indicating higher congestion. The standard deviation of the vehicle speed, particularly during rush hours, also decreased when the speed limit was reduced (see Willers et al. 2013, Fig.3a/b).

Table 1. Average observed vehicle speeds (km/h), direction into town, under different conditions.

Speed regime 100 km/h			Speed regime 80 km/h		
Free flowing speed	rush hour	Difference	Free flowing speed	rush hour	Difference
87	63	24	74	56	18

The intercept (α) in the regression model showed that the city background underestimated the true local background but even without a proper upwind/downwind research setup the effect of the speed limit change could be studied with the available routine monitoring sites. A significant change in emissions per unit of traffic was observed.
Linear regression underestimates the standard errors of the regression parameters when applied to hourly air quality data. The relative uncertainty of the effect estimator in OLS was 7%, increasing to 15% if Newey-West estimators are used (depending on the numbers of lags included). Bootstrapping yielded a 15% relative uncertainty, going up to 45 % depending on the block size. OLS is too optimistic and can lead to false positive outcomes. However, the other methods involve making assumptions with major impact on the outcome. A proper time-series statistical treatment could be needed to obtain correct uncertainties.

Acknowledgement
We would like to thank Joost Wesseling for testing the impact of block size in block bootstrapping.

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CHARACTERIZATION OF INDOOR/OUTDOOR PM_{10}, $PM_{2.5}$, PM_1 AND RADON CONCENTRATIONS IN AN OLD MEDICAL CENTER

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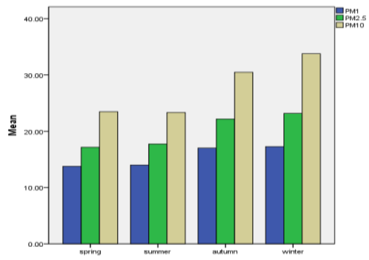
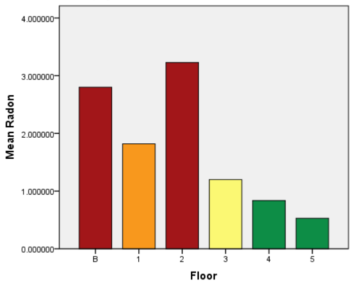
Summary
This study aims to quantify and analyse indoor and outdoor PM_{10}, $PM_{2.5}$, PM_1 concentrations and [222]Rn emissions in an old medical centre (Imam Khomeini Hospital) which is located in downtown district of Iran's capital city. We investigated these concentrations were monitored in six floors and three locations (nursery station, treating rooms, outdoors) with portable analysers, in six days of every seasons through a year. At same time all ambient air temperature, pressure and humidity data and air conditioning system arrangements and design basis collected to know what are the probable meaningful relations are exist among particulate matters, [222]Rn, and air conditions. Finally some improvements for modelling are recommended.

Introduction
The significance of both particulate matter and Radon emissions in medical centres is underscored by the presence of a large numbers of patients, visitors, and medical staffs. The link between increased particle pollution and health issues has been well documented (e.g. Pope and Dockery, 2006). However, research has shown that Radon emissions also contribute significantly to atmospheric particle concentrations, highlighting the need to investigate this kind of emissions and their sources, relations, and health effects. Considering this, we quantified the indoor and outdoor PM_{10}, $PM_{2.5}$, PM_1 concentrations and [222]Rn emissions at same time to assessment of probable risks.

Methodology and Results
Particulate matters analyser (Dust Trak 8520), Radon meter (RADSTAR RS800), ambient air condition analyser (Lutron MHB 38SD) were employed in the medical centre for monitoring and recording data (see Fig.1). The PM10 and PM2.5, PM1 average concentration were 27.75, 20.05, 15.50 and varied between 7-49 µg/m3, 6-37 µg/m3 and 5-33 µg/m3, respectively. The records showed that the average of Radon emissions in floors of building were 2.8 Bq m^{-3} , 1.8 Bq m^{-3} , 2.8 Bq m^{-3} 3.2 Bq m^{-3} , 1.2 Bq m^{-3} , 0.83 Bq m^{-3} and 0.53 Bq m^{-3}respectively. The statistical analysis between all dependant and independent variables has done by SPSS and strong positive correlation was observed between PM10 and PM2.5, PM1 changes in floors, seasons of year, and locations based on ambient air conditions. The concentration of [222]Rn and PM2.5 and ambient pressure showed meaningful relations.





The outdoor/indoor parameter changes calculated in this study and a regression model established to analysing all variables. The CONTAM software applied for modelling of all indoor areas with many type of conditioners for assessing of exposure of PM and Radon as well. The current study has shown that the combined Radon and PM10 in 2nd floor and in summer time have a little unhealthy potential for medical centre.

Conclusions
Radon will not contribute significant to atmospheric particles as unhealthy potential but we recommend that this study continue in other sites and locations.

Acknowledgement
We acknowledge Dr. N.Mansouri and Mr. Sadrzadeh for their help during this study.

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MEASUREMENTS OF OZONE AND RELATED TRACE GASES AT SEMI-ARID URBAN SITE OF INDIA: DIURNAL AND SEASONAL VARIATIONS IN AIR QUALITY

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Summary
Aim of the study is to characterize the temporal variations of trace gases. The relationships between trace gases and role of meteorological parameters have been investigated. We have also used NCEP wind and back trajectory data to understand the role of regional transport in the variations of trace gases. The study is based on the measurements of O_3, CO and NO_x along with meteorological parameters at Udaipur in western India. The day time O_3 mixing ratio varies from season to season with highest in pre-monsoon season while lowest in monsoon season. The mixing ratios of both CO and NOx show very clear seasonality with highest during winter season and lowest during the monsoon season. The mixing ratios of O_3 were mostly observed in the low CO and NO regimes.

Introduction
In recent years, the rapid urbanization and industrialization have resulted in substantial degradation of air quality in many urban regions of India. The increasing level of air pollution is a major cause of concern and impact may extend from local to global scale (Sahu et al., 2011). The large emissions of trace gases and aerosols from a variety of sources are one of the major environmental issues in urban and industrial areas (Wang and Hao, 2012). The precursor gases emitted in this part of the world can be transported to the longer distances due to strong convective dynamics. Therefore, urban emissions in the tropical regions such as India can influence the O_3 formation at remote regions (Brankov et al., 2003). The variations in surface level temperature can strongly influence the kinetics of reactions producing O_3 and also through the mixing with O_3-rich free tropospheric air (Wang et al., 1998).

Methodology and Results
The observational site and road map of Udaipur city have shown in Fig. 1. This city is located in the Arawali hill ranges in the southern part of Rajasthan, a western state of India. The surface level measurements of O_3 and its precursors (CO, NO_x) were performed using online analysers. The meteorological parameters were simultaneously measured using automatic weather station. We have used hourly data of trace gases on diurnal scale
and Seasonal scale.

Fig.1 Observational site

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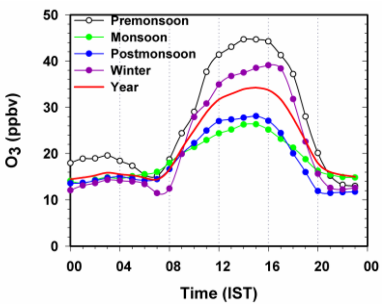

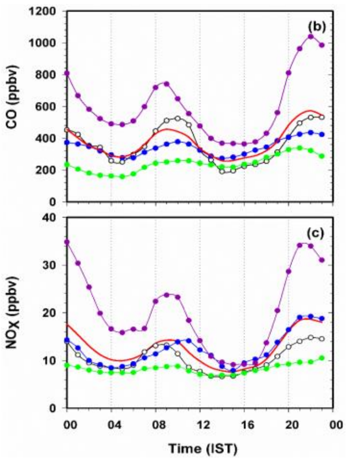

Fig.2 Diurnal variations of O_3 CO and NOx

Conclusions
The major sources of primary gaseous pollutants are the emissions from biomass/biofuel burning, vehicular exhaust and small industries at Udaipur. The pattern of diurnal dependence remained same but strength of variability varied from season-to-season. The seasonal changes in other processes like PBL depth, photochemistry and meteorology seem to play important role in the observed distributions of trace gases at Udaipur. The data presented in this study is useful to understand the regional air quality and
atmospheric chemistry of in the western region of India.

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SOURCE APPORTIONMENT AND EMISSION MODELS-INVENTORIES

PM1 CHARACTERISATION AND SOURCE APPORTIONMENT AND AEROSOL SIZE DISTRIBUTION AT A HOT-SPOT POLLUTION AREA (MILAN, ITALY).

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Summary

This work aimed at a detailed physical and chemical characterisation of PM1 and at singling out major sources contributing to the high concentrations observed in the urban area. Examples of number size distribution and of elemental, ionic and carbonaceous fractions size distribution will be also presented.

Introduction

It is well known that the particle size plays a major role in determining the penetration of particles in the respiratory system and their effects on the human health. Despite this fact, data on PM1 composition and sources are still relatively rare. Hot-spot pollution areas are peculiar sites where source emissions and meteorological conditions foster particulate matter accumulation and very high aerosol concentrations are often registered. The Po Valley is one of the main hot-spot pollution areas in Europe, especially during wintertime. Despite the high levels of PM registered in the area, little knowledge on PM1 and ultrafine particles composition and sources is available, apart from a couple of studies carried out by our group in 2002 and 2004 in the same area.

Methodology and Results

PM1 was sampled at an urban background station in Milan, Italy, during winter 2011-2012. Milan is the greatest urban area in the Po Valley, a well-known hot-spot pollution area in Europe, especially during wintertime. Parallel PM1 sampling was carried out during daytime and night-time (07-16, 19-04) on PTFE and quartz fibre filters using two low-volume samplers for a total of about 250 samples. Mass concentration was determined by the gravimetric technique and all the PM1 samples were chemically characterised for elements, inorganic ions, levoglucosan, EC/OC and water soluble organic compounds, allowing to perform the mass closure (see Fig.1). BC determination was also carried out on both PTFE and quartz fibre filters by a polar photometer (Vecchi et al., 2014). Moreover, BC concentrations in PM1 were monitored with a 5 minute resolution by a Multi-Angle Absorption Photometer (MAAP).

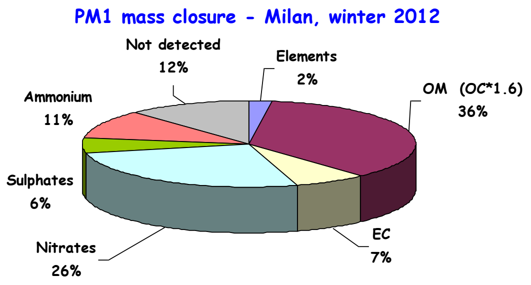

Fig.1 Source apportionment of PM1

The aerosol number size distribution was obtained by an optical particle counter (range 0.25-32 µm in 31 size bins) and a differential mobility particle scanner (8-700 nm in 31 size bins). The size-segregated mass, ionic and elemental concentrations were obtained by analyses performed on samples collected using multistage cascade impactors. The aerosol size distribution showed 3-4 modal distribution for both mass and chemical components in most cases. Two accumulation sub-modes were often detected at 300 nm and 600 nm and they can be likely related to fresh and aged aerosol.

PM1 data were analysed by receptor modelling using Multilinear Engine ME-2 and 6 factors were identified. The most relevant contributions to PM1 as daily averages were from ammonium nitrate (36%), ammonium sulphate (25%), and biomass burning (about 21%) followed by traffic (9%) and industry (8%), and road dust (2%). It is noteworthy that only for wood burning a higher contribution during night-time was detected.

Conclusions

The detailed chemical-physical characterisation of PM1 allowed performing the source apportionment through receptor modelling evidencing major source contributions to this aerosol fraction.

The detailed chemical characterisation of size-segregated samples allowed to gain insight into atmospheric processes (e.g. aging) impacting on aerosol particles.

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CAN FLOATING CAR DATA HELP IMPROVING TRAFFIC EMISSIONS ESTIMATES?

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Summary
Highly accurate traffic information can help to improve the estimates of traffic related pollutant emissions. In the last years there has been an increase in the use of navigation devices (i.e smartphone applications, in-dash devices). Additionally, some new vehicles are equipped with onboard diagnostic systems that collect data on time, position, speed and fuel consumption. Data from these devices has been used by companies and governments to offer solutions on traffic flow in real-time. In this work we explore how data obtained by navigation devices and on-board-systems can be used to improve traffic emission estimates in urban environments.

Introduction
Traffic emissions are a major source of air pollution in urban areas all over the world. There are numerous scientific evidences that air pollution possess a threat to human health (e.g. Lanki, et al., 2015). In order to manage air quality effectively it is necessary to estimate accurately traffic emissions. The estimation of vehicle emissions at fine scale is mainly challenging due to limitations in the availability and quality of traffic-related input data.
Traffic emissions depend, among other variables, on the vehicle speed and the traffic flow. Traffic models can be used to estimate vehicle speed and traffic flow in different road segments (Zhou et al.,2015). The main challenge for the use of traffic models is that they need to be calibrated for the local conditions. Another approach is the usage of automatic traffic recorders (ATR) to obtain vehicle speed data. However, ATR systems are expensive and they are usually only located in main streets, not providing a wide coverage of the city.
Nowadays, most drivers use navigation devices and most vehicles are equipped with onboard diagnostic systems. The data obtained from these systems is usually referred as Floating Car Data (FCD), and it consist of data (i.e. GPS, fuel consumption) collected from individual vehicles while moving in the city. The main focus of this technology is traffic management, however it offers a great potential for other applications as for instance emission estimation as it provides high temporal and spatial resolution of vehicle speed.

Methodology and Results
In this work we explore two approaches to estimate traffic emissions: (i) Buses equipped with onboard diagnostic system (OBS) and; (ii) historical speed data collected by TomTom.
Two buses from the Oslo fleet were equipped with OBS and GPS to collect data on location, time stamp, speed and fuel consumption with temporal resolution of 1 second. One of the buses is a diesel-fuelled vehicle and the other uses Compressed Natural Gas (CNG). The buses cover and alternate between several line routes in Oslo offering a good spatial coverage of the urban area.
Vehicle speed data collected by TomTom was acquired for the city of Oslo. TomTom uses multiple sources to collect GPS data, as for instance, in-dash and on-dash devices, LIVE navigation devices, smarthphone navigation apps and fleet management systems. The different sources are fused and GPS derived speed can be obtained in a temporal resolution of 15 minutes over a road segment. Information such as type of vehicle, technology, age and fuel is not available from the TomTom database.
We have generated speed, fuel consumption and traffic emission maps for the city of Oslo using the detailed information on FCD provided by the two methods tested in this work. The results show significant differences in the speed when it is obtained using FCD versus other methods (i.e. speed limit, traffic models). These differences on speed have an impact on the estimated traffic emissions.

Conclusions
FCD have advantages over other traditional methods to estimate traffic emissions (e.g. lower cost, higher resolutions). FCD systems are becoming ubiquitous and nowadays most of the urban fleets (taxis, buses, god transport, etc.) and private vehicles are equipped with navigation systems. The results obtained in Oslo show that FCD offer the possibility of estimating more realistic speed profiles and fuel consumption at higher resolutions than conventional systems. The FCD has been successfully employed in a traffic emission model in Oslo. The combination of aggregated data from TomTom with detailed data from specific fleets offer the possibility to distinguish driving patterns (i.e. public transport uses dedicated lanes and have more stops than private vehicles).

Acknowledgement
Citi-Sense-MOB is funded by The European Mobile and Mobility Industries Alliance (EMMIA).

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ESTIMATING THE AIR MANGANESE EMISSION IN THE SANTANDER BAY (NORTHERN SPAIN)

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Summary
The levels of atmospheric manganese in the Santander Bay (Northern Spain) are high, exceeding in some sites the WHO annual guideline value (150 ng/m^3) [1]. The air quality relative to the Mn exposure in the Santander Bay may be evaluated by means of air quality models, which require reliable Mn emission rates from the identified sources. Because Mn is neither included in the Spanish National Emission Inventory, nor in the European Pollutant Release and Transfer Register (E-PRTR), the manganese emission needs to be calculated. Thus, the manganese emission inventory in the Santander Bay from 2008 to 2013 was carried out, and the manganese emission rate for each identified point and area source was calculated to be implemented in future air quality models. Since Mn was not used as gasoline additive (methylcyclopentadienyl manganese tricarbonyl, MMT) in Spain, the majority of the emitted manganese was attributed to local industrial activities.

Introduction
The presence of metals in air adversely affects the human health. Manganese is one of metals of concern; although it is essential for humans and other species, it is neurotoxic at very high levels. When inhaled, it can produce significant neurotoxicity, and people expose to high levels of Mn may suffer a disease called "manganism" [2]. The effects of the non-occupational exposure to Mn are not clear enough at the moment, but the WHO recommends an annual guideline value of 150 ng/m^3. This value has been exceeded in some sites of the Santander Bay, mainly in the town of Maliaño, where a ferromanganese and silicomanganese plant is located [1]. So, the aim of this work is to evaluate the main emissions of atmospheric manganese to the Santander Bay in order to have reliable input data for future air quality models to be implemented in this area.

Methodology and Results
The manganese emission inventory considered only local industrial sources: a ferromanganese and silicomanganese plant, a non-integrated steel plant and two iron foundries. Since the ferroalloys plant was the major Mn emitter, their emissions were evaluated in two ways: (i) through emission factors developed by the US EPA[3] and energy consumption factors for SiMn and FeMn, after considering several assumptions (efficiencies of the hooding systems and the particulate matter control devices); (ii) and through the measured PM10 concentration data. Continuous PM10 monitoring data were available for the gas stream exiting the main electric furnaces, EAF1 and EAF2 (see the point sources F1 and F2 in Figure 1); additionally, discrete PM10 measurements in other point sources were also available in the Environmental Report published by the company (e.g. F7 in Figure 1). Fugitive emissions were also considered through area sources, taking into account the particulate matter emissions from the openings on the wall of the main buildings where electrical furnaces were located (see D7 in Figure 1). Emissions from non-systematic point sources were also considered (see F13 and F14 in Figure 1). The results show the high contribution of the ferroalloys plant to the total Mn emissions in the Santander Bay followed by the non-integrated steel plant. Considering the efficiencies of the hooding systems given in the BREF document of non-ferrous metallurgy, the contribution of fugitive emissions is much higher than that of the point sources, which are equipped with high efficiency particulate matter control devices. The annual Mn emissions (kg Mn/year) were also calculated as instantaneous manganese emission rates (g Mn/s) for weekend and non-weekend scenarios. This will allow to implement such inputs into air quality models.

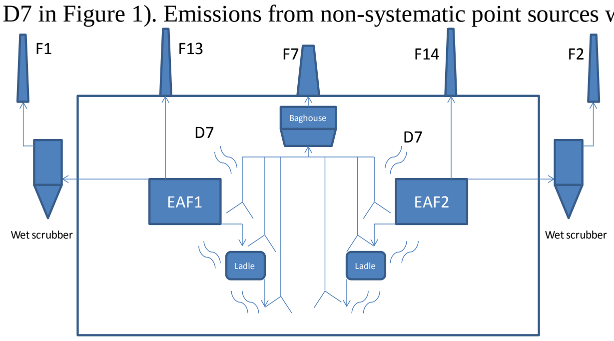

Figure 1. Diagram of the manganese emissions from a ferromanganese alloy smelter

Conclusions
The evaluation of the atmospheric manganese annual emissions in the Santander Bay indicates the high contribution of a ferroalloys plant to the total emissions and the importance of the fugitive emissions with respect to those of point sources.

Acknowledgement
This work was supported by the Spanish Ministry of Economy and Competitiveness (MINECO, CTM2013-43904-R). The authors also thank the Regional Environmental Department of the Cantabria Government for providing PM10 emission data.

