Proceedings of Abstracts

11th International Conference on Air Quality Science and Application

Universitat Pompeu Fabra Campus de la Ciutadella
Barcelona 12 to 16 March 2018

EDITORS

Ranjeet S. Sokhi, María José Gállego, Pushp Raj Tiwari, Joan Marc Craviotto Arnau, Cristina Castells Guiu, Vikas Singh

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Preface

The 11th International Conference on Air Quality - Science and Application is being held in the cosmopolitan city of Barcelona, Spain. Our local hosts are MANNERS and Ajuntament de Barcelona. The meeting is a continuation of the series that began at the University of Hertfordshire, UK in July 1996. Subsequent meetings have been held at the Technical University of Madrid (1999), Loutraki, Greece (2001), Charles University, Prague (2003), Valencia, Spain (2005), Cyprus (2007), Istanbul, Turkey (2009) Athens, Greece (2012), Garmisch-Partenkirchen (2014) and Milan (2016).

Over the years 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, scientific research is showing 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, citizens and users 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 proceeding presents a collection of abstracts presented at the Conferences spanning a range of science themes including:

Air pollution sources and emissions
Air quality management for policy support
Air quality measurements and process studies
Air quality forecasting
Air quality in global cities
Atmospheric-climate interactions and impacts
Characterisation and monitoring of air pollutants
Development, application and evaluation of air quality related models
Dust and its impacts on air quality and health
Health integrated assessment for air quality policy support
Health impacts from air pollution exposure
Indoor air quality
Local air quality and impacts studies
Meteorological processes and interactions
Remote sensing and satellite observations

Ranjeet S Sokhi, University of Hertfordshire, UK
Joan Marc Craviotto Arnau, Spain
March 2018

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Oral Sessions

PART ONE

Keynote Speakers

PUTTING PEOPLE AT THE HEART OF AIR QUALITY MANAGEMENT

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Summary
This paper will present an overview of a range of work that has focussed on developing a new paradigm for air quality management This will not only argue that developing a more social approach to air quality management is both desirable and necessary, but also how it is possible.

Introduction
One of the key reasons why efforts to improve air quality have not been more successful across Europe has been the failure to elicit more political support at both national and local levels. This can be seen as being due, in no small part, to a failure to capture sufficient public engagement to create the democratic mandate for significant action on air pollution. This has happened for a number of reasons. Partially, the 'successful' development of legislation through the Air Quality Framework and Daughter Directives and subsequent EU and national policies, has led to a set of numeric "µg/m^3" limit and target values that, whilst based on health evidence. In turn this has led to approaches to AQM based on abstract numbers, rather than real-world impacts. A second reason may lie in the absence of 'people' in models and scenarios used to estimate and predict air pollution concentrations. For example, these models represent the flows of cars along roads, and it requires a great leap of imagination to link these to the reasons for actual journeys that people make. The modelling of emission sources, not the human activity that results in them, leads to a bias in policy that focuses on mitigating emissions through technological change, not through human behaviour, and a reliance on technological innovation not social innovation.

Methodology and Results
The paper will illustrate this argument through a discussion of methods and outputs from a range of projects including:

- the EPSRC funded Disruption project which examined low carbon mobility (www.fleximobility.solutions) ;
- the EPSRC funded MOT project which has provided a new approach to attribution of emissions from point-of-use to vehicle owners;
- work being undertaken to support distributional impact assessments for three of the UK's proposed Clean Air Zones;
- The EU H2020 ClairCity (www.claircity.eu) project that is working with citizens to develop city policy scenarios that meet both air quality and climate change targets, and fulfil citizens' requirements for a high quality of life.

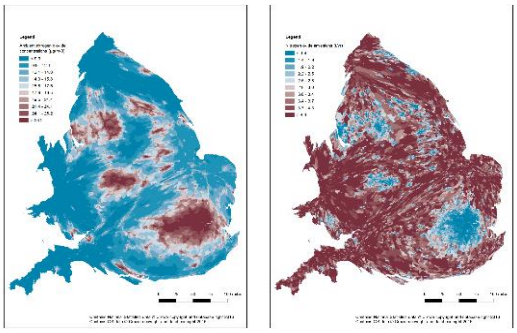

Fig.1 Differences between NO_2 concentrations, and NOx emissions allocated to vehicle keepers (RAC, 2017)

The methods employed vary from detailed data analysis and emissions calculations for over 30 million individual vehicles in the UK (MOT), microsimulation of behaviour to drive air quality modelling and source apportionment (ClairCity), focus groups and long-term social ethnography (Disruption), literature reviews and citizen and stakeholder engagement (ClairCity).