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QUANTIFICATION AND CHARACTERIZATION OF EMISSIONS FROM OPEN-FIELD AGRICULTURAL RESIDUE BURNING IN MAHARASHTRA

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Summary
This study aims to estimate and compare the total air pollutant emissions from open filed agriculture residue burning with bottom up and top down approaches for India and assess its spatial distribution. A total of 980 Gg/yr CO emissions are estimated for India using Global Fire Emissions Database (GFED). Western Indo-Gangetic Plain, Central India and Southern India together contributes 80% of the total open agriculture residue burning emissions, which is bound to increase with further mechanization of farming in India. Bottom up and top down comparison shows that there are uncertainties in emissions estimation as top down underestimates and bottom up overestimates the emissions. All these uncertainties need to be improved to get better estimation of the emission from agriculture residue burning depending upon the geographical area and seasons by field survey and measurement of emission from actual field burning.

Introduction
Open biomass burning is the largest source of carbonaceous particles and second largest source of trace gases. In South Asia, open field agriculture residue burning dominates the open biomass burning.In India, it contribute about 20% of carbonaceous aerosol emissions (Venkataraman et al., 2006). Bottom up and top down estimates have uncertainty in emission estimation. Considering this, emission from bottom up and top down approaches have been estimated and compared.

Methodology and Results
The state wise emissions from open field agriculture residue burning were calculated using bottom up and Top down methodology.A geographical information system (GIS)-ArcGIS was applied to allocate emissions in different regions of India and the spatio-temporal comparison of emissions between both methodologies (Bottom up and Top down) was done. From top down approach, total 980 Gg/yr CO emissions were estimated for India using GFED database.Western Indo-Gangetic Plain (IGP), Central India and Southern India contribute 60%, 12% and 10% of total open agriculture residue burning emissions, respectively, which is bound to increase with further mechanization of farming in India. Spatio-temporal distribution of CO emissions shows maximum emissions in October-November from IGP followed by March-June and December-February. The comparison between bottom up and top down estimation shows an average factor difference of 11.95. Also, the state-wise CO emissions had shown different pattern as maximum emission from Top down approach (GFED) were calculated for Punjab followed by Haryana and Uttar Pradesh but maximum emissions for Uttar Pradesh were calculated from bottom up methodology. Thus, there are uncertainties in emissions estimation as top down underestimates and bottom up overestimates the emissions. Field surveys to understand the crop residue uses and distribution and measurement campaigns to characterize the emissions from open burning of different agricultural crop residues is currently underway.

Table1. Monthly CO emissions from open field agriculture residue burning

MONTH	CO (Gg)
December	23
January	22
February	33
Total (DJF)	78
March	57
April	126
May	130
June	25
Total (MAMJ)	338
July	3
August	4
September	6
Total (JAS)	13
October	210
November	422
Total (ON)	632

Table 2. Comparison between top down (GFED) and bottom up CO emissions (Gg)estimation

Year	INDIA (GFED)	INDIA (Bottom up)	Ratio (Bottom up /GFED)
2010	0.782	11.36	14.52
2011	0.996	11.7	11.75
2012	1.098	11.24	10.24
2013	0.955	11.39	11.93
2014	1.06	11.55	10.89
Average	*0.98*	*11.53*	*11.95*

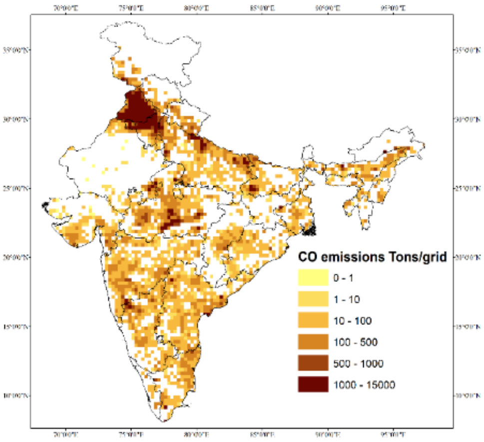

Figure 1. Spatial distribution of CO emissions in India

Spatio- temporal distribution of CO emissions

Conclusions
The open agriculture residue burning is highly variable in different states of India. There are uncertainties in the estimation of emissions from both bottom and top down methodology. The emission calculation uncertainty are related to the amount and type of agriculture residue burned in the field, proportion of crop residue burned in the field, burn efficiency and the EFs. All these uncertainties need to be improved to get better estimation of the emission from agriculture residue burning depending upon the geographical area and seasons

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ATMOSPHERIC PARTICULATE POLLUTION TO NEARBY BIZERTE LAGOON (MEDITERRANEAN LAGOON)

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Summary

Town of Bizerte are exposed to a atmospheric particulate pollution due to automobile traffic, industrialization, but also to soil dusts. Monitoring networks and data about air pollution are still rare. This study is a preliminary work about particulate and heavy metals pollution, at around the lagoon of Bizerte (North Tunisia, Mediterranean lagoon). Aerosols had been collected with a PM_{10} sampler. Analytical technique ICP-AES was used to identify the metallic composition of PM_{10}. Experimental results and statistical analysis with Particulate Matter data identify the different sources of emissions. The major sources are traffic and industrialization. It is necessary to develop monitoring network and sanitary and environmental impact studies in these cities.

Introduction

Studying the problem of air pollution has become a priority of the globe interest, especially, to determinate the air quality, the pollutant effects and to find solutions to ameliorate the situation which, unfortunately, become worse and worse every day. The suspended particles or particulate matter is an air pollutant consisting of a complex mixture of organic and inorganic substances suspended in the air, solid and / or liquid. These particles vary in size, composition and origins (Hashisho and El-Fadel, 2004). In the last few decades, the phenomenon of Particulate Matter pollution has been analyzed extensively. Many researchers have been developed in this context and especially on the relationship between particulate matter (PM) and health effects (Strawa and al., 2010). In Tunisia, many regions suffer from high concentrations levels of PM, the most affected ones are Bizerte. Hence, regarding the air quality problem, the identifying sources of emissions are early warning system for providing air quality information towards the citizen becomes an obvious and imperative need.

Methodology and Results

This article presents the results of a first study of particulate air pollution heavy metals on to nearbyof lagube of bizerte for which there is currently no data (see Fig. 1). The filters were mineralized by an attack by HNO_3 in microwave. The solutions were then were analyzed by ICP AES. Chemical analysis of the dust deposited on filter (PM10) was performed on 11 samples of different receptor sites around the lagoon of Bizerte. The elements analyzed are divided into four groups: (1) NO^{3-}, Cl^{-}, Ca $^{++}$, Mn and Zn with an average concentration is between 111.75 and 528.48 mg/Kg. (2) Cd, Co, Se, As, NTK, Mg +, Na^{+}, K^{+}, and PO_4 with an average concentration of between 1.71 and 6.08 mg / kg. (3) Cu, Pb, Ni and Cr with average concentrations between 27.89 and 86.90 mg/kg.

(4) Fe with an average concentration 7716.50mg/kg. The application of Principal Components Analysis allows to distinguish and distribute the PM_{10} sources based on correlations between measured chemical compounds. Five PM_{10} sources were identified that are allocated to traffic in the mineral (marine aerosol), industry, and natural source terrigenous, port activity (see Fig.2).

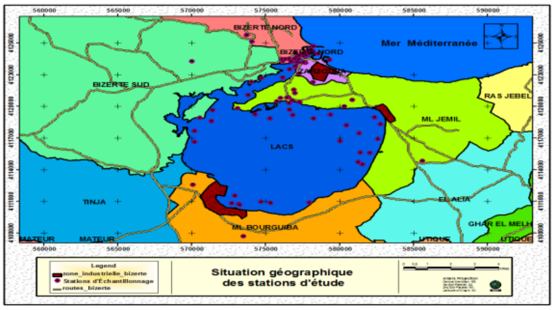

Fig.1 sampling map

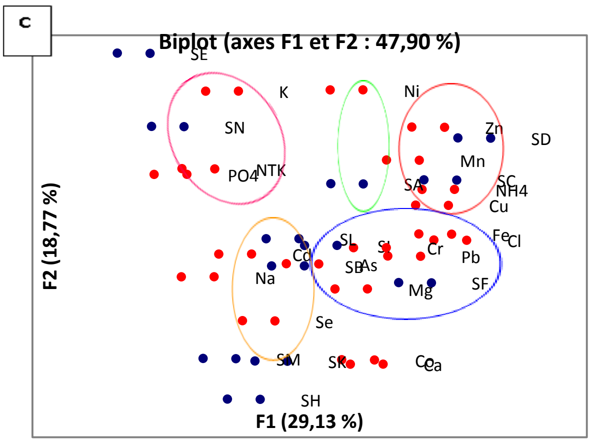

Fig.2. Identify emission sources of PM10 (PCA)

Conclusions

The PM_{10} in ambient air in the region of Bizerte come from many sources and is a complex heterogeneous mixture. The chemical composition of this mixture may change in space, according to the emission sources.

Acknowledgement

This work was supported by Agency for Environmental Protection (ANPE).

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FUGITIVE PARTICULATE MATTER EMISSIONS AT CONSTRUCTION SITES

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Summary

This study aims to examine the fugitive Particulate Matter (fPM) emissions from loose, owe to construction activities, Calcisols (soils with substantial accumulation of secondary carbonates), widespread in arid and semi-arid regions. A two months field campaign was conducted at a construction site, at rest, within the city of Doha (Qatar) to measure number concentrations of PM over a size range of 0.25-32 µm using light scattering based monitoring stations. The fPM emission fluxes were calculated using the Fugitive Dust Model (FDM) in an iterative manner and were fitted to a power function, which expresses the wind velocity dependence. The outcome of this study contributes to the improvement of PM emission inventories, since it focuses on an overlooked but significant pollution source, especially in dry and arid regions, and often located very close to residential areas and sensitive population groups.

Introduction

A major source of airborne pollution in arid and semi-arid environments, i.e. North Africa, Middle East, Central Asia, and Australia, is the fugitive Particulate Matter (fPM), which is a frequent product of wind erosion (Tsiouri et al., 2014). However, accurate determination of fPM is an ongoing scientific challenge (Neuman et al., 2009). Up to date, the vast majority of studies on fPM emissions modelling covers the wind erosion of typical soils and bare land of North America and Europe. Therefore, we focus in this study on the modelling of fPM emissions from a common soil – the Calcisols - in dry and a semi-dry regions to understand the behaviour and obtain the emission factors of fPM produced by a specific type of soil and surface conditions. We consider the wind erosion of loose soil owe to human activities i.e. construction earthworks.

Methodology and Results

A two months field campaign was conducted at a construction site within the city of Doha (Qatar) to measure PM concentrations over a size range of 0.25 to 32 µm using Grimm 365 air quality monitoring stations. The time period of the campaign was chosen deliberatively when the construction site was at rest and the only source of particles was wind erosion of the loose soil. FDM was implemented to calculate PM concentrations and obtain their emission rates in an iterative procedure. The model results were fitted to a power function, which expresses the wind velocity dependence. The power factors were estimated as 1.87, 1.65, 2.70, and 2.06 for the four class sizes (≤2.5 µm, 2.5-6 µm, 6-10 µm, and ≤10 µm) of particles, respectively. Overall, fitting is considered good with an adjusted R^2 varying from 0.13 for the smaller particles and up to 0.69 for the larger ones. These power factors are in the same range of literature values for similar sources (USEPA, 1995) as shown in Fig.1.

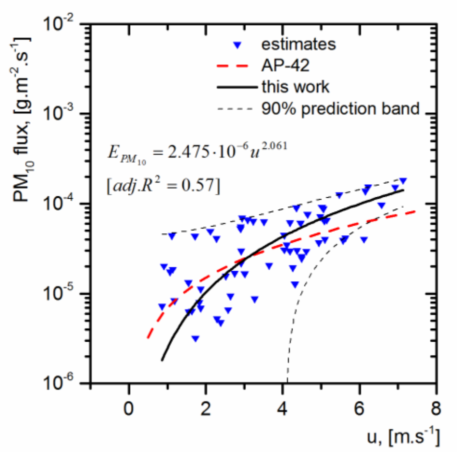

Fig.1 Comparison between this study (estimated emission fluxes), the proposed function and USEPA's AP-42 emission rates for PM_{10}

Conclusions

The release of PM from loose soil is poorly characterized in the literature and widely used inventories. This is a unique study focusing on the development of fPM emission factors from construction areas, and a specific soil type in dry and a semi-dry regions. However, further campaigns are necessary to reduce the uncertainty, include more fPM sources (e.g. earthworks) and other types of soils.

Acknowledgement

This work has been carried out under the jointly awarded grant to Texas A&M University (Qatar) and University of Surrey (UK) by the Qatar National Research Fund (a member of The Qatar Foundation; grant number: NPRP 7-649-2-241). The statements made herein are solely the responsibility of the authors.

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SOURCE APPORTIONMENT USING PMF RECEPTOR MODEL OF AIRBORNE PM_{10} IN THE PORT-CITY OF RIJEKA (CROATIA)

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Summary
This study was a part of MED project POSEIDON, with aim to compare air pollution by particulates in 4 ports: Brindisi, Patras, Venice and Rijeka. PMF receptor model was used for apportionment of principal air pollution sources. The receptor model was applied to existing data on air pollution with PM_{10}, Cd, Pb, Cu, Zn, Fe, Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+}, Ca^{2+} and 12 species of PAHs from 2008 to 2010. These constituents formed only 44 % of total PMF mass. Results obtained from the PMF model indicated 5 principal air pollution sources/factors in Rijeka: Biomass Combustion (4%), Secondary Inorganic Aerosols (21 %), Metal Industry (5 %), Sea Spray (8%) and Soil/Road Dust (6%). Conditional Probability Function was used to show connection between wind directions and factors in order to determine particulate sources of PM_{10} air pollution: shipyards, oil refineries, waste yards, roads, domestic heating, sea, and port.

Introduction
The air quality monitoring programme began in Rijeka in early 1970s, following the construction of new industrial facilities in the city's eastern industrial area (new petroleum refinery, oil burning power plant, coke plant). For this reason, the monitoring programme has focused on air pollution caused by these industrial sources. In this study the receptor model was therefore used to determine and quantify the impact of other sources, especially those coming from harbour and maritime traffic.

Methodology and Results
Sampling of PM_{10} on quartz filters were carried by HV sampler (flow: 1 m3/min) on the roof of the Institute building. After preconditioning and weighting the PM_{10} were analysed on metals (Pb, Cd, Fe, Zn, Cu) by AAS, major ions (Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Mg^{2+}, Ca^{2+}) determined by IC and PAHs determined by HPLC with coupled UV/Fluorescence detector (Phe, Anth, Py, Flo, Chr, BaA, BbF, BkF, BaP, IP, BghiPe, DBA). A total of 180 samples were collected from 2008 to 2010. In order to identify possible sources of PM_{10} the US EPA PMF 5.0 software was used (Cesari et.al., 2014). The input data were concentrations and uncertainties of chemical species contained in PM_{10}. For the analysis of the source contribution regarding the wind directions, the daily values of the wind speed and prevailing direction were used for calculation of Conditional Probability Function-CPF (Ashbaugh et. al., 1985). CPF estimates the probability that a given source contribution from a given wind direction will exceed predetermined threshold criterion. The 44 % of PM_{10} mass was explained by measured species, and after PMF analysis 5 factors were determined. The Metal Industry factor contribution was 5%, determined by high Cd, Pb, NO3-, Fe and Zn concentrations and according to CPF the most possible sources of this factors were shipyards. The most abundant factor (21 %) is Secondary Inorganic Aerosols (SIA) determined by high SO_4^{2-} and NH_4^+. It originated from Oil refineries and the most common path of ships towards the harbour. The factor of Sea Spray which contributed 8% was determined by high concentrations of ions characteristic for sea salt (Cl^-, Na^+, Mg^{2+}) but also nitrate, as a result of nitrate-chlorine depletion in aged sea salt. The Biomass Burning contribution was 4%, determined by high concentrations of K^+ ion and PAH which is characteristic for domestic heating in urban residential areas. The Dust factor contribution was 6%, determined by high concentrations of Ca^{2+}, Fe, Zn and Cu originating both from harbour where the metal waste and fertilizers are reloaded and from inland metal waste recycling deposit. There is also possibility that this factor is originating from the north-west part of city, because of resuspended road and construction site dust.

Conclusions
Combining the receptor model results with wind direction data by use of simple probabilistic function indicated possible sources of PM_{10} in the city of Rijeka. The harbour contribution was found in SIA and biomass burning (fuel combustion), as well as dust factors (fertilizer reloading in the port). Further proofs of port impact were obtained from vanadium concentration, as well as and V/Ni ratio.

Acknowledgement
The work presented is a part of MED project POSEIDON – Pollution monitoring of ship emission: An integrated approach for harbours of the Adriatic Basi**n**. We acknowledge Veljko Zubak for technical assistance.

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TAXI TIMES EFFECT ON AIRCRAFT EMISSIONS AND POLLUTANTS DISPERSION

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Summary

In order to study aircraft emission impact in a very delicate ecosystem, the Venice lagoon, a study has been performed for the Marco Polo Airport, Tessera, Venice. Emissions have been calculated with the EDMS (Emissions and Dispersion Modeling System) andpollutants dispersion with the lagrangian particle model SPRAY5. This study was aimed to understand the impact of taxi times on emission dispersion. Marco Polo Airport is characterized by lower taxi times respect to the EDMS default values that are generally used. Using real times instead of deault ones both emissions and concentrations decrease.and impact area diminishes.

Introduction

In recent years, studies that focused in aviation emissions had increased in importance, due to their impact in air quality and public health impact. Demand for air travel has been increasing in Europe and is expected to further increase in upcoming years. This demand is foreseen to exceed airport capacity by 2.3 million flights in the most-likely growth forecast European scenario for 2030. Most studies highlighted that aircraft emissions have an impact on air quality in the airports (Carslaw et al., 2006; Herndon et al., 2004) and in their surroundings (Hu et al., 2009). As a consequence an increase of aircraft movements can affect airports air quality. The ability to quantitatively predict the effects of airport operations is of importance for assessing the impact on air quality and health. Air pollution risk is of considerable concern for airports that are sited near urban areas and current emission regulations had focused on local air quality in surroundings of airports.

Methodology and Results

Main exhausts have been calculated using a dedicated software, EDMS (EDMS, 2013). A special attention has been paid to the quantity of emission emitted during the taxi phases of the LTO (Landing and Take Off) cycle that are the most impacting phases affecting directly working people, passengers inside the airport and surroundings areas. Taxi times affect emission factors and consequently pollutant concentrations. Average taxi times variability has been evaluated and their relative emissions have been calculated for several time modulation.

	CO_2 (t/y)	**H_2O (t/y)**	**CO (t/y)**	**THC (t/y)**	**NMHC (t/y)**	**VOC (t/y)**	**TOG (t/y)**	**NOx (t/y)**	**SO_2 (t/y)**	**PM_{10} (t/y)**	**Fuel Consumption (t/y)**
Default	89563	35115	384,54	70,96	82,04	81,618	82,04	331,73	33,24	2,51	28387
Real	72209	28311	249,46	49,27	56,97	56,675	56,97	308,37	26,80	2,06	22887
Diff%	19	19	**35**	**31**	**31**	**31**	**31**	7	19	18	19

Fig.1 Differences in percentage between emissions calculated with Default and Real Taxi times.

A Lagrangian particle model, SPRAY5, (Tinarelli et al, 2000) was used to calculate PM_{10} dispersion from Marco Polo Airport. It has been estimated that changing in taxiing times from default to real can cause a 40÷60% decrease of the PM_{10} concentration. It also reduces the impacted areas predicted in the sorroundings of the airport.

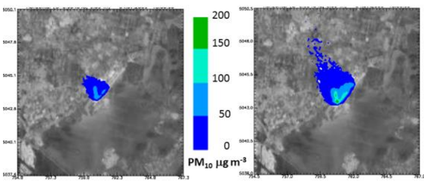

Fig.2 PM10 dispersion in Marco Polo Airport calculated with real (left) and default (right) values

Conclusions

Taxi times variation strongly depend on delays, weather conditions or airport runaway management. Among the LTO phases, taxies seem to be the most impacting mode. Taxi times changes can strongly affect aircraft emissions and dispersion. A better knowledge on taxi times effects can help better managing airports air quality impact.

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INTEGRATED SOURCE APPORTIONMENT IN SUPPORT OF AOSTA VALLEY AND PIEMONTE AIR QUALITY PLANS

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Summary
The knowledge of the origin of the main contributions to ambient concentrations is a key precondition for the elaboration of a coherent and effective air quality plan, to focus control actions on emission sources most affecting the pollutant levels, especially in areas where ambient air quality standards are not respected. Model-based source apportionment performed over Aosta Valley and Piemonte regions (NW Italy) allowed to relate main emission sectors, pollutants and affected areas, thus giving precious information to regional planners.

Introduction
The attribution of contributions given by multiple emission sources to air concentrations can be achieved by using different methodologies, either receptor-oriented or source-oriented. In the case of Aosta Valley and Piemonte regions, the need of covering different part of the territory, together with the existence of well-established regional modelling systems fed by regularly updated emission inventories, both routinely used for yearly assessments and daily forecasts, has determined their use also to apportion sources contributions to ambient concentrations.

Methodology and Results
The two regional modelling systems, based on FARM chemical-transport model, also includes the FARM/BFM facility, allowing to apportion sources contributions on ambient concentrations of any target pollutant using the so called "brute force method" (Burr and Zhang, 2011). According to it, precursors emissions are cyclically altered by the desired combinations of sectors and geographic areas, multiple model sensitivity runs are then performed and results are finally combined with the one from a reference run to give contributions estimates. This approach was applied to a modelling domains 90*60 km wide with 1 km resolution (Aosta Valley) and 220*284 km wide with 4 km resolution (Piemonte), covering each region and the adjacent parts of Italy, France and Switzerland. Fig. 1 shows as an example the variation of PM_{10} yearly concentrations over Aosta Valley resulting from the sensitivity run for domestic heating emissions, evidencing the role played by the built-up areas in the central valley as well as the smaller centers in the lateral valleys, as a result of region morphology, meteorology, population distribution and related heating emissions. The combination of similar runs for the other sectors allowed to estimate their relative contributions to ambient concentrations, as shown in the example of Fig. 2 for PM_{10} at different locations in the region. Peculiarities were evidenced for the different pollutants and areas: the heating sector is the dominant sector for PM_{10} concentrations over most of the region (also due to the use of biomasses) and for NO_2 concentrations in the lateral valleys; road traffic otherwise plays the dominant role for NO_2 in the main valley (also linked to the presence of a major highway connecting Italy and France), and is by far the main contributor to benzene concentrations; the few industrial activities in the region give limited contributions to NO_2, PM_{10} and SO_2 concentrations in parts of the main valley; other sectors (painting activities, off-road transport, animal husbandry) play local roles for specific pollutants.

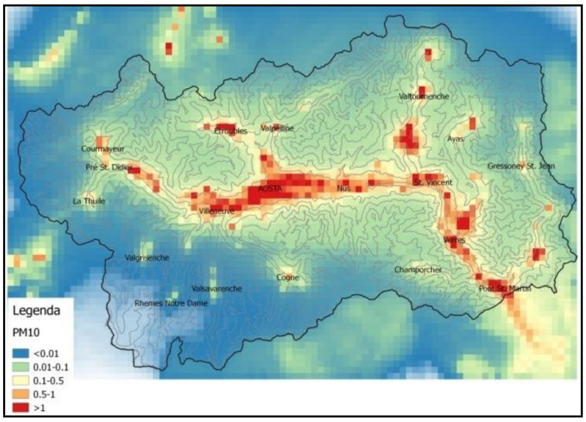

Fig.1 Variation of PM_{10} concentrations produced by sensitivity run on domestic heating sector

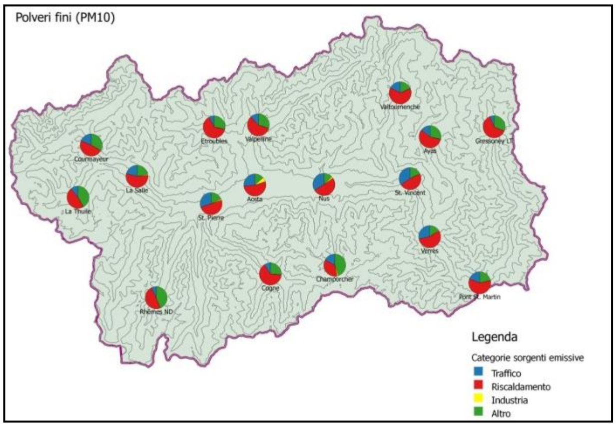

Fig.2 PM_{10} main sources contributions at selected locations

Conclusions
Source apportionment allowed to obtain a clearer picture of contributions from main emissions sectors to ambient concentrations. Specificities found by area and pollutant will help the regional stakeholders in focusing the actions of their plans aimed at improving the air quality levels of the territories of competence, as also requested by EC.

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THE IMPORTANCE OF MOTOR VEHICLE EMISSIONS ON THE $PM_{2.5}$ POLLUTION OF THE CITY OF MEDELLÍN AS DEDUCTED FROM THE HOURLY VARIATIONS IN $PM_{2.5}$ CONCENTRATIONS AND FROM CHEMICAL ANALYSIS OF $PM_{2.5}$ MATERIAL

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Summary

A complete analysis of hourly time data for $PM_{2.5}$ concentrations in set of sampling stations in the city of Medellín, Colombia, shows that there is a distinct cyclical trend in the behaviour of the data; with the appearance of two peaks clearly distinguished form the average and the lower value data. This behaviour is clearly related to the influence of vehicle traffic. This influence was confirmed by an independent chemical analysis of $PM_{2.5}$ collected in samples.

Introduction

The city of Medellín, with its growing population and vehicular traffic, is experiencing $PM_{2.5}$ atmospheric concentrations that are higher than the established standards. There are important local efforts to mitigate and solve this situation. In this sense, it is important to clarify and stablish what are the real sources for this type of pollution. This study analyses the importance of vehicle related emissions as a means to contribute a real knowledge of the situation and so help design solutions for it.

Methodology and Results

A complete analysis of hourly time data for $PM_{2.5}$ concentrations in set of sampling stations in the city of Medellín, Colombia, with more than 14.000 data points per station were taken into account, obtained during three years, in six sampling stations distributed through the city. There is a distinct cyclical trend in the behaviour of the data, with the appearance of two peaks clearly distinguished form the average and the lower value data (figure 1). This behaviour is clearly related to the influence of automotive traffic, as industrial sources (usually is boilers and furnaces) are operated, in general, continuously. Statistical analysis of the data and its two peaks, indicate that here is a basic background concentration, significantly affected by variations that repeat at certain times, which coincide with the peak traffic hours and the expected atmospheric reactions and aerosol formation associated with such emissions (which are rich in sulphate, ammonium and nitrates).

Variations contributed between 48% and 64% to the total values.

The importance of vehicle emission was confirmed by an independent chemical analysis of $PM_{2.5}$ collected in samples as compared to chemical compositions of automobile and vehicle emissions and their associated sources (pavement, tire and brake wear; resuspension of deposited materials on streets and ionic materials resulting from atmospheric side reactions).

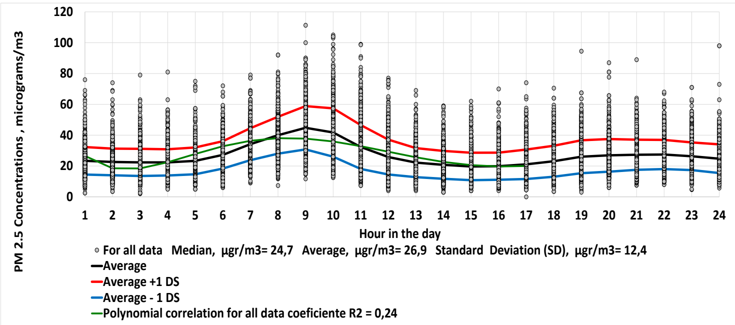

Fig.1 $PM_{2.5}$ hourly concentrations in all sites

Conclusions

It was concluded, based in the two approaches used, that motor vehicle direct and associated emissions are responsible for the larger part of the $PM_{2.5}$ concentrations in the city, with influence factors between 75% and 84 % according to the studied site.

Acknowledgement

This work was supported by POLITÉCNICO COLOMBIANO JAIME ISAZA CADAVID and AREA METROPOLITANA DEL VALLE DE ABURRÁ. We acknowledge the DRI Institute for the analytical assistance.

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VISIBILITY IMPAIRMENT SOURCE APPORTIONMENT ANALYSIS IN AN URBAN AREA DURING 2007 TO 2009

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Abstract

Visibility is an excellent indicator of air quality because its impairment results from light scattering and absorption by atmospheric particles and gases. In this study, principal component analysis (PCA) method was used to analyze variations in visibility compared with variations in meteorological variables (including wind speed, temperature, relative humidity) and air pollutant concentrations (including SO_2, CO, O_3, NO_2 and PM_{10}) between 2007 and 2009, to identify the emission sources on visual air quality over the urban city of Tehran, Iran.

Whereas the average value of mid-day visibility is around 10 km, the poor visibility is not exceeded 6 km at three stations within Tehran urban area during the study period. PCA identified two significant components with eigenvalues greater than one, which account for about 60% of the variance in the poor visibility data base. The poor visibility is mainly related to PM_{10} concentration and industrial pollution as well as traffic emissions throughout the area. The results revealed that much of the first principal component is based on PM_{10} variability, suggesting that PM_{10} concentration is the major contributor to visibility deterioration in the studying area.

Keywords: Visual air quality, Air pollutant, Meteorological variables, Tehran

SOURCE APPORTIONMENT ANALYSIS OF ATMOSPHERIC PARTICULATE AIR MATTER OVER A SOUTHERN MEDITERRANEAN COAST

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Introduction

The Mediterranean basin is considered as one of the most controversial regions for aerosol transportation due to its location at the intersection of air masses circulating among the three continents.

The Mediterranean basin is characterised by a cross road of different kinds of atmospheric PM, due to the variety of the region around it.

In Tunisia, the industrialisation policy has started to impose some problems of pollution and the degradation of the urban environment especially in Gabès in south Tunisia. Gabès is one of the biggest industrial cities in Tunisia. Most industries are chemical oriented; the fast growing numbers of factories has resulted in fairly serious air pollution (Taieb and and Ben Brahim, 2012, 2013b, 2013a). That is why, this study will provide a comprehensive report on mass concentrations and characterisations of PM in the Gulf of Gabès, in south Tunisia.

Methodology and Results

In order to identify the source apportionment of particulate matter PM_{10} in the southern Mediterranean coast of Gabès (Tunisia), .The chemical characterization included a gravimetric determination of atmospheric particles mass concentration, measurements of the major anions (SO_4^{2-}, NO^{3-}, Cl^-) and cations (Ca^{2+}, Mg^{2+}, K^+, NH_4^+) concentrations in the aerosol samples by ion chromatography and analysis of 18 elements by energy dispersion X-ray fluorescence. Aerosol ion balance of various PM_{10} constituents are used to identify possible sources of the particulate matters. Thanks to these analysis, the particulate masses were reconstructed from the main possible constituents: crustal matter, marine aerosols and anthropogenic source.

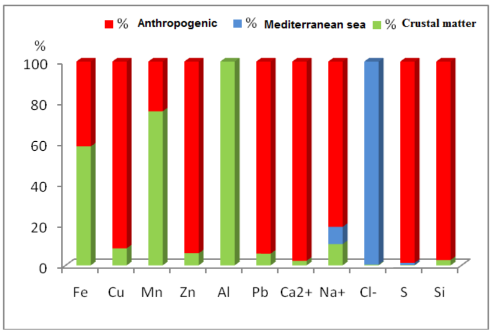

Fig.1 Source apportionment of PM_{10} composition

Conclusions

Knowledge of source strengths and locations is also a valuable aid for interpreting observations and model results and ultimately choosing appropriate mitigation strategies.

For these reasons we have identified the qualitative composition of PM_{10} atmospheric aerosols in the region of Gabes, using chemistry and mineralogy analysis.

Acknowledgement

We are thankful to the National Agency for Environmental Protection (ANPE) in Tunisia for providing the air quality data. Also we would like to thank Mr. Remy BOUSCAREN, for his encouragement.

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APPLICATION OF AERMOD FOR DETERMINATION OF AIR QUALITY IN AN INDUSTRIAL REGION, TURKEY

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Summary
In this study, a comprehensive emission inventory was prepared including all anthropogenic pollutant sources in Kutahya region which is located in the inner western part of Turkey. The region has many industrial facilities such as two major power plants, mining facilities especially one of them is important lignite mine of the region and many food industry. Besides, high PM_{10} and SO_2 concentrations are observed in the region due to lignite with low calorific value 6280kcal/kg use in residential areas in winter.
AERMOD was used to determine the contributions of all pollutant sources to air quality in the region. Emission inventory and modeling studies were carried out for four primary air pollutants (SO_2, PM_{10}, NO_x and CO) in the area of 140 km × 110 km for the year of 2014. In the study, pollutant sources were classified as industrial plants, residential heating and traffic. Finally, for testing the performance of the model, model predictions and observations from the air quality monitoring stations located in the region were compared statistically. According to comparison of the model results with observations obtained from central station, index of agreement was found as 0.80 for SO_2. There is also a passive sampling campaign conducted in this study in 110 points for two weeks period. Addition to monitoring stations concentrations obtained from passive sampling points was used for statistical analysis of model results.

Introduction
Because of the increase in energy use and population as well as the rapid development on industrialization, it has been unavoidable to experience air-pollution problems in many cities around the world. Monitoring and management air quality in the cities are the key parameters to deal with air pollution problems (Fu et al., 2013). Kütahya has high PM_{10} concentrations despite natural gas mainly used in industrial plants in the city. Therefore, this study was carried out in this region.

Methodolgy and Results
Data on facilities of the industrial plants, fuel consumptions and passing numbers of vehicles, natural gas and coal consumption statistics in residential areas were obtained from the relevant institutes and prepared emission inventory for SO_2, PM_{10}, NO_x and CO. According to the results of emission inventory, while industrial plants are the most polluting sector for SO_2, PM_{10} and NO_x, traffic is the most polluting sector for CO. There were almost no contribution coming from traffic sector for SO_2 and PM_{10}. For the model study, AERMOD dispersion model was used. Considering maximum annual average SO_2 concentrations, it was dominated by thermal power plant located in Tavşanlı district. Spatial distributions of air quality levels originating from all pollutant sources in the region were presented as pollutant distribution maps. According to the maps, higher SO_2 concentrations were observed around thermal power plants (see Fig.1).

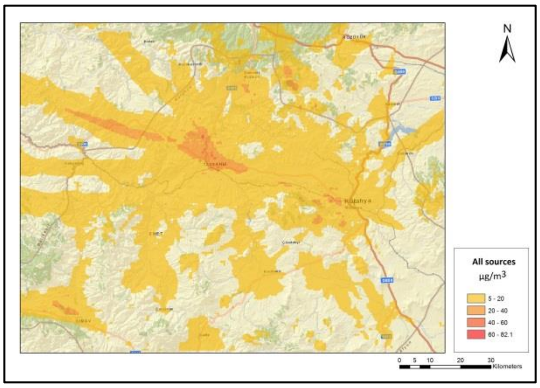

Fig.1. Spatial distributions of annual average SO_2 concentrations from all sources

Conclusion
Industry sector especially thermal power plants main reason of high SO_2 concentrations in the region, but PM_{10} concentrations are mainly coming from mining facilities. While traffic is the most polluting sector for CO emissions, residential heating is another important pollutant sector for CO emissions with 44% contribution value. Index of agreement was found high according to the result of comparison of model results with the observations from central station for SO_2. It could be said that despite the uncertainties in emission inventory, model predictions are relatively good.

Acknowlegment
This research was carried out with support from the TÜB 112Y305 project, funded by the TÜBİTAK.

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URBAN METEOROLOGY

WIND TUNNEL EXPERIMENTS FOR DEVELOPING STREET NETWORK PARAMETERISATIONS

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Summary

Street network models of urban dispersion have proved successful in predicting the effect of building and street geometry on short range dispersion. However, there remain numerous issues that limit their general applicability. DIPLOS addresses some of these issues by focussing on the dispersion of localized releases within urban street networks, and on dispersion processes at short range.

Introduction

The accidental or deliberate release of hazardous airborne materials in densely populated areas is a contemporary threat that poses new scientific and modelling challenges. The dispersion modelling community is faced with the task of providing first responders with models that allow for a fast but accurate prediction of plume pathways, enabling to make informed decisions for evacuation and sheltering procedures.

DIPLOS (Dispersion of Localised Releases in a Street Network) is a collaborative project between institutions in the UK and France that aims to develop and improve dispersion parameterizations in emergency response tools like the street-network based dispersion model SIRANE.

The specific objectives of the project are:

1) To perform detailed wind tunnel experiments, large eddy simulations (LES) and direct numerical simulations (DNS) of dispersion from continuous and short-duration releases in simulated urban arrays for different geometries and wind directions under neutral stability. This will generate a comprehensive high-quality dataset of simultaneous flow and concentration data that will enable fulfilment of two further objectives:

2) To quantify and parameterise the main exchange processes at intersections and in streets of finite extent, including the effects of secondary sources, three-dimensional flow structure, tall buildings and wind direction.

3) To implement the new parameterisations in the SIRANE dispersion model, to apply the model to simulate realistic case studies in central London and to evaluate the model runs against data from the wind tunnel and LES.

Fig.1 The DIPLOS array in the EnFlo wind tunnel

Results and discussion

The work presented here concentrates on the EnFlo wind tunnel experiments, discussing the difficulties faced in obtaining sufficiently high quality simulations, the results so far obtained and the plans for further experiments.

The wind tunnel measurements include flow and concentration profiles, flux measurements and flow visualisation experiments. Mean velocities and turbulence were measured by means of Laser Doppler Anemometry (LDA), while tracer concentration experiments were conducted using two fast response flame ionisation detectors (FFID) simultaneously.

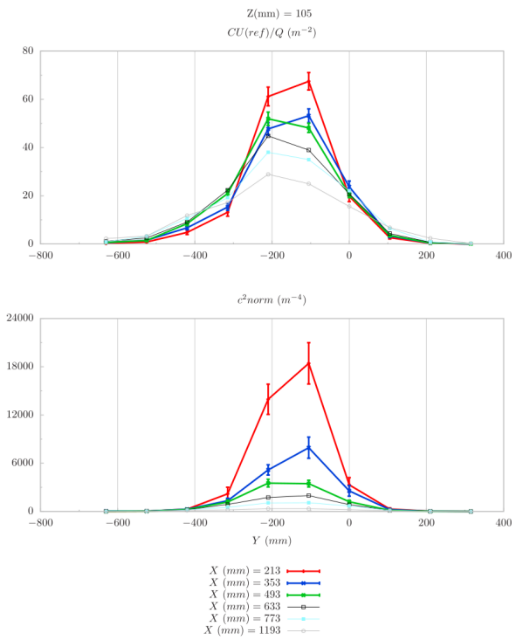

Fig.2 Concentration measurements results

Acknowledgement
This work was supported by EPSRC (EP/K040731/1).

SPECIAL SESSION – AIR POLLUTION METEOROLOGY FROM LOCAL TO GLOBAL SCALES

URBAN NEAR-GROUND LEVELS OZONE PROFILE IN THAILAND

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Summary
The tendency near ground ozone concentration is toward increasing in Bangkok, Thailand and it can harmful on human health. This study shown vertical profile of ozone and precursor gases (NO_X, NO, NO_2) concentrations including the relationship between ozone and precursor gases. Ozone significant remark on highest level (110 meters) diurnal variation of hourly average ozone was increasing after sunrise by photochemical reaction from precursor gases.