Conclusions

It has become clear that the tight focus on controlling exhaust emissions from cars has failed and will not be resolved in the near future. Also, there is a pressing need to align air quality management with other environmental (e.g. climate change) and health (e.g. obesity) challenges. To properly understand how to reduce polluting activity, we need to much better engage with why people appear to be locked into activities that pollute.

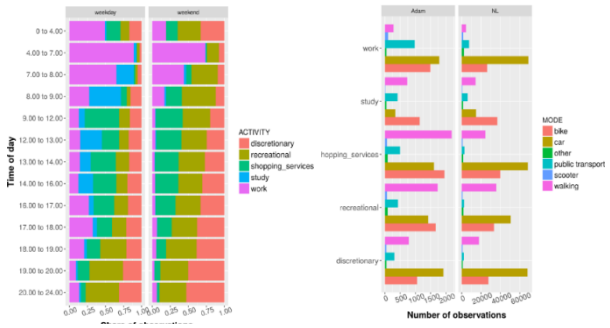

Fig.2 How activity determines time and mode of transport and therefore emissions

Acknowledgement

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FAIRMODE WG5: A NOVEL CITY PILOT APPROACH FOR IMPROVING AIR QUALITY MANAGEMENT PRACTICES

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Summary
This paper presents the activity of the recently created FAIRMODE working group 5. This activity deals with promoting the efficient use of the methodological approaches and guidance developed so far in the various FAIRMODE working groups. The final aim is to support and improve air quality management practices at urban and regional scale. This abstract presents the general concept of the work, with a focus on the "emission" modelling work recently started.

Introduction
In the last years, the FAIRMODE community has proposed different methodological approaches, tools and guidance on various topics related to the use of models for different purposes, from emissions' estimation to assessment, and from source apportionment to planning (e.g. Guevara et al., 2017; Lopez-Aparicio et al., 2017; Thunis et al., 2016a and 2016b). Nowadays, the FAIRMODE steering group and community think it is time to better disseminate and consolidate all the work done, with the overall aim of improving air quality management practices.
This new activity (called "FAIRMODE management practices") involves a selected number of "pilot regions/cities" who apply and test the methodologies, tools and guidance developed within FAIRMODE on their modelling systems and local data. On one side, this will improve their modelling capabilities. On the other side, the feedback received from the pilot regions/cities during this process will serve to improve the FAIRMODE methodologies, tools and guidance. Results of this process will be in terms of:

- Strengthening the links between FAIRMODE and the local and regional authorities;
- Making sure these authorities make use of most of the available FAIRMODE tools and methodologies in order to ensure that the whole modelling chain (including input data) is robust and
- Improving the FAIRMODE support thanks to the authorities feedback.

Implementation
The implementation of the "FAIRMODE management practices" covers two distinct phases: Assessment and Planning.
The assessment phase will consist in checking the quality of the air quality modelling chain by:

- Benchmarking the emission data;
- Ensuring the model applications fulfil the modelling quality objectives;
- Participating in the emissions and air quality composite mapping exercise to check consistency with neighbouring countries or other maps developed for the same area.

The planning phase will consist in supporting air quality planning by developing or adapting the modelling techniques proposed in FAIRMODE. Two possible options consist in: improving the existing "default" SHERPA (Screening for High Emission Reduction Potential on Air, Thunis et al., 2016b) based on EU wide top-down information, or developing a "local" SHERPA based on bottom-up data.

- In the first option, potential discrepancies between SHERPA and local knowledge will be analysed in terms of emissions, source apportionment and/or model responses;
- In the second option, a "local" version of SHERPA will be implemented, on the basis of model simulations and input data provided by the pilot city/region. In addition, differences between the "local" and "default" versions will be explored in terms of emissions, source apportionment and model responses.

First results
We will present in detail the concept and structure of the "FAIRMODE management practices", focusing on the assessment (in particular "emission") part, that is the activity that has been recently launched.

Acknowledgement
We acknowledge all the cities and regions that are participating to the pilot activity.

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MODELLING OF THE URBAN, REGIONAL AND GLOBAL AIR QUALITY ON A HIGH RESOLUTION FOR SEVERAL DECADES, FOR HEALTH IMPACT ASSESSMENTS

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Summary
We have modelled the urban, regional and global concentrations for the periods of 35 and 37 years, on urban and larger scales, respectively. The selected period extends from 1980 to 2014 on urban scale, and up to 2016 on regional and larger scales. The global and continental scale simulations of the atmospheric composition were made by the SILAM model. The global, European and Fennoscandian reanalysis were done using 1.44°×1.44°, 0.5°×0.5° and 0.1°×0.1° longitude-latitude resolutions, respectively. The urban computations were made for the Helsinki Metropolitan Area, using the multiple source Gaussian models CAR-FMI and UDM-FMI, on spatial resolutions of tens of meters. The temporal resolution was hourly for all the computations