Introduction
Nowadays, the tendency near ground ozone concentration is toward increasing in Bangkok Metropolitan region of Thailand (Pollution Control Department, 2014), where is located on the central Thailand. However ozone is occurred from Nitrogen (NO_X) which is Nitrogenoxcide (NO_1) and Nitrogendioxcide (NO_2) these are from vehicle and instruction by photochemical reaction

Methodology and Results
In this study, to examine, the near ground ozone were measured by ozone analyzer and also vertically measured the precursor gases that are NO_X, NO and NO_2 by Nitrogen oxides analyzer on three levels (30, 75 and 110 meters) at Micrometeorological and quality monitoring station. The station is 117 meters tower that is located at Faculty of Environmental Kasetsart University where is a part of an urban in Bangkok, Thailand (13.85º N, 100.34ºE) (see Fig.1). However the result as shown in Fig.2 ozone significant remark on highest level (110meters) was maximum point on February that was 138 ppb. Furthermore, diurnal variation of hourly average ozone was toward increasing after sunrise and most time ozone was maximum in the afternoon especially 1-3 pm (13.00-15.00) on the 110 meters of tower (60.34 ppb.). The hourly average ozone was almost as same as in 110 meters (60.32 ppb.). Then hourly average ozone was decreasing in the nocturnal and was minimum in the early morning 6-8 am (6.00-8.00) at the 30 meters (6.59 ppb.) while precursor gases were increasing in the early morning and were decreasing in the afternoon, alternately.

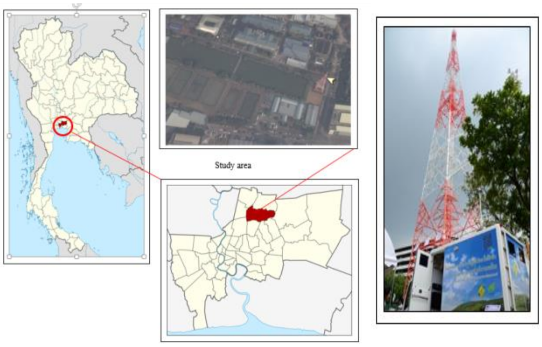

Fig.1 Study area in Bangkok, Thailand

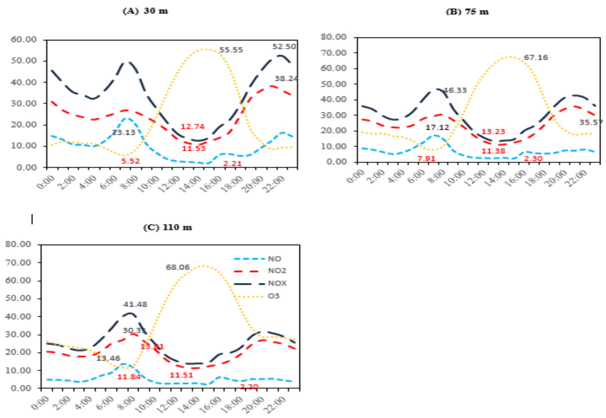

Fig.2 Diurnal variation of NO_x NO NO_2 and Ozone concentrations on 3 levels (30, 75, 110 meter)

Conclusions
Ozone concentration were highest concentration at 110 meters, maximum in the afternoon 1-3 pm (13.00-15.00) and minimum in the early morning 7 am (7.00) while Nitrogen (NO_X) which is Nitrogenoxcide (NO_1) and Nitrogendioxcide (NO_2) were highest concentration at 30 meters, minimum the afternoon 1-3 pm (13.00-15.00) and maximum in the early morning 6-8 am (6.00-8.00)

Acknowledgement
The author is deeply appreciated to Ph.D. Surat Bualert who has supported the knowledge and gave me advice. This study could not complete if without the data from Monitoring of Meteorological and Air Quality in Thailand Station that is supported the finance by Hydro and Agro Information Institute

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MIXING AND DEPOSITION PROCESSES DURING LONG-RANGE TRANSPORT OF SAHARAN DUST

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Summary
This study focuses on the important role of mixing and deposition processes on the distribution, lifetime, and particle properties of mineral dust transported from the Saharan desert towards Europe and across the Atlantic Ocean. Regional dust modelling is used to address the questions of (1) how the Saharan dust export towards Europe and the Caribbean region is influenced by the atmospheric circulation over North Africa, (2) which role the different removal and mixing processes play during long-range transport, and (3) what is the impact of dust radiative forcing on atmospheric dynamics and transport?

Introduction
As the largest fraction of particulate aerosol mass, aeolian dust from arid and semi-arid regions represents an important factor in the Earth system. It can affect the climate directly by aerosol-radiation interactions or indirectly by modifying cloud properties, atmospheric dynamics, and the biogeochemical cycle. In addition, soil dust has an impact on air quality and visibility with potentially adverse effects on human health, transportation, and the solar energy production. The Sahara desert is the most important dust source worldwide, which contributes at least 50% to the global dust load. In particular, the Mediterranean and Southern Europe are frequently affected by Saharan dust storms, and large amounts of dust are carried towards the Caribbean within the Saharan Air Layer (SAL), with maximum transport in late boreal spring and early summer. During long-range transport, the dust particles are transformed by aging and mixing, which may have significant but as yet unquantified effects on the dust impact on radiation, cloud properties, and the biogeochemical processes of ecosystems.

Methodology and Results
Aerosol transport modelling is used to investigate the export of Saharan dust towards Europe and across the Atlantic Ocean, which are the main transport pathways. The emission, transport, dry and wet deposition of Saharan dust as well as the effect of dust radiative forcing are simulated with the regional model COSMO-MUSCAT (e.g., Heinold et al., 2011). In addition to the potential importance of sporadic downward mixing, a particular focus is on the effect of non-sphericity on gravitational settling of dust particles. The COSMO-MUSCAT simulations are combined with trajectory analysis to study particle aging and dust-cloud interactions. The model results are compared against various standard observations over Europe. In the Caribbean region and across the tropical Atlantic, field measurements are available for model evaluation from the transatlantic cruise of the research vessel Meteor in May 2013 (Kanitz et al., 2014) and from the Saharan Aerosol Long-Range Transport and Aerosol-Cloud Interaction Experiment (SALTRACE) at Barbados Island in June to July 2013. First results show that as the source activity, dust deposition is driven by the atmospheric circulation patterns over North Africa (Fig. 1). Convective mixing controls dry deposition in the tropics and can explain sporadic deposition events in the subtropics, whereas dust transport and deposition over Europe is largely related to mid-latitude synoptic disturbances.

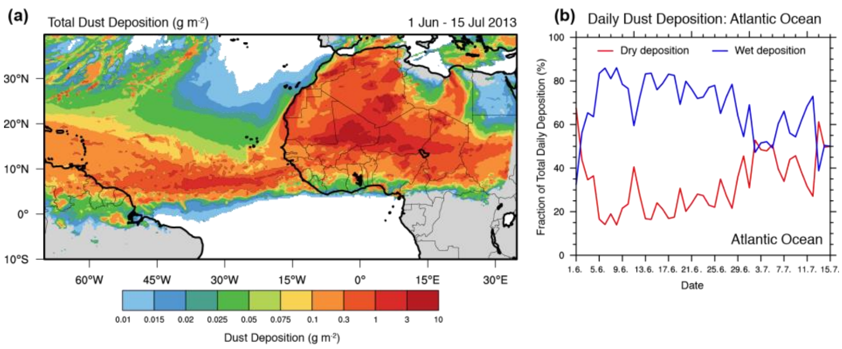

Fig. 1 (a) Modelled total deposition of Saharan dust accumulated over the period 1 June – 15 July 2013 and (b) relative importance of dry and wet deposition for the Atlantic.

Conclusions
Mixing and deposition are important aspects of the atmospheric life-cycle of mineral dust, which control the distribution and properties of dust particles. Combing 3D dust simulations and trajectory analysis, gives new insights into the different processes associated with dust removal and ageing. Overall, this study provides an improved model-based assessment of the varying contribution of Saharan dust to the aerosol burden in Europe and across the Atlantic Ocean.

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MODELLING URBAN HOURLY WIND SPEEDS BASED ON MEASURED NEARBY AIRPORT WIND SPEEDS

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Summary
In the present study a model for the relationship between urban and rural wind speed is set up and validated against three anemometer measurement stations. In the model, the effect of the upwind terrain is taken into account using an internal boundary layer approach. The results show that it is possible to model the wind direction dependency of this relationship, but major biases exist in the model.

Introduction
In semi-empirical air quality models, such as the Operational Street Pollution Model (OSPM), the urban wind speed has been shown to be one of the most sensitive model parameters (Ottosen et. al. 2015). An accurate model for the roof level wind speed could thus contribute greatly to the accuracy of this type of models. The urban wind speed has been extensively studied (e.g. Fisher et. al. 2005) and many models for the urban wind speed have been developed. However, only a few model comparisons have been performed due to a lack of urban wind speed measurements. In the present study a model is set up and validated against three sets of anemometer data from Copenhagen, Denmark. In all cases, the input wind speed is measured at Kastrup Airport, approximately 10 km South of Copenhagen.

Model development and measurements
In the model, the urban boundary layer is represented as a series of layers on top of each other. In each of these layers, the neutral Monin-Obukhov Similarity Theory (MOST) profile is assumed to be valid (Hanna and Britter, 2002), but with different roughness length and displacement height for the individual layers. The roughness length and displacement height is calculated using morphological methods based on input regarding land use and building geometry from a Geographic Information System (GIS). The impact of the upwind roughness length and displacement height at the receptor is modelled using an internal boundary layer approach. The model is validated against three sets of anemometer data: One long time series spanning 16 years and two six month campaigns. The long time series uses a cup anemometer, whereas the two shorter campaigns use sonic anemometers.

Results
The modelled and measured relative wind speed between the airport and the long time series station is shown in Fig. 1. The results show that the model represents well the overall average wind speed reduction at the urban location and some of the qualitative features of the measurements, whereas others are significantly underestimated. A similar trend is seen in the other measurement stations.

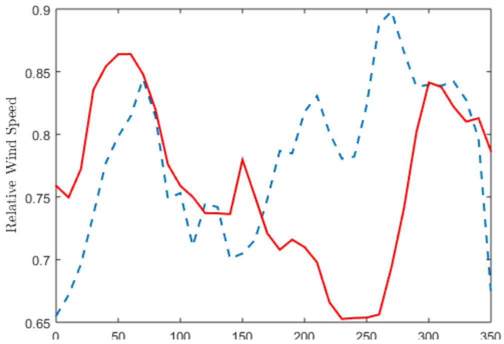

Fig.1 Modelled and measured median relative wind speed between the airport and the long time series as a function of wind direction.

Conclusions
In the present study a model for the relationship between urban and rural wind speed was set up and validated against measurements from three stations. The results show that it is possible to reproduce the wind direction dependency of this relationship, but that more knowledge is needed to accurately model the urban wind speed.

Acknowledgements
This publication was made possible by a NPRP award [NPRP 7-674-2-252] from the Qatar National Research Fund (a member of The Qatar Foundation). The statements made herein are solely the responsibility of the authors.
The HPC (High Performance Computing) resources and services used in this work were provided by the IT Research Computing group in Texas A&M University at Qatar. IT Research Computing is funded by the Qatar Foundation for Education, Science and Community Development (http://www.qf.org.qa).

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MODELING THE ASH DISPERSION AND DEPOSITION FROM THE COTOPAXI VOLCANO: THE AUGUST 14TH 2015 ERUPTION

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Summary
Potentially affected regions by volcanic ash should rely on information regarding the possible ash dispersion trajectories and ground deposition patterns. On August 14, 2015, Ecuador's Cotopaxi volcano awoke with its first significant eruption in more than 70 years. The ash dispersion and deposition of this eruption was simulated coupling the Weather Research and Forecasting (WRF) and the FALL3D models. Although working with preliminary Eruption Source Parameters (ESP), ash fallout results were consistent with measurements. Modeling can be used for forecasting the ash dispersion and deposition under defined scenarios of eruption. The approach can also be used to build ash fallout maps, as basic information for planning and environmental management.

Introduction
Volcanic ash can cause air pollution events and have other impacts, such as damage to buildings and crops, health issues caused by inhalation of particles, and air traffic disruptions. Regions potentially affected should rely on information regarding the possible ash dispersion trajectories and ground deposition patterns. On August 14, 2015, Ecuador's Cotopaxi volcano awoke with its first significant eruption in more than 70 years. The volcano is about 50 km south of Quito (capital of Ecuador). There were two short-duration explosions (09:30 and 19:00 UTC) with plumes of 7.8 and 9.3 km above the crater, respectively. Ash affected towns and villages at the NW of the volcano. Based on records from a network of ash meters, the erupted mass was estimated between $1.66 \pm 0.24 \times 10^8$ kg (Bernard *et al*., 2015).

Method and Results
The ash dispersion and deposition of this eruption was numerically simulated coupling the WRF model with the FALL3D volcanic ash dispersion model. Preliminary ESP were used, based on the grain size distribution of the coarse fraction of collected ash. Durations of plumes were adjusted to obtain a modeled value of the erupted mass (1.69×10^8 kg) into the expected range. The simulated deposit (Fig. 1) shows dominant ash fallout on the NW side of the volcano, in agreement with observations. The comparison of ash load measurements with simulations at 14 stations of the monitoring network (Fig. 2) gives a correlation coefficient (R^2) of 0.67.

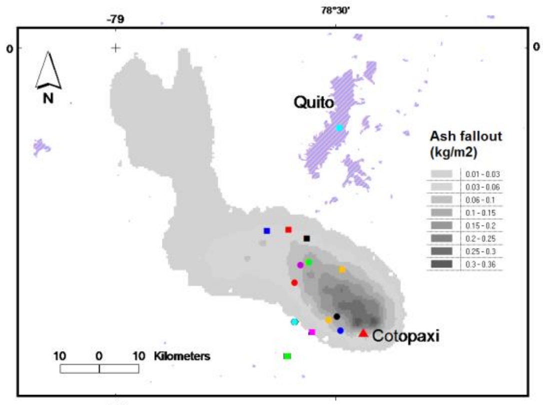

Fig.1 Modeled ash fallout (kg/m^2)

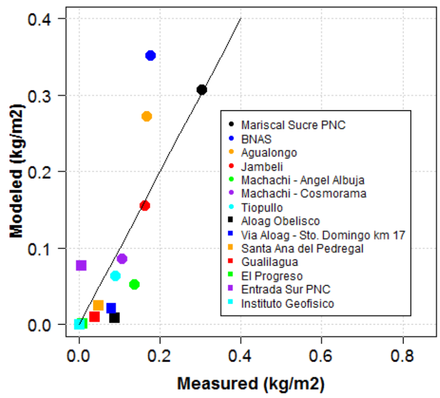

Fig.2 Comparison of measurements and modeled results (R^2=0.67)

Conclusions
Although working with preliminary ESP, ash fallout modeling results were consistent with measurements. Exploring parameterization schemes and the updating of the ESP could improve the performance of numerical models This approach can be used for forecasting the ash dispersion and deposition under defined scenarios of eruption. The approach can also be used to build ash fallout maps and as basic information for planning and environmental management.

Acknowledgement
Simulations were performed at the High Performance Computing system at the Universidad San Francisco de Quito.

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MODELING THE WIND DIRECTION AND SPEED AT DIFERENT FLIGHT LEVELS OVER THE COTOPAXI VOLCANO DURING THE ERUPTIVE PERIOD OF AUGUST 2015

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Summary
Regions that are potentially affected by volcanic ash should rely on information regarding the possible dispersion trajectories. On August 14, 2015, Ecuador's Cotopaxi volcano awoke with its first significant eruption in more than 70 years. During this day, the plumes reached 9.3 km above the crater (km ac). During the following days, the emissions were variable with heights up to 3.2 km ac. The Weather Research and Forecasting (WRF) model was used for simulating the meteorology of the period of August 14-30, 2015. Wind Direction (WD) and Wind Speed (WS) results for heights up to FL500 over the Cotopaxi volcano were compared with data of ash plumes identified by the Washington Volcanic Ash Advisory Center (VAAC). In comparison with observations, modeled WD was in better agreement than modeled WS. The influence of parameterization schemes should be explored to improve the performance in modeling the WS.

Introduction
Volcanic ash can cause air pollution and other impacts, such as damage to buildings and crops, health issues and air traffic disruptions. Potentially affected regions should rely on information regarding the possible ash dispersion trajectories. For this purpose, the availability of historic wind roses at different heights over volcanoes could be very useful. On August 14, 2015, Ecuador's Cotopaxi volcano awoke with its first significant eruption in more than 70 years. There were explosions with plumes of 7.8 and 9.3 km ac. During the following days, there were variable emissions with heights up to 3.2 km ac.

Methods and Results
Using the WRF model, meteorology of the period of August 14-30, 2015 was simulated with high spatial (4 km) and time (1 h) resolutions. Using the computed wind components for the cells over the Cotopaxi's crater, the WD and WS were obtained, for 15 heights varying from 1 to 15 km ac. Results were compared with 55 pairs of WD and WS of ash plumes identified in satellite imagery by the Washington VAAC. These pairs correspond to flight levels between FL220 (FL220=220 hundreds feet above sea level≈6.7 km asl) and FL500 (Fig. 1). The comparison of WD (Fig. 2) gives a correlation coefficient (R^2) of 0.84. The value of the Gross Error is 20.6°, lower than 30°, which is considered as benchmark for meteorological mesoscale model evaluation (EEA, 2011). The Root Mean Square Error for WS is 3.5 m/s, larger than 2 m/s, the benchmark for WS.

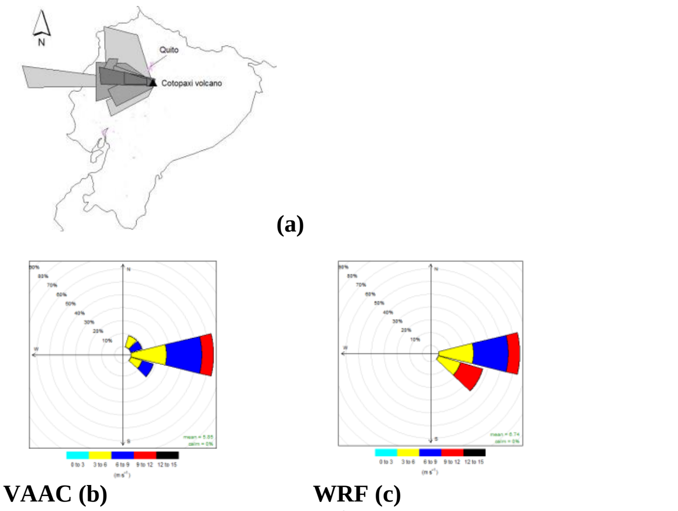

Fig.1 (a) Ash plumes (FL300) identified by VAAC (August 14-30, 2015). (b),(c) Wind roses from VAAC data and WRF model (FL300)

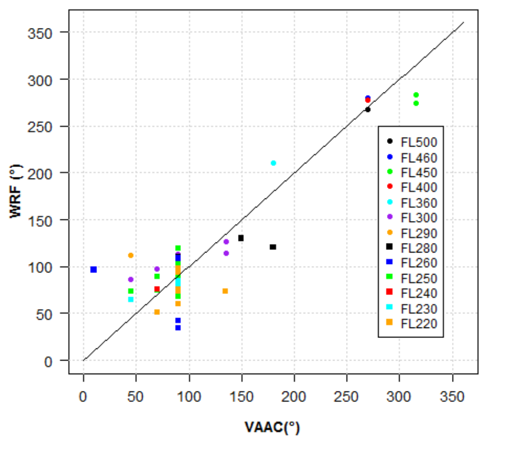

Fig.2 Comparison of VAAC's and modeled WD (R^2=0.84, Gross Error=20.6°)

Conclusions
In comparisons with observations, computed WD was in better agreement than WS. In spite of the WS uncertainty, modeled information is valuable to foresee the volcanic ash dispersion trajectories. The influence of parameterization schemes should be explored to improve the performance in modeling the WS. The shown approach can be used for generating wind roses for a representative year, under defined scenarios of eruption.

Acknowledgement
Simulations were performed at the High Performance Computing system at the Universidad San Francisco de Quito.

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INFLUENCE OF URBAN SENSIBLE HEAT FLUX ON TROPICAL ATMOSPHERIC STABILITY, BANGKOK THAILAND

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Summary
This study describes the relationship between temperature profile and sensible heat flux in tropical urban area. The measurement has been operated on Kasetsart Tower (KU Tower) located in Bangkok, Thailand. The ambient temperature was measured at three levels (30, 75 and 110meter),The sensible heat flux was measured by using Integrates open-path analyzer and sonic anemometer (IRGASON).The meteorological parameters such as wind, humidity etc. also used to evaluate atmospheric stability including theirs effects on vertical air pollutant concentrations. PM10 were collected at three levels. They were used to describe the effect of atmospheric stability. The result shows that PM10 was found maximum at 110meter and minimum at 30meter.

Introduction
Bangkok is the dominant urban area, which the increase population. It is found that the pollutant can be generating by fuel energy and combustion from traffic jam. Synoptic proxy for risky area illustrates urban heat Inland phenomena. Those effects conduct the increase of the positive temperature gradient of the cool spot. In April, 2012 Bangkok has been maximized temperature is 40C^0 be comparable in 1979's summer estimate by Bangkok's microclimate station. (Queen Sirikit National Convention Center). However, research has shown that the meteorological measuring near of Kasetsart University; representative of a large city zones areas. The sample was collected during the summer from April to May.

Methodology and Results
In this study, we have a technique lately developed for stability classification using ADR-1500 and Irgason. Collected in air pollutants and Microclimate factors are described in 2sections were estimated between the vertically in the urban area. The Particulate matter is evaluating against the Pasquil-Giffort "Heat flux" PGH design, and assigns pollution concentrations more underestimates all peak pollutant concentrations. The PM10 concentration varied between 5.6-14 µg/m3, respectively. Database between temperature gradient 3levels (30,75and 110meter) and sensible heat comparing with R-Square and estimate distinction R^2 as 0.494 (temperature gradient 30/110) which was constantly at the daytime (Q4) 07:00-18:00 am. Temperature and sensible heat flux were respectively 34.26% and 98.89 % were exhibited highly Unstable Class the stability class begins turbulent-movement.

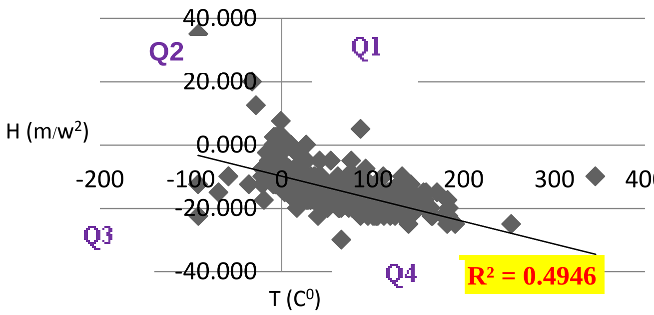

Fig.1 Relationship R^2 between temperature gradient 30/ 110 meters and sensible heat flux

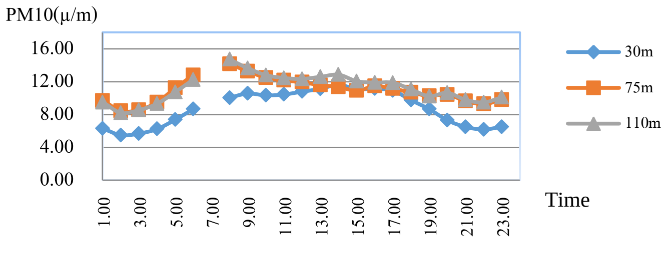

Fig.2 Concentrations of particulate matter at 3levels

Conclusions
The temperature profile can be decrease with the vertically height and the maximum at the ground level (30metre). Duration in daytime the temperature was highest in the afternoon 13.00-14.00am. Concurrent data between Sensible Heat flux and Temperature were increase together.

Acknowledgement
This study could not complete if without the data from Monitoring of Microclimate and Air Pollutants in Thailand. And the author is deeply appreciated to Ph.D. Surat Bualert, who has supported the knowledge and gave me advice.

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INFLUENCE OF TEMPERATURE INVERSIONS ON AIR QUALITY OVER TEHRAN, IRAN - A CASE STUDY

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Summary

The present study aims to examine the association between pollutant concentrations and meteorological variables throughout a surface temperature inversion occurred over Tehran during 26th December 2014 – 3rd January 2015, which exceeded the national standard levels for $PM_{2.5}$ concentrations. During such polluted episode, the daily averaged concentration of PM_{10}, $PM_{2.5}$, and nitrogen oxide (NO) were about three times higher than a typical day, while carbon monoxide (CO) and nitrogen dioxide (NO_2) increased by a factor of two. The hourly variations in pollutant concentrations and meteorological parameters were analysed and the observed relationship was statistically evaluated by using the Pearson correlation coefficient. The results indicated a negative moderate correlation ($r = -0.40$) with wind speed and all pollutants but ozone (O_3). The effects of other weather elements were variant depending on the pollutant .The findings highlighted the effective role of wind speeds in comparison to other parameters in causing elevated air pollutants in Tehran, as well as their dispersion.

Introduction

Tehran's air quality is highly influenced by meteorological parameters as well as anthropogenic emission sources. Due to the geographic characteristics of Tehran, temperature inversions are one of the main causes of its air pollution; meteorological factors play a significant role in increasing or decreasing the pollutant concentrations during such phenomenon (Bahari et al., 2014). Considering this, the importance of evaluating the effects of meteorological conditions on air pollutant levels during a polluted episode is therefore stressed.

Methodology and Results

The hourly and daily variations of PM_{10}, $PM_{2.5}$, CO, NO_2, NO, and O_3 concentrations were analyzed with respect to the changes in some meteorological parameters such as wind speed, wind direction, temperature, and relative humidity (see Fig.1). The air monitoring measurements of Sharif station as well as meteorological measurements of Mehrabad station were used for this study. The PM_{10} and $PM_{2.5}$ concentration which are the critical pollutants in Tehran, varied between 25-229 µg/m^3 and 10-123 µg/m^3, respectively. The average wind speed during the study period was 3 m/s (measured at 1km height) with various directions mostly north-west to south-west. The Pearson correlation coefficient was applied to estimate how pollutant concentrations were related to the weather parameters during this period. The findings revealed that $PM_{2.5}$ had the highest negative correlation ($r = -0.43$) with wind speed, while NO_2 appeared to have the lowest negative correlation ($r = -0.30$) with temperature. The vertical temperature profile was also analyzed for the investigation of maximum mixing height and atmospheric stability. According to the analysis, the period of study was the result of an anticyclonic high pressure condition, which provided the stable atmospheric condition.

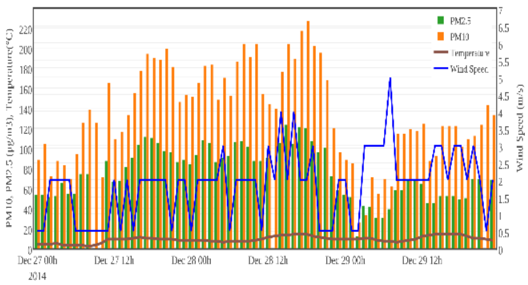

Fig.1 The effects of the temperature inversion on the levels of PM_{10} and $PM_{2.5}$

Conclusions

As the number of air pollution episodes in Tehran continues to increase, understanding the weather conditions and variations in meteorological elements becomes important. The analysis of meteorological parameters could be helpful to improve the current models for air quality forecasting, and to take effective measures in order to reduce adverse impacts of air pollution.

Acknowledgement

This work was supported by Air Quality Control Company of Tehran, which provided the air monitoring measurements.

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SPECIAL SESSION – AIR QUALITY MANAGEMENT FOR POLICY SUPPORT AND DECISIONS

LIFE-SAVING INFORMATION: MORTALITY RISK REDUCTION FROM AIR QUALITY FORECASTS

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Summary
Fine particulate matter air pollution resulting from the combustion of fossil fuels account for about 200,000 annual premature mortalities in the United States. We investigate how individuals seek out information regarding air quality, adjust their behaviour in light of adverse air pollution information, and thereby mitigate pollution-related mortality risk. We focus on the U.S. EPA air quality index forecast program (AQIF), a systematic approach to communicating day-ahead air quality forecasts for large metropolitan areas nationwide. First, we find that online search intensity for pollution information is associated with higher pollution levels and more adverse pollution forecasts. Second, we find that adverse pollution forecasts reduce attendance at Major League Baseball games, conditional on realized air quality and a rich set of baseball controls. Third, we employ two statistical approaches, one based on accurate forecasts and one based on forecast errors, to estimate the mortality risk reduction delivered by the pollution forecasts. In the former approach, the design of the AQIF motivates a regression discontinuity model in which we compare mortality outcomes in the neighbourhood around the thresholds that determine one of the six color-coded categories for informing the public about the next day's expected air quality. In the latter approach, we effectively compare mortality outcomes for a given PM2.5 concentration on days with accurate forecasts with days on which the forecast had been for a cleaner air quality index category than was realized. In our analysis of nearly 20 major U.S. cities over 2004-2009, we and that the program reduces about 130 premature mortalities annually associated with higher PM2.5 concentrations, which would scale to about 950 premature mortalities avoided nationally.

Introduction
Fine particulate matter air pollution resulting from the combustion of fossil fuels account for about 200,000 annual premature mortalities in the United States ([6]). This level of pollution-related mortality reflects significant improvements in air quality since 1970 resulting from regulations that reduce particulate matter pollution and prevented more than 180,000 premature mortalities each year. Additional regulations to lower particulate matter-induced mortality will likely be expensive. For example, the recently promulgated Mercury and Air Toxics Standards by the U.S. EPA would impose annual costs of about \$10 billion to prevent 4,000 - 10,000 particulate matter-related mortalities. The potentially large human health benefits and increasing regulatory costs suggest an opportunity to explore and exploit all low-cost ways of reducing particulate matter-related mortality.

Methodology and Results
We selected the following 18 U.S. cities based on population and air pollution levels: Atlanta, Bakersfield, Baltimore, Boston, Charlotte, Chicago, Dallas, Denver, Detroit, Fresno, Houston, Los Angeles, Philadelphia, Pittsburgh, Riverside, Sacramento, San Diego, and Washington DC. Cities with relatively high air pollution are more likely to have air pollution alerts and would allow us to have more power to detect an impact of AQI forecast error on mortality. During the 2004-2009 period, these urban cities varied in population, mortality, and air pollutant concentrations. We obtained individual, daily mortality data from the National Center for Health Statistics (NCHS) for the years 2004 to 2009. We obtained daily air pollution concentrations of CO (ppm), NO2 (ppm), ozone (ppm) PM2.5 (µg/m3) and PM10 (µg/m3), as well as day-ahead AQI forecast from the U.S. EPA between 2004 and 2009. We calculated the daily AQI associated with the air pollution concentration using the AQI formula. In addition, we reviewed old newspapers for the cities in our sample to confirm that local weather forecasts included air quality index forecast information. Note that U.S. EPA guidance on the AQIF program includes suggested ways of communicating forecast color-coded information in newspapers, radio, and television. AQI forecast was reported differently across time, season, and cities. For some cities, the EPA forecast data consisted of the maximum of the six pollutant-specific AQIs or consisted of individual AQIs related to major pollutants, such as PM2.5 and ozone. The nature of the AQI forecast data was determined by a systematic investigation in local newspapers (on January 1st and July 1st of each year between 2004 and 2009). We then could calculate the error of AQI forecast, which corresponds to the categorical difference between the day-ahead forecasted AQI and the actual AQI. We employ regression discontinuity techniques to evaluate the potential impact of air quality index forecasts on various health outcomes.

Conclusions
We analyze the potential impacts that providing individuals with information about future air quality could have on premature mortality in 18 metropolitan areas in the United States. While we find mixed evidence in city-specific time series analyses, our panel-based analyses suggest that accurate air quality forecasts of adverse PM-2.5 pollution reduce premature mortality. When extrapolated nationwide, our estimate of nearly 1,000 premature mortalities avoided is on par with the lower end of the range of premature mortalities avoided from the promulgated Mercury and Air Toxics Standards regulation. This regulation carries an estimated annual cost of about \$10 billion, orders of magnitude more costly than a pollution forecast program.

Acknowledgement
We thank Napat Jatusripitak for excellent research assistance and John White and Dianne Miller for providing air quality index forecast data. Seminar participants at Harvard and the World Congress of Environmental and Resource Economists provided useful feedback on an earlier version of this paper. We thank the Ziff foundation at the Harvard University Center for the Environment.

ASSESSING THE ECONOMIC VALUE OF A REGIONAL AIR QUALITY PLAN

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Summary
When developing an air quality plan, regional authorities usually devise a number of individual actions, constituted by the application of both technical (end-of-pipe) and energy efficiency measures. They may range from the incentives to buy less polluting vehicles, to the enforcement of stricter rules on domestic heating. The assessment of the economic effectiveness for society as a whole of the individual measures and of the overall plan requires a flexible support system able to quickly perform air quality impact evaluations on the specific area. One such systems is RIAT+, a software package developed during a series of European research projects, that has been used to evaluate costs and benefits of the Lombardy Region Air Quality Plan (PRIA). The paper discusses the basic issues dealt with during this evaluation and critically reviews the results.

Introduction
As it clearly emerges from the preamble to Air Quality Directive 2008/50/EC (AQD), European air quality legislation puts the main emphasis on protecting human health and the environment as a whole and stresses that "it is particularly important to implement the most effective emission reduction measures at local, national and Community level." It is thus required that an air quality plan is adopted, particularly by all the regions suffering for air quality conditions that are considered poor with respect to the European standards. Possible reduction measures may fall in a very wide range and involve many different sectors. It is thus important that those finally included in the plan are not only effective from the point of view of reducing air pollution, but also constitute the most efficient ones from the viewpoint of public investment. Such an analysis has been conducted within the recent plan of Lombardy region using an Integrated Assessment Modelling (IAM) package (Carnevale et al., 2012a).

Methodology and Results
The overall approach followed for the assessment is sketched in fig. 1. The definition of a specific scenario (some or all PRIA measures) is split into energy efficiency one (entailing a certain benefit representing the energy savings) and end-of-pipe ones, the adoption of which has a certain cost. The adoption of each measures means a certain change in the emission, which is distributed over the regional territory in different way, depending on the type of measure. A shift of the car fleet to a different EURO class, for instance, means an emission reduction only on the road network, while better heating system reduce emission on urban areas.

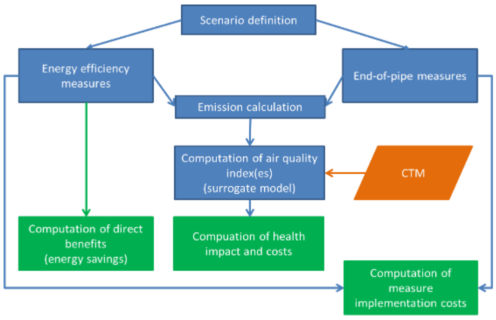

Fig.1 Scheme of the overall assessment procedure

To evaluate the effects of these emission changes, instead of implementing a full chemical transport model, which will be computationally too heavy, RIAT+ (www.operatool.eu) adopts a surrogate model, calibrated on few CTM results (Carnevale et al., 2012b). From the results of the surrogate model (see fig. 2), using the well-known impact pathway approach, it is possible to evaluate the improvements in the health of the population and the consequent reduction of external costs.
The final economic assessment is thus obtained by comparing the sum of energy savings and external cost reductions with the implementation costs of the corresponding measures.

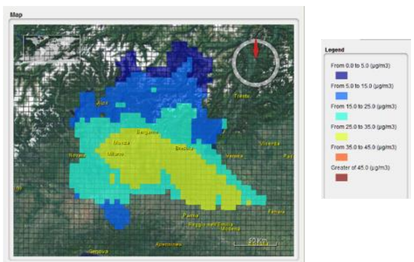

Fig.2 Average yearly PM10 concentration adopting PRIA measures

Conclusions
Assessing the economic value of an air quality plan is a complex task, that requires the estimation of the costs and the benefits of both end-of-pipe and efficiency measures. These measures must be fed into a decision support system including a calibrated air quality model to understand the efficiency of each single measure and of the overall plan. The application of the RIAT+ system to the Lombardy Region air quality plan showed that it has a positive economic balance.

Acknowledgement
This work was supported by "Progetto VALUTA" of ARPA Lombardia.

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INTEGRATED EFFECTS OF NESTING, HORIZONTAL RESOLUTION AND LOCAL INFORMATIONS ON AIR QUALITY FORECAST PERFORMANCE AT DIFFERENT SCALES

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Summary

The integrated forecasting system QualeAria (www.qualearia.eu) is up and running since 2007 with the main aim to provide meteorological and air quality fields to drive regional/urban modelling downscales. This is currently performed through the forecast systems of some of the Italian Regional Environmental Agencies, that fed by QualeAria products are used to provide information to the public and support daily air quality management. The comparison of forecasts against observations, made across scales and system, has evidenced the role of phenomena generated at regional/global scales, along with the key role of fine grained information available at local scale (e.g. improved emission inventory, topography and land use description).

Introduction

According to European Directives, incorporated as well by the Italian legislation, air quality models have been adopted by some of the Regional Environmental Agencies (among the others ARPA Lazio, ARPA Friuli Venezia Giulia and ARPA Valle d'Aosta) as support for assessments and monitoring of the state of the atmosphere. Their use in predicting high concentrations episodes two or more days in advance has become a key factor in defining new mitigation strategies and communicating to the population. Their accuracy is progressively improved by implementing state of the art models, fed by proper dynamic boundary conditions accounting for larger context along with accurate emissions inventories. The last element is especially relevant when increasing the modelling spatial details over the target area of interest, as is the case of Rome (http://www.arpalazio.net/main/aria/), Valle d'Aosta (VdA) (http://www.arpa.vda.it/) and Friuli Venezia Giulia (FVG) (http://www.arpa.fvg.it/), where innermost nests reach 1 km of resolution.

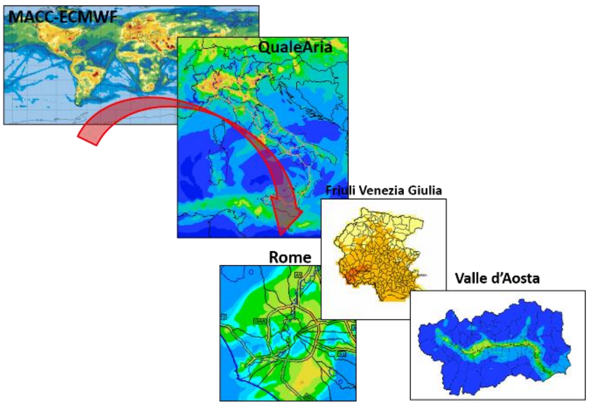

Fig.1 Modelling downscaling from global to local.

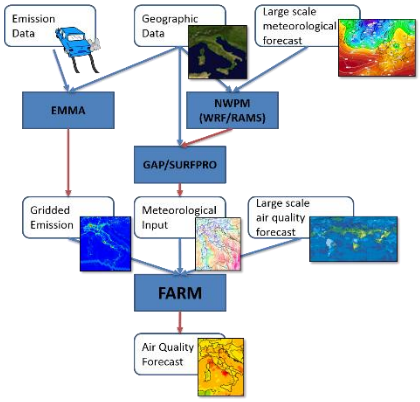

Fig.2 Integrated air quality forecast system framework.

Methodology and Results

QualeAria and local air quality forecast systems are based on FARM (Flexible Air quality Regional Model), a 3D Eulerian model simulating dispersion and chemical reactions of atmospheric pollutants, and share the same modelling framework as shown in figure 2, but with different meteorological driver. The prognostic meteorological models, that provide the downscaling of synoptic weather forecast on the computational domains of interest are RAMS for QualeAria and Rome, WRF for FVG and COSMO for VdA. A meteorological interface module (GAP+SURFPro) then matches the standard output from the meteorological driver with the needs of FARM (grid adaptations, diffusion parameters, deposition velocities, etc.); EMMA (Emission Manager), prepares gridded hourly emissions of all the pollutants considered starting from detailed inventories. Updated and consistent boundary conditions are provided by the cascade of larger scale systems: ECMWF MACC C-IFS-TM5 (part of the Copernicus Atmosphere monitoring service) at global level, and then QualeAria over Italy, up to 5 days ahead. The comparison of modelled concentrations against the values measured at air quality stations of the regional monitoring networks, for specific episodes and on a statistical basis over a year, is part of the periodical activities of forecast services. Results across the scales of the different systems have evidenced as the increase in resolution and an accurate description of emissions from local inventories can lead to better forecast performances, especially for NO2 and PM maxima; on the other side, a correct reproduction of ozone maxima and a proper PM background is strongly linked to an appropriate downscaling from the continental scale.

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MODELLING AMBIENT AIR QUALITY USING A SECTOR BASED LAND USE REGRESSION TECHNIQUE

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Summary

This paper describes the development of a land use regression (LUR) model for the estimation of background air quality across the Republic of Ireland for the criteria pollutants NO_2, PM_{10}, $PM_{2.5}$, SO_2 and O_3. This study forms part of an integrated collection of air quality forecast models and spatial mapping tools which require only simple input data and low computational resources, collectively known as the Irish Air Quality Modelling Suite (EirQMS). The LUR model has been spatially refined by calculating predictor variables within wind-dependent sectors or "wedges", and comparing against long-term average pollutant concentrations within each sector.

Introduction

Poor ambient air quality can affect public health; result in increased mortality rates and impact on sensitive ecosystems. The importance of ambient air quality to environmental and health policy thus led to the introduction of the Ambient Air Quality and Cleaner Air for Europe (CAFE) Directive (2008/50/EC), a legislative framework promoting good air quality. Member states are required to demonstrate compliance with limit values and also to interpret pollution levels in terms of geographical distribution and collective population exposure. This work presents a novel statistical method of utilising air quality data collected as part of the regulatory process to produce national scale maps of ambient air quality for Ireland.

Methodology and results

Within a setting of relatively limited monitoring and emission data availability, LUR was selected as the most appropriate technique to elucidate the spatial variation of pollutant concentrations and its relationship to local and regional emission sources. Circular buffers were delineated around monitoring sites at varying distances (50m – 5km), and further subdivided into wind direction sectors (e.g. N, NE, E, etc.). Geospatial datasets representing key emission sources were identified for each pollutant (e.g. traffic, land-use, coal burning houses). LUR predictor variables were then derived within each sector. Annual mean concentrations from each of 45 (active and closed) air quality monitoring sites were calculated for each of the wind sectors by pairing measured meteorological data with the relevant air quality monitoring point. The division of a concentration time series at a point into 8 sectors maximises the number of data points available for the LUR; however, it also reduces data points available for long-term mean value calculation. Diurnal and seasonal concentration variations may lead to a biased annual sector average estimate when calculated from sub-annual datasets. A kernel regression based correction technique was thus employed correct the data for such biases (Donnelly *et al.,* 2015). NO_2, O_3 and $PM_{2.5}$ results were highly satisfactory with model r values of 0.89, 0.82, and 0.71, respectively. A limited number of monitoring stations together with a bias in the monitoring network (which was identified as part of this work) resulted in poorer fits for PM_{10} and SO_2 (0.46, 0.58, respectively). However, for all pollutants the work has contributed to an increased understanding of the role of natural and anthropogenic emission sources on local and regional scale air quality in Ireland.

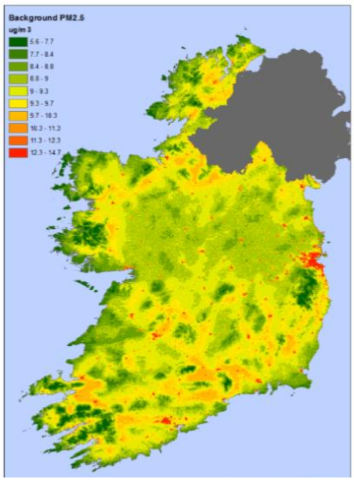

Figure 9 Annual mean $PM_{2.5}$

Conclusions

The output from this modelling work is a set of annual mean maps for each of NO_2, PM_{10}, $PM_{2.5}$, Ozone and SO_2. The NO_2 maps shows the dominant influence of traffic emissions on national (and urban) NO_2 concentrations. PM_{10} shows increases near coastal regions and also in regional towns due to the effects of solid fuel burning. $PM_{2.5}$ increases near major roads due to fine particulate emissions. As expected, ozone shows increases near coastal regions and decreases in heavily traffic areas where there are elevated NO emissions. The SO_2 map was limited by the number of monitoring stations available within each air quality zone. However, the clear influence of the coal ban zones can be observed in the final map.

These annual mean maps can be used for a variety of purposes:

- Direct analysis of air quality anywhere in Ireland
- For Assistance in determining appropriate areas to locate future air quality monitors (minimise monitor placement bias)
- Personal exposure studies.

This methodology is being explored to provide real-time regional air quality forecasts, through integration with a statistical forecast model which currently provides predictions of daily pollutant concentrations at selected monitoring sites.

Acknowledgements

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STATISTICAL ESTIMATION OF LOCAL AMBIENT AIR QUALITY

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Summary
Estimation of the level of ambient air pollution is a complicated task, which includes concentration measurements, modelling of dispersion and transport of air pollutants and estimation of possible effects of a large number of different local sources. Understanding of spatiotemporal variability in ambient air pollutant concentrations in urban areas is useful in many contexts and needs additional, mainly statistical estimation tools. This study presents a newly developed statistical method, which can be a useful tool in planning an aimed measurement campaign to estimate the local ambient air quality around a new source. By the aid of this method the necessary time length and the best starting date of the measurement campaign can be estimated.

Introduction
Observation of mean concentrations and possible exceedances of short term limit values around local point sources needs a large number of measurement points. In absence of a dense monitoring network, the best way is to combine targeted measurements and statistical estimation methods. This work presents a new statistical method for calculating the necessary time length of a measurement campaign to be carried out to estimate the local ambient air concentrations around a source. There are two practical problems which make the estimation difficult: one is that often there are no measurements previously performed at the area nearby a source, the other is that the time disposable for performing necessary measurements is highly restricted, no more than a few months. In this study, the length of the measuring period is optimised by two different estimation methods, followed by a method for estimating the number of limit value exceedances.

Methodology and Results
A suitable dataset to conduct the statistical modelling was obtained from the National Urban Air Quality Monitoring Network. This ambient air monitoring program continuously observes the hourly and daily means of concentrations of 12 pollutants and 5 meteorological parameters. Data of 8 monitoring stations located in downtown and suburban areas of Budapest were available for the period of 1991– 2013. To estimate the optimal length of a measuring campaign, two important concentration measures – daily mean and limit value exceedance – were examined. The first question addressed was how many daily measurements are needed to ensure that the mean of these daily mean measured values lies within a specified interval of the expected value with a large probability. A much simpler and practically useful approach is to take the background concentration as the average concentration of a given particular year, hence the second question is how long measuring period shorter than one year is necessary to form an average (within-year average) enough close to the annual average. The answer for the second question depends on the starting date of measurements due to the annual course of pollutants concentrations. Fig.1 shows the minimum necessary measurement lengths for daily mean SO_2 concentrations. Months in the horizontal axis refer to the starting date of the measurements. The most appropriate start of the measurement campaign is in August (40 days) and July (85 days), or in February (120 days) in case of a winter starting. These measuring periods satisfy practical possibilities.

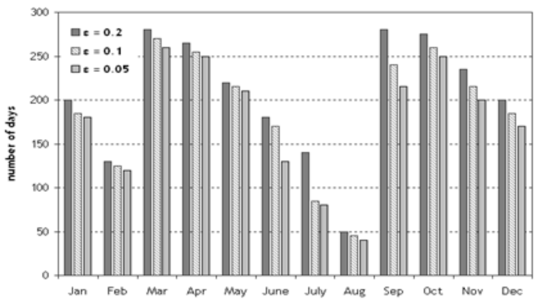

Fig.1 Necessary measurement length in days for estimating daily average concentration of SO_2

In addition to the average concentrations, the limit value exceedance should be examined in the prevailing measurement campaign. New statistical formulae developed for this purpose are being tested currently. The core of the method is to join typical meteorological conditions accompanied by possible limit value exceedances.

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THE USE OF SODAR MEASUREMENTS IN ASSESSING ANEMOLOGICAL CONDITIONS OF KRAKOW

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Introduction

Geographical location of Krakow in the terrain with diverse surface features with dominant parallel course in the valley of deep valley the Vistula river causes development of specific local climate conditions. Almost all meteorological elements are subjects of considerable modifications a result of mutual impact of topographical conditions and urbanization. Additionally, considerable municipal, traffic and part industrial emissions, put the city in risk of episodes with high concentration of air pollutants. The main causes responsible for such situation are air temperature and wind (particularly vertical its profile).

Methodology and Results

Existing results from studies on anemological conditions in Krakow obtained mainly from land stations, but also from sodar measurements conducted at the turn of 20th and 21th century in the station in Czyzyny, show that air flow in near-ground layer air in Krakow is determined mostly by general atmospheric circulation of atmosphere. Location of Krakow in the Vistula valley in direction W - E, surrounded by hills from its northern and southern side determines the shape of wind rose. On the area covering Krakow wind from western directions dominates, but wind from eastern directions occurs very often. Characteristic feature of anemological conditions in Krakow is a frequent the occurrence lack of weather calm wind during ayear (approx. 20-30%), as well as occurrence of very weak gentle wind (approx. 40%) of speed lower than 2 m/s during a year. Measurement experiments with the use of sodars of different class which were conducted in previous years proved usefulness of such devices in evaluating anemological conditions of the city, but the measurement technologies made it difficult to use results for modelling purposes. Therefore, after many years and with different technological opportunities a new type of sodar was used to support studies on wind field in Krakow.

The sodar purchased under the project (Sound Detection And Ranging) PCS.2000-24 produced by METEK® is an active surface-based remote sensing device Its operating principle is based on the Doppler effect, therefore it is called a Doppler sodar. It is used to measure physical properties in vertical profile of boundary layer of atmosphere, in particular speed and direction of wind, class of atmospheric stability and identification of inverse inversion layers. Working parameters of the METEK® Sodar PCS.2000-24 are as follows: frequency 1.5 … 2.6 kHz, minimum measuring height $\geq$ 15 m, vertical resolution height resolution $\geq$ 5 m, standard measuring height up to 500 m.

As it was mentioned before sodar measurements made in the framework of the project MONIT-AIR "Integrated monitoring system of spatial data to improve air quality in Krakow" (http://www.ekocentrum.krakow.pl/742,a,monit-air.htm), are used mainly to study ventilation conditions of the city and to provide specialised empirical data for calibration and verification of the wind field model in the city. Therefore they require proper preparation and development of data necessary for modelling. Some measurement data obtained directly from measurement can be useful without prior processing. These are:

- determining wind vector above 30 - 500 m,
- with vertical resolution of 10 m,
- determining thermal and dynamical properties of atmosphere through parameterisation to so called atmosphere stability classes,
- assessment of altitude on which inversion layers occur.

Conclusions

Measurement of vertical physical properties of atmosphere with the use of such device for the very first time took place in December 2014. Since then two three measurement campaigns were conducted: at the III Campus of the UJ (meteorological station of the Institute of Geography and Spatial Management at Gronostajowa str.) and at Municipal Water Supply and Sewerage Company, Water Treatment Plant "Bielany" at Ks. Jozefa str. and reservoir of Krzemionka at Swoszowicka 8 str. Upon further continuation of the project it is planned to conduct sodar measurements in next few points in the city. Preliminary results of studies on physical properties of near-ground layer of the with the use of sodar in places of its present localization will be shown in the presentation. They were referred to meteorological conditions occurring in land stations as well as in upper atmosphere indicating importance of air masses inflow on shaping wind profile in ground level atmosphere and in various topographic conditions.

A METHODOLOGICAL APPROACH INQUANTIFYING UNCERTAINTIES OF AIR QUALITY HEALTH IMPACT ASSESSMENTS

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Summary

Evaluation of uncertainty in complex health impact assessment of air pollution is usually disregarded regardless of its importance. The reasons behind this arise due to the inherent complexity in the processes involved, the lack of knowledge on the parameter distribution and most importantly due to the lack of a framework to assess the uncertainty. This paper presents a methodological framework to estimate explicitly the uncertainty associated with the health impact from exposure to $PM_{2.5}$ in the city of London.

Introduction

Uncertainty in atmospheric transport and dispersion is usually associated with the modelling input (e.g. the emissions and the meteorological input), the parameterization (e.g. the vertical turbulent mixing, the wet scavenging, the horizontal turbulent mixing, the dry deposition) and the practical solution of transport and diffusion equations (Dabberdt and Miller, 2000; Diez et al., 2014). In all cases uncertainty is computed in accordance to the modelling components, since the chemical and physical processes modelled are not linear and some of the uncertainties present may compensate each other.

Methodology and Results

A methodological framework to explicitly estimate uncertainties associated with the health impact from exposure to pollutants is generated. The proposed uncertainty framework consists of a combination of qualitative and quantitative assessment tools categorized into three tiers. Tier 1 corresponds to the qualitative part, where all sources of uncertainty are tabulated in a matrix, annotating uncertainty's direction, level and appraisal of the knowledge-base; tiers 2 and 3 involve the quantitative evaluations of those sources of uncertainty with the highest degree of influence to the final result(s), provided sufficient information and resources are available.

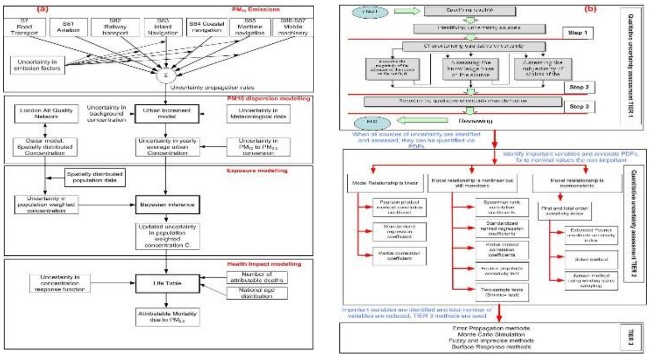

Figure 1. Framework (a) full chain health impact and (b) tiered uncertainty assessment

The statistical methods employed include screening methods utilizing the local and global sensitivity algorithms (tier 2), the Bayesian theory and Monte Carlo Simulation methods (tier 3). In order to conduct an uncertainty assessment, a flow chart of calculations needs to be decided upon which analysis is based. In particular, the chain of calculations required to conduct the health impact assessment due to $PM_{2.5}$ exposure is depicted in figure 1. This flowchart is subjective as it is based on the scope of the assessment, the data availability and the available modelling resources.

Conclusions

This paper presents a holistic approach to identify and quantify the uncertainties arising across the process of assessing the health impact. The main relevant uncertainty sources include emissions in transportation, the associated urban $PM_{2.5}$ concentration and exposure modeling. The uncertainty approach employed depends on the limitations imposed by the complexity of the models and the scientific soundness.

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EFFECT OF OZONE ENRICHED WATER AS BIOCIDE ON AIRBORNE BACTERIAL AND FUNGAL CONCENTRATION IN INDOOR ENVIRONMENT

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Summary

Application of Ozone in gas form is considerably a risk of ozone related respiratory health problem for humans. The microbicidal activity of Ozone enriched water was studied against indoor bioaerosol. In this investigation, the effects of ozone enriched water concentration; contact time and relative humidity (RH) on inactivating airborne bacteria and fungal aerosols by ozone were evaluated in a public toilet. It was observed that the survival fraction of airborne bacterial and fungal aerosol decreased exponentially with increasing ozone dose and exposure time. Airborne bacteria and fungi required ozone doses of 1.4 mg/L to 2.0 mg/L for 80.2% and 90% inactivation, within 30 mins respectively. The results indicate that the 0.8mg/L ozone concentration resulted 47.3% of the microbial free environment within 30minutes exposure which is ideal for indoor application and it may control the bioaerosol for longer time and exhibit the ozone in tolerable limit. 0.8mg/L concentration of ozone water, perhaps releases ozone in the form of gas as 0.016mg/m3 which falling within the permissible limit of ambient air quality standard (AAQM) prescribed by the Central pollution control board, India and US-EPA air quality standard. The detailed study confirms that application of ozone in liquid form may be the appropriate method for improving indoor air quality.

Introduction

Microbial contamination includes bacteria, fungal spores and pollens, algae, proteins and viruses in indoor air air play important roles in public health and climate (Despres et al., 2012; Fiegel et al., 2006; Sun and Ariya (2006). Indoor air quality is affected by many factors like accumulation of microorganisms in air conditioning systems, microorganisms from outdoor source, contamination of building materials and poor hygiene (Aakash Khurana, 2003). Microbiological air quality management in indoor environment is an important criterion that people spent more time in an indoor environment. Periodic cleaning of the indoor environment, common disinfectant does not eliminate all microorganisms which can cause variety of health problems including hypersensitivity, pneumonitis, sick building syndrome, legionnaire's disease, asthma and allergies in humans. The present study was made an attempt to develop a novel method using zone water to provide a microbial free environment.

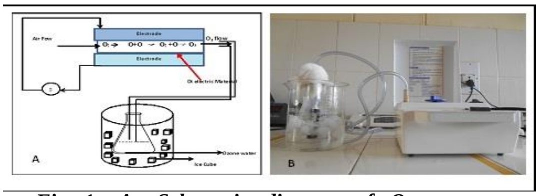

Fig 1: A- Schematic diagram of Ozone water generation; B- Laboratory set up for ozone water

Methodology and Results

Ozone enriched water was prepared following bubble diffusing method by passing oxygen through an Ozone generator model TL03 at a fixed voltage (230 V), and a constant flow rate of 20 L h-1 (Langlais et al., 1991). The generated ozone was passed through Teflon tube into double distilled water under cold condition, because a fall in the temperature of the aqueous medium increases ozone solubility, augmenting its availability in the medium (Fig 1). The active ozone concentration in liquid (55.2 mg/L =0.05mg/ml) was determined by modified Indigo method (Bader and Hoigne, 1980) and stored in a dark room. The ozone water was diluted to 100ml of double distilled water in different concentration like 0.2mg/L, 0.4mg/L, 0.8mg/L, 1.0mg/L, 1.2 mg/L, 1.4 mg/L, 1.6 mg/L, 1.8 mg/L and 2.0 mg/L nd sprayed in pubic toilets.Bioaerosol samples were trapped on bacterial and fungal media. The experimental results showed that ozone water used in these experiments effectively cleared the microbial pollution in indoor air. Ozone contains molecules of three unstable oxygen atoms (O3) and will break down quickly and form radicals, have a high oxidation potential or redox makes it a strong oxidizer and disinfectant. The 0.8mg/L concentration of ozone water, perhaps releases ozone in the form of gas as 0.016mg/m^3, which falling within the permissible limit of ambient air quality standard (AAQM) prescribed by the Central pollution control board, India. The permissible limit for ozone is 180 µg/m3 (0.18mg/m3). The results indicate that the 0.8mg/L ozone concentration resulted 47.3% of the microbial free environment within 30minutes exposure, which is ideal for indoor application and it may control the bioaerosol for longer time and exhibit the ozone in tolerable limit.

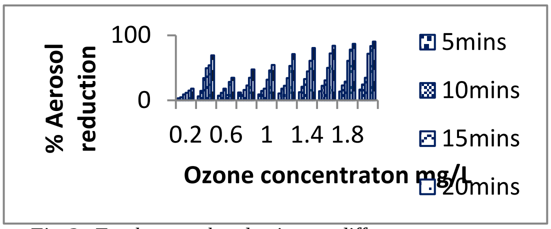

Fig 2: Total aerosol reduction at different ozone water exposure time

Conclusions

The present study revealed that Ozone enriched water significantly reduced the bioaerosol in indoor environments. Application of Ozone water concentration ranges from 0.2mg/L to 2.0mg/L are within the safer zone prescribed by USEPA, USA and AAQM, India . The detailed study confirms that application of ozone in liquid form may be the appropriate method for improving indoor air quality.

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APPRAISAL, A FP7 PROJECT ON INTEGRATED ASSESSMENT MODELING FOR REGIONAL AIR QUALITY POLICY

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Summary

According to World Health Organization (WHO), poor air quality causes thousands of premature deaths in Europe each year. The measures adopted by the European Union are not sufficient to solve this issue in the most critical areas of the Member States. So, regional and local authorities are required to design air quality plans, to complement the EU level policies. The FP7 APPRAISAL project identifies the current European best practices and proposes an integrated methodological approach to support local authorities in designing Air Quality (AQ) plans.

Introduction

Exceedance of air quality limit values in urban areas in Europe remains widespread, particularly for PM, NO_X and O_3. This is not only an issue of compliance; it also has significant implications on European citizens' health and well-being. In response to this issue, EU regions have to devise "air quality plans and programmes" as requested by the European Commission 96/62/EC Directive, updated in the 2008/50/EC Directive and in the Commission Implementing Decision 2011/850. APPRAISAL project (www.appraisal-fp7.eu), funded within of the Seventh Framework Programme (FP7), aims at supporting the regions' activities by providing a survey of the current state-of-the-art in Europe and a framework for an integrated approach to this problem.

Methodology and Results

The APPRAISAL results are:

1. The overall review, and collection in an online database, of the Integrated Assessment methodologies used in different countries at regional and local scale, from the simple (scenario analysis) to the more comprehensive (cost-benefit, cost-effectiveness analysis). This includes evaluating both top-down and bottom-up approaches to systematically analyse their strengths and weaknesses and to identify key areas to be addressed by further research.
2. The design of an Integrated Assessment Modelling framework, based on the information collected during the review process, for different policy-maker requirements, model capabilities and levels of data completeness (AQ plans taxonomy). It is based on the DRSIR framework (EEA 2007) and defines two decision pathways:
   - Scenario analysis. The emission reduction measures are defined based on expert judgment or source apportionment, and their effect is tested through simulation of foreseen emissions. Though being the most commonly used, this approach does not guarantee that cost-effective measures are selected, and only allows for "ex-post analysis" of costs and other impacts (health effects, ecosystems exposure, climate change).
   - Optimization approach. This approach determines cost-effective measures for air quality improvement by solving a suitable optimization problem. A "feedback" is provided on the "effectiveness" of the measures, in terms of both costs and effects. This helps the decision-makers by highlighting the set of measures that can provide the best results in terms of health effects, ecosystems exposure, climate change or other target impacts.
3. The definition of general guidelines on how to implement the defined Integrated Assessment Modelling framework, based on identified strengths and weaknesses and best practice examples among the Integrated Assessment systems in place within MS.
4. The design and the assessment of AQ plans for Porto and Brussels regions based on such guidelines.
5. The communication to key stakeholders, and in particular to policy-makers, of the state-of-the-art scientific knowledge on emission abatement assessment and the contribution to the Air Quality review.

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SPECIAL SESSION – CLIMATE CHANGE AND HUMAN HEALTH

CLIMATE CHANGE AND ITS IMPACT ON HUMAN HEALTH

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Summary
Last 25 years are the warmest since the beginning of meteorological measurements. Meteorological parameters for Rijeka indicate annual mean temperature increase of approx 1.5^{o}C, as well as maximum temperature increase of 10^o C for the period 1977-2013. In the same time, the number of rainy days increased by 50, while the precipitation depth showed practically no linear trend, but periodic behaviour. At the same time reduced emissions from point sources resulted in steep decline of air pollutants like SO_2, NO_2 and particulates. Airborne O_3 is following the same trend (Alebic-Juretic, 2012) in spite of expected increase due to temperature rise. Such condition may represent threat to human health, either by introducing some insects-vectors of infectious disease or suffering from exposures to higher ambient air temperatures and/or pollutants (ozone and PM). The hospitalization rate because of asthma (caused by allergy) and gastrointestinal diseases including diarrhea in the recent period (2000-2013) do not support yet the thesis of climate change impact on human health. For such a purpose more precisely statistic records and longer periods might be needed.

Introduction
Air pollution is strongly influenced by weather conditions, and subsequently very sensitive to climate change. The interrelationship between climate and air quality is highly dynamic. Generally, change in climate affect air quality by perturbing ventilation rates (wind speed, mixing depth, convection, frontal passage), precipitation scavenging, dry deposition, chemical production and loss rates, natural emissions (methane, VOC) and background concentrations. Altered atmospheric chemistry/composition (PM, NOx, ozone) and warmer climate, in combination with the prolonged seasonal presence of allergenic pollens is likely to further increase allergic respiratory diseases and bronchial asthma among urban population (d' Amato et al., 2010). Trends in meteorological parameters and air pollutants in the period 1977-2013 are presented in this work. Rate of allergic respiratory and gastrointestinal diseases in the period 2000-2013.are analysed in respect to temperature increase.

Methodology and Results
Analyses of long term meteorological data since 1977 indicate annual mean temperature increase in the city of Rijeka of approx. 1.5^{o}C, as well as maximum temperature rise of 10^{o}C. The last two decades appear to be the warmest with average temperature of 14.5^{o}C, while the last decade (2001-2010) has the highest average temperature of 14.7^{o}C, with temperature anomaly of +1.1^{o}C (Alebić-Juretić, 2012a) above climate normal 1961-1990 (Reviews, 2001) confirming the warmest decade worldwide. The anomaly is even higher ('+1.25^{o}C) if the period 2001-2013 is considered. In the whole time period, the number of rainy days increased by 50, while trend in the precipitation depth is almost constant, though exhibiting a certain periodicity. Air pollution data for the same period 1977-2013 indicate high pollution by SO_2 and NO_2 and moderate pollution by NH_3, PM and PAHs. In spite of air quality improvement (lowest air pollution ever) within the Rijeka Bay Area the global warming is still overwhelming.
From the hospitalization records in Rijeka Clinical Hospital two diagnosis codes were selected for conditions that might be affected by global warming: asthma caused by allergy (code J.45.0) due to prolonged period of blossom, and diarrhea and gastroentheritis with infectious origin (code: A 09) due to increased possibility for food poisoning in warmer climate. Though the hospitalization rate because of asthma caused by allergy showes a slight increase with temperature, this is not significant. Correlation temperature vs. diarrhea and gastrointestinal diseases with infectious origin is also insignificant.

Conclusions
There is no evidence of significant impact of increased warming on human health (allergic asthma or gastrointestinal diseases with infectious origin) since 2000, a year when present disease coding is introduced. For such a purpose more precisely statistic records and longer periods might be needed.

Acknowledgement
Technical assistance of Mrs. Vlatka Čulev is gratefully acknowledged.

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STUDY OF PERSONAL EXPOSURE TO ATMOSPHERIC PARTICLES BY VOLUNTEERS FROM EDUCATION SECTOR IN SOUTHERN BRAZIL

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Summary
Measurements of the personal respirable particles concentrations are important to assess personal exposure to atmospheric particles and it is essential to evaluate the health effects. To measure the dose intake, pilot measurements were performed in individuals who work in education sector in southern Brazil. Mass concentrations of particles with aerodynamic diameter of 1.0, 2.5 and 10 µm were measured using personal monitor.

Introduction
Exposure to ambient air pollution is largely determined by the concentrations of pollutants existing in air where people stay and length of stay. The determination of the total exposure is essential for the assessment of health effects, and in populous regions, the problem of air pollution has constituted one of the most serious threats to the quality of life of its population (Olmo et. al., 2011). This pilot study aimed to evaluate the viability of measurements of real personal exposure to atmospheric particles by adults from education sector living in a medium-sized city in southern Brazil.

Methodology and Results
Five adults, non-smoking, non-alcoholic and non-hypertensive from education sector of the Londrina city, were selected to evaluate the viability of the personal exposure measurements and the performance of equipment used. Sampling was carried out during 8 hours, starting when the volunteers were getting out home to go work, all going to the same institution, using different modes of transportation. For the mass concentration of the particles, we used the monitor brand Met One Instruments, Aerocet 831 model, which provides mass concentration of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ with temporal resolution of 1 minute. This equipment was in a backpack, with inlets out of it, at shoulder height, as shown in figure 1; the flow of the equipment pump was 2.83 L min^{-1}. A Global Positioning System DG-100 (Global Sat) with data logger registered the movement of volunteers was also used. The received doses were calculated using the following equation:

$$Received\ Doses = \frac{M_{PM_{10}} * IR * FE * DE}{(BM * MT)}$$

where M_{PM10} is the average mass concentration of PM_{10} intake (mg L^{-1}); IR is the intake rate (L $hour^{-1}$); FE is the frequency of exposure (hour day^{-1}); DE is the duration of exposure (day); BM is the body mass (kg); MT is the average time season which measurements occurred (hour). Averages concentrations of 8 hours were calculated for $PM_{1.0}$ and PM $_{2.5}$ for each volunteer, which are shown in Figure 2. Only the V5 volunteer took out bus to go to the institution, and he had the lowest concentrations; the others used car. The highest concentration was for the volunteer V4, which may be because he lives near airport.
The mean received dose of PM_{10} for the five volunteers was 47,108 mg kg^{-1} $hour^{-1}$.

Fig.1 Backpack with the equipment for particulate matter measurements.

Conclusions
The $PM_{2.5}$ concentrations were on average 30% higher than those of $PM_{1,0}$, as expected. The received doses mean may be considered relatively low, but it should be noted that the education sector is even less exposed than other economic sectors. This pilot study has demonstrated that personal exposure monitoring is a viable method for improving knowledge about individual level exposure to atmospheric particles. Future studies are needed to evaluate the personal exposure, as this provides a better understanding of the damage that fine particles causes on human health.

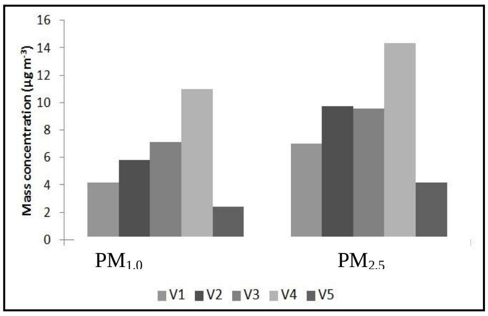

Fig.2 Average mass concentrations of $PM_{1.0}$ and $PM_{2.5}$ for volunteers.

Acknowledgements
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MID-21ST CENTURY AIR QUALITY AT THE URBAN SCALE: CASE STUDIES FOR PARIS AND STOCKHOLM

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Introduction

There is a growing body of literature on the projected effects of climate and emission reduction scenarios on future air quality for the regional and global scale. The fact that today most of the world's population lives in cities stresses the need to resolve the variability of pollutant concentrations and provide predictions of future air quality at the urban scale. It has been repeatedly shown that coarse resolutions are inadequate to resolve fine scale features. In the present assessment, Stockholm and Paris cities are used as illustrative examples of large urban agglomerations that have very different origins of influence therefore particularly interesting to compare; Paris is largely affected by local emissions while Stockholm experiences significant contribution by non-local sources.

Methodology

Ozone, PM10 and PM2.5 concentrations over Paris, France and Stockholm, Sweden were modeled at 4 and 1 km horizontal resolutions respectively for the present and 2050 periods employing decade-long simulations simulated with the Eulerian chemistry-transport models CHIMERE and MATCH in nested simulations. We account for large-scale global climate change (RCP-4.5) and fine resolution bottom-up emission projections developed by local experts and quantify their impact on future pollutant concentrations.

Results and conclusions

We identify biases related to the implementation of regional scale emission projections over the study areas by comparing modeled pollutant concentrations between the fine and coarse scale simulations. We show that over urban areas with major regional contribution (e.g., the city of Stockholm) the bias due to coarse emission inventory may be significant and lead to policy misclassification. Our results stress the need to better understand the mechanism of bias propagation across the modeling scales in order to design more successful local-scale strategies. We find that the impact of climate change is spatially homogeneous in both regions, implying strong regional influence. The climate benefit for ozone (daily average and maximum) is up to −5 % for Paris and −2 % for Stockholm city. The joined climate benefit on PM2.5 and PM10 in Paris is between −10 and −5 % while for Stockholm we observe mixed trends up to 3 % depending on season and size class. In Stockholm, emission mitigation leads to concentration reductions up to 15 % for daily average and maximum ozone and 20 % for PM and through a sensitivity analysis we show that this response is entirely due to changes in emissions at the regional scale. On the contrary, over the city of Paris (VOC-limited photochemical regime) local mitigation of NOx emission increases future ozone concentrations due to ozone titration inhibition. This competing trend between the respective roles of emission and climate change, results in an increase in 2050 daily average ozone by 2.5 % in Paris. Climate and not emission change appears to be the most influential factor for maximum ozone concentration over the city of Paris, which may be particularly interesting in a health impact perspective.

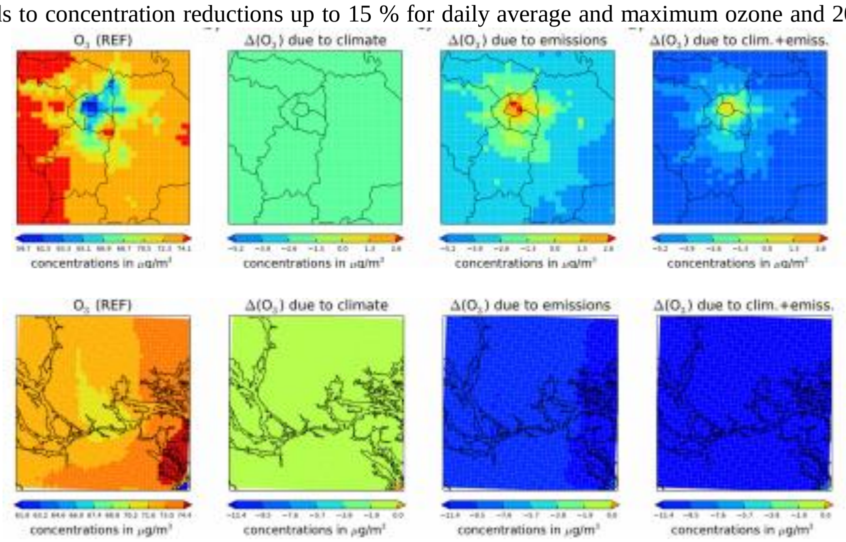

Fig.1 Surface ozone in Paris (top row) and Stockholm (bottom row). Current levels (first column), change due to climate change (second column), change due to emission change (third column) and change until 2050s (fourth column).

Acknowledgement

This work was funded by the European network ERA-ENVHEALTH and its participating partner organizations (ADEME and ANSES in France, BelSPO in Belgium, Swedish EPA in Sweden and UBA in Germany).

CLIMATE, AIR QUALITY, AND HEALTH BENEFITS OF OFFSHORE WIND IN THE USA

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Summary

This study evaluates the health climate and benefits of offshore wind energy projects in two areas being developed for offshore wind, off the coast of New Jersey and Maryland, USA. This study finds that there are substantial climate, air quality, and health benefits to offshore wind. These benefits do not scale linearly with the size of the project, indicating the value of detailed modelling. Offshore wind, with other energy efficiency and renewable energy projects, can be a useful tool not only for climate mitigation, but could also be a useful tool for air quality management.

Introduction

Energy efficiency (EE) and renewable energy (RE) can be a tool for mitigating climate change, since these projects can reduce the use of fossil fuels and reduce greenhouse gas emissions (Buonocore et al. 2015). These projects can also have "co-benefits' by reducing emissions of air pollutants, improving air quality, and benefitting health. Recently, two areas in the Atlantic Ocean on the continental shelf off the coast of the USA have been opened for development of offshore wind, one off the coasts of Maryland and Delaware, and one off the coast of New Jersey. Here, we estimate the climate, air quality, and health benefits of different sizes of offshore wind facilities in each location.

Methodology and Results

To simulate the health and climate benefits of offshore wind, we employed a multi-step model framework (Buonocore et al. 2015). First, we estimated electricity production based on turbine characteristics and local meteorology. We then used an electrical dispatch model, PROSYM, to simulate how additional generation from the simulated offshore wind facilities would affect electrical generation, and emissions of SO_2, NO_x, and CO_2 throughout the power grid in Eastern North America. We then apply an impact assessment model to estimate the economic value of the public health benefits of the NO_x and SO_2 reductions, and estimate the value of the CO_2 reductions using the social cost of carbon. Our results show that offshore wind is able to substantially reduce emissions of NO_x, SO_2, and CO_2, with substantial benefits to climate and health. The results also show that location is an important determining factor for emissions reductions and benefits – the 1100 MW project off New Jersey displaces much more emissions than the 1000 MW project off the coast of Maryland. Size is also an important factor, however, the emissions reductions and benefits do not scale linearly with size, largely due to the local power mix and grid conditions.

Project	**Total Generation per Year (GWh)**	**Total SO_2 per Year (1000 tons)**	**Total NO_x per Year (1000 tons)**	**Total CO_2 per Year (1000 tons)**	**Premature Deaths Avoided per Year**	**Total Benefit per Year (million $)**
1100 MW New Jersey	3701	2.44	1.4	2200	13	200
3000 MW New Jersey	10092	12.0	3.7	6100	52	690
1000 MW Maryland	3239	3.95	1.4	2200	18	240
200 MW Maryland	648	1.47	0.6	460	7	75
300 MW Maryland	972	1.45	0.6	610	7	82
400 MW Maryland	1295	1.47	0.7	800	7	92

Conclusions

This study shows that offshore wind is capable of displacing substantial emissions of CO_2, NO_x, and SO_2 from fossil fueled electricity sources. Offshore wind is capable of mitigating substantial emissions of CO_2 emissions, while also having substantial benefits for air quality and health. Offshore wind is useful as a climate change mitigation plan, but offshore wind, along with other energy efficiency and renewable energy projects and policies, could also be useful tools for air quality management as well.

Acknowledgement

This work was supported by a grant from The Heinz Endowments (Grant number C2988), the Charles F. Wilinsky award at Harvard School of Public Health, and funds from the Mark and Catherine Winkler Foundation.

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ESTIMATION OF POTENTIAL ADVERSE HEALTH EFFECTS IN ASSOCIATION WITH WEATHER PARAMETERS, AMBIENT AIR POLLUTANTS AND POLLEN IN THE AUGSBURG REGION

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Summary
The region of Augsburg provides a unique opportunity to assess the health impacts of changes in living conditions and health-related behaviour. Specifically, through the Helmholtz Research Network REKLIM and the Environmental Health Research portfolio, temporal-spatial variation in micro-climates and air pollution concentrations have been monitored during the last two years and can now be analysed with newly collected health data which has become available in summer 2015.

Introduction
The Helmholtz Research Network REKLIM (Regional climate changes, http://www.reklim.de) will improve the knowledge of regional effects of global climate change. One important research topic is the interaction between health effects of weather and ambient air pollution which may be essential for predicting the consequences of climate change on population health, especially in urban areas. So far, both environmental stressors have most often been assessed separately. Within the REKLIM initiative, we study the associations between exposures to air temperature as well as air pollution and health data in the region of Augsburg, Germany.

Methodology and Results
Measurements of air temperature and relative humidity were conducted at 55 monitoring locations (thereof 35 in the city of Augsburg and 20 in the two adjacent rural counties) resulting in on average 250,000 observations in the city of Augsburg and 92,000 in the rural counties (readings every 4 minutes). The monitoring sites were chosen based on the spatial spread of the home addresses of the study participants as well as the expected spatial variation of the meteorological variables. The sampling campaign started in May 2013 and ended in May 2015. Currently, exposures to air temperature, relative humidity and air pollution (particulate matter in different size fractions, black smoke, nitrogen oxides, and ozone) are estimated at the residential addresses of approximately 2,300 individuals participating in the Cooperative Health Research in the Augsburg Region (KORA) study, by applying land-use regression (LUR) models. It is planned to use seasonal and annual averages for assessing the effects of weather and air pollution on cardiovascular and respiratory function.

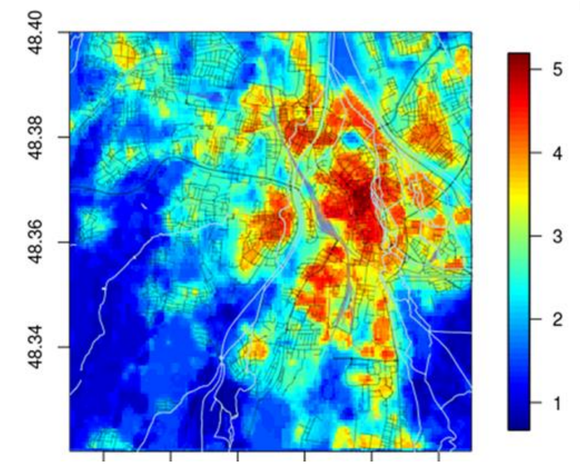

Fig.1 Modelled spatial air temperature distributions (June, 04:00, "calm and clear" synoptic condition).Fig.2 Spatial distribution of BrC, in µg/m^3, asa marker for the smoldering phase of biomass burning, measured with a 2 wavelength (880 nm and 370 nm) microaethalometer around a neighborhood-scale site (star) in Sparks, Nevada, USA from ~8 pm to ~2 am. Data were spatially interpolated by kriging from average values assigned to evenly-spaced grid squares.

At first we modelled air temperature at the 35 sites located in the City of Augsburg by use of land-use characteristics as predictor variables. After model evaluation via cross-validation appropriate statistical models are applied to gridded land-use data to derive spatial urban air temperature distributions. Various models were tested and applied for different seasons and times of the day and also for different synoptic conditions (e.g. clear and calm situations, cloudy and windy situations). Preliminary results of the analyses confirm the general applicability of the selected statistical approach, but also highlight pronounced variations concerning the contribution of the predictor variables with respect to season, time of the day and synoptic situation. Figure 1 shows an example of the results of the modelling for July, at 04:00 (before sunrise) and for a calm and clear weather situation. We modelled the deviations from the temperature measured at the reference station "Augsburg-Airport".
The re-examination of the KORA cohort (FF4) from June 2013 until September 2014 fell into the study period of this project. In total, data of 2,279 participants (39-88 years) was collected at the KORA study center in Augsburg (response rate: 69%). Data from questionnaires and health modules as well as biosamples are available now and will be associated with the data of the modelled environmental exposure data.

Acknowledgement
The sampling of the meteorological data was funded by the Helmholtz Climate Initiative REKLIM (Regional Climate Change), a joint research project of the Helmholtz Association of German research centres (HGF). The collection of the air pollutant was funded by the European Community's Seventh Framework Program (FP7/2007e2011) under grant agreement number 211250 (ESCAPE project) as well as by Helmholtz Zentrum München, German Research Center for Environmental Health through the Environmental Health Research portfolio. The examination of the KORA cohort was funded by Helmholtz Zentrum München, German Research Center for Environmental Health.

INDOOR CLIMATE VARIABLES AND ENDOTHELIAL FUNCTION IN ADULTS

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Summary

This study aims to investigate the association between indoor climate variables, i.e. temperature and relative humidity, and endothelial function in office workers. We found significant linear associations between the 5-minutes averaged climate variables and endothelial function, measured as reactive hyperemia index. The association was positive for temperature and negative for relative humidity. In our exploratory analysis looking at longer time windows (up to 4-hours) we confirmed the same direction of the associations. Our findings suggest a potential role of short term changes in indoor temperature and relative humidity in endothelial function in adults and needs to be replicated in larger samples and using outdoor climate variables ad exposure.

Introduction

Endothelial dysfunction is a pathological state of endothelium characterized by a failure in performing its homeostatic function considered to be one of the first steps of the atherosclerotic process. Potential risk factors for endothelial dysfunction include climate variables. Endothelial function could be measured as reactive hyperemia index (RHI), investigated noninvasively using a technique based on pulse wave amplitude measurements by finger plethysmography. We investigated the association between indoor climate variables, i.e. temperature and relative humidity, and endothelial function in office workers.

Methodology

Data were collected in the frame of an intervention study, the intervention consisting in changing the cleaning products in use with low volatile organic compounds (VOCs) and aldehydes emissions ones, therefore not relevant for climate variables. 82 volunteers were visited twice, before and after one month of intervention. Visits were conducted in Wednesday to Friday of the week before and after the intervention and included the measurement of RHI. Smoking history and self-reported medical history were collected in the frame of an online questionnaire. Continuous monitoring of temperature [°C] and relative humidity [%] was conducted at a 1 minute sampling rate five days of each campaign week (Monday to Friday) during working hours (from 9AM to 5PM). In our main analysis we investigated the 5 minutes mean temperature and relative humidity before the visit took place. We also ran exploratory analyses on longer averages (30 minutes to 4 hours). RHI values were ln-transformed to achieve normality and homogenize variance. We fit mixed effects model with random intercept for each participant. We first ran single exposure models for our exposures. Confounders to be included in the models were selected a priori: age, gender, BMI and smoking history (current, former and never). Since we used data from an intervention study, we included a dummy variable for the intervention campaign (before/after) and the intervention area (intervention/sham). Moreover, since visits took place at different time of the day we included time of the day as continuous.

Results

Data on RHI, medical history, smoking status and microclimate variables were available in 44 workers (n obs = 68). Baseline mean(SD) age was 48(8) years and the sex ratio was 1.08, approximately one third of participants were overweight or obese (BMI ≥ 25 Kg/cm2). Participants were mainly never or former smokers (76%). We found abnormal ln(RHI) levels, i.e. equal or lower than 0.57, in 8% (n = 6) of participants. 5-min averaged temperature was inversely correlated with relative humidity (Spearman's rho -0.367 [p = 0.002]). In our models adjusted for age, gender, BMI, smoking history, intervention campaign, intervention area and time of the day we found temperature and relative humidity exposure to be associated with RHI. An IQR decrease in room averaged temperature in the previous 5 minutes (-1.62 °C) was associated with a significant 12.1% (C.I. 95% -1.9% to -23.4% p = 0.033) decrease in RHI. We also found a slightly significant decrease in RHI for an IQR increase in room averaged relative humidity in the previous 5 minutes (8.2%) (-9.2% [C.I. 95% -17.2% to -0.4%]; p = 0.058). In our exploratory analyses looking at different time windows (moving averages) and lags we confirmed the same direction of the associations observed with the 5 minute moving averages, particularly for relative humidity.

Fig. 1A

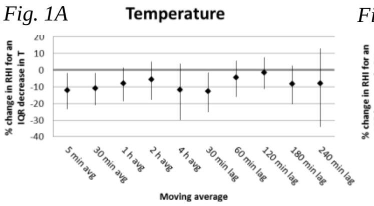

Fig. 1B

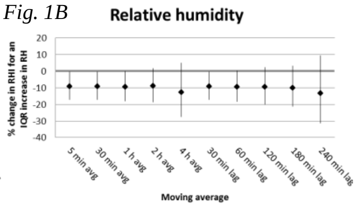

Fig. 1 Estimated % Change (CI 95%) in RHI for an IQR Decrease in T (Fig. 1A and Increase in RH (Fig. 1B) in Different Time Windows (Results from the Exploratory Analysis).

Conclusions

Our findings suggest a potential role of short term changes in indoor temperature and relative humidity in endothelial function in adults. Further research is needed to confirm our findings in larger samples and with outdoor climate variables.

SPECIAL SESSION – MODELLING AND MEASURING NON-EXHAUST EMISSIONS FROM TRAFFIC

HIGH TIME RESOLUTION MEASUREMENTS TO IDENTIFY NON-EXHAUST EMISSIONS FROM ROAD TRAFFIC: A PILOT STUDY IN LONDON (UK)

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Introduction

Several studies assessed the importance of the characterisation of particulate matter emitted by road transports. There are still uncertainties about its impact on human health, but adverse effects have been issued, like the increasing number of heart/pulmonary diseases after the exposure to high concentrations (i. e. emissions from high traffic roads). It is then important to quantify these emissions, in particular in urban areas, in order to abate them through new regulations.

The results we are going to show are part of a pilot study inserted in a collaborative project about the characterisation of non-exhaust emissions from road traffic. Non-exhaust emissions are defined as the emissions due to traffic and produced by tyre abrasion, clutch, brake and road surface wear, and resuspension of road dust.

High resolution samplings were carried out simultaneously at two sites in London (UK) during June and July 2014. One of the chosen sites, Brent, is located on a highway of the mega-city, with high traffic volumes. The second site, North Kensington, is located in a residential area.

The campaign provided the hourly elemental composition of fine and coarse particulate matter giving very useful information about the main emission sources in the urban area. The contribution of traffic was estimated through the Lenschow approach applied to the two sites (Fig. 1).

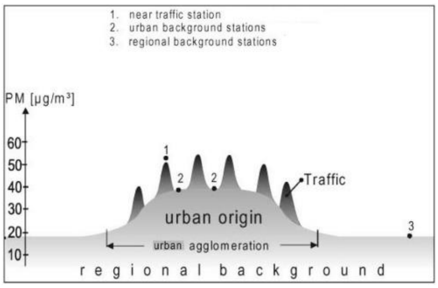

Fig. 1: Profile scheme of PM ambient concentrations (Lenschow et al., 2001)

Methodology and Results

At each site hourly samplings were carried out using the Streaker Sampler. It performs a continuous sampling for one week and collects separately the coarse (particles with aerodynamic diameter 2.5 µm < d < 10 µm) and fine (d < 2.5 µm) particulate matter fractions through an impaction stage. Thanks to hourly resolution it was possible to identify emission sources even if active only for a few hours.

The deposits of collected particles were analysed in order to determine the elemental concentrations in the two fractions through the PIXE (Particle Induced X-ray Emission) analysis.

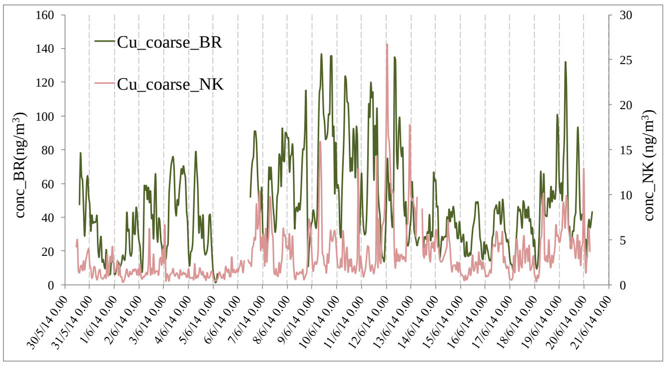

Fig. 2: Streaker sampler data for the coarse fraction of Cu detected at the two sites

Hourly concentrations were mostly higher in heavily traffic congested site for the coarse fraction (an example is reported in Fig. 2), while they were similar at the two sites as far as the fine fraction is concerned. We observed higher coarse concentrations during day-time (in respect to the night-time ones) and in weekdays (in respect to weekends), most likely due to the action of mechanical resuspension of road dust and to non-exhaust emissions.

Acknowledgement

We acknowledge King's College London and the Council of Brent for the availability of sampling sites' cabins and ancillary data.

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APPLICATION OF TWO ROAD DUST EMISSION MODELS TO ASSESS THE AIR QUALITY IMPACT OF OPTIONS FOR REDUCING NON-EXHAUST PM_{10} EMISSIONS

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Summary

The aim of this study is to assess the sensitivity of modelled non-exhaust emissions of respirable particulate matter (PM_{10}) to changes in the use of studded tyres and different road maintenance measures. The NORTRIP (Denby et al., 2013) and FORE (Kauhaniemi et al., 2011) road dust emission models were combined with the street canyon dispersion model OSPM (Berkowicz, 2000) to evaluate the air quality effect of emissions and to compare with kerbside measurements. Both models demonstrate significant impact of studded tyres emissions with the FORE model predictions being slightly more sensitive to this parameter. The FORE model indicates a higher impact of sanding. Inter-annual variation of impact was influenced by the changes in meteorological conditions and associated road maintenance input data.

Introduction

Development and regulations regarding car engines and exhaust cleaning systems have resulted in a significant decrease of exhaust particulate emissions of modern vehicular traffic fleet. However, non-exhaust traffic emissions remain a concern and are still unregulated. In northern parts of the world studded tyres as well as traction and dust control measures used during winter and spring months have a significant impact on non-exhaust particulate emission. Quantification of this impact using modelling tools can support the formulation of strategies for reducing the emissions and consequent air quality effects. Considering this, we applied two emission models in order to assess sensitivity of PM_{10} emissions to different measures.

Methodology and Results

Assessment was carried out for a segment of Hämeentie, a street canyon located in central Helsinki, Finland, for four years (2007-2009 and 2014). Two emission models, NORTRIP and FORE, were applied using available input data for traffic, meteorology and road maintenance activities to calculate PM_{10} emissions which were subsequentl implemented in the OSPM dispersion model. Evaluation of model predictions against measurements was done for years with available kerbside PM_{10} concentrations (2009 and 2014). Modelled mean annual concentrations agreed reasonably well with the measured ones. The concentrations estimated with the NORTRIP model were slightly lower compared with the FORE results. Both models were used to examine sensitivity of predicted PM_{10} emissions to reductions in the number of vehicles with studded tyres and use of traction sand. The effect of application of traction and dust binding salts was studied using the NORTRIP model. Impact of different measures is presented as relative change compared to the reference case in Fig. 1. Reduction of studded tyre traffic share from the current 80% to 50% ("st 50%" in Fig. 1) would reduce PM_{10} by about 7 to 16% depending on the year and model. Further reductions in studded tyre use would reduce PM_{10} by 30-40% (NORTRIP) or 40-50% (FORE) in the theoretical case with no studded tyres in traffic ("no st" in Fig. 1). The emissions predicted by FORE were more sensitive to the use of sand. The NORTRIP model results indicate that dust binding can have an important role in reducing PM_{10} emissions. Meteorological conditions had a significant influence on emissions.

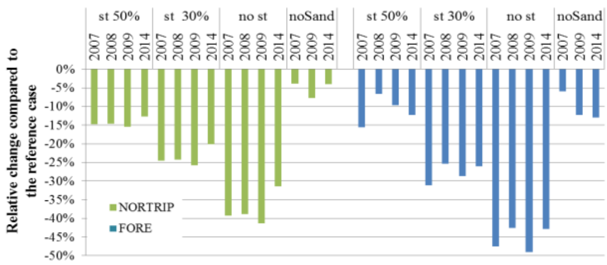

Fig.1 Model predicted changes in PM10 emissions in Hämeentie 2007-2009 and 2014

Conclusions

Both models demonstrate a significant impact of studded tyre use on the emissions. Traction sanding was identified as a potentially important source of emissions. The possibility to quantify the impact of different measures before implementing them into the abatement strategies for the non-exhaust PM_{10} emissions is an important asset for the air quality management.

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SPECIAL SESSION – TRANSPORT RELATED AIR POLLUTION PM AND ITS IMPACT ON CITIES AND ACROSS EUROPE

AIR QUALITY IMPACT ASSESSEMENT FOR RINGLAND

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Summary
"Ringland" (www.ringland.be) is a civilian spatial planning initiative led by a consortium of spatial planners in Antwerp, Belgium, which aims to cover the city's busy ring road (R1) in an attempt to create more greenspace and improve the quality of living for the local residents. The initiative crowd-sourced over a 100 kEUR from enthusiasts to fund a number of environmental, health and economic impact assessment studies. This contribution will report on the air quality impact of the envisaged tunnel-complex. Given the multiple entrance and exits of the Ringland tunnel system, a tunnel model was created to estimate emission losses from the several portals. The redistributed emission estimates were fed to a Gaussian dispersion model, IFDM (Lefebvre et al., 2013), to estimate the impact on annual averaged NO_2 and $PM_{2.5}$ concentrations at high spatial resolution. The results, indicating a substantial reduction of the NO_2 and $PM_{2.5}$ concentrations except at the tunnel exits, were subsequently used by epidemiologists to estimate the health outcome for the project.

Introduction
The busy Antwerp ring road has been at the centre of a major public/political debate in Flanders for more than a decade, featuring many local civilian initiatives. The tunnel complex which the Ringland initiative proposes, separates the R1 into a local traffic tunnel and a tunnel for through traffic, with several entrances and exits as well as a number of surface-level interchanges along the way. A good estimation of the redistribution of traffic emissions from the tunnel portals is therefore essential for any air quality impact assessment.

Methodology and Results
To redistribute the traffic emissions to the different tunnel portals, the Hardy-Cross method (Cross, 1936), typically used for hydraulic network calculations, was used. In this method a network of pipes (traffic tunnels in our case) can be solved iteratively for total pressure in its nodes and flow speed in its pipe segments when the pressure losses (or gains) are known in each segment. Next to friction losses near the walls, a pressure gain is induced by the vehicle piston effect (Bring et al., 1997; Okamoto et al., 1998), allowing us to compute the flow in the complete tunnel system depending on tunnel geometry and traffic intensity/composition.
The model estimated respectively 14.6 % of the total R1 traffic emissions are released near the western exit/entrance of the tunnel complex, 21 % to the north and 10.1 % to the south and 15.7 % to the eastern main exit/entrance. The remainder of the emissions are released along the several exits along the trajectory (with a maximum of 7 % of the total near the busiest section of the R1).

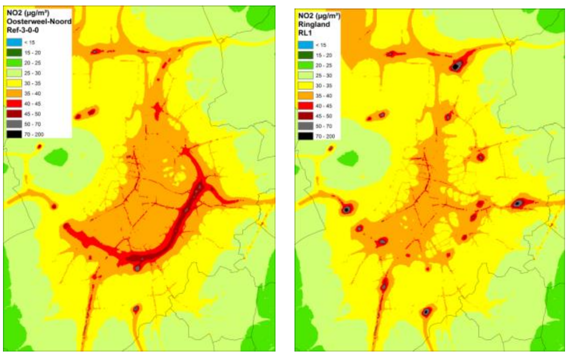

Fig 1. NO_2 concentrations in 2020 in one of the likely future scenario's for Antwerp (left), right: ringland NO_2 map.

The IFDM dispersion model (Lefebvre et al., 2013) was used to compute the redistributed emissions on the ambient annual averaged concentrations for the whole agglomeration. Sizeable reductions were found, not only near the original location of the R1, but also in the urban background. The tunnel portals remain hotspots, with significant increases, however limited to a few 100 m from the portal. Overall, 97 % of the population see a reduction in concentrations levels, whereas only 3 % see an increase.

Acknowledgement
This work was supported by the Ringland initiative and the contributing citizens of Antwerp.

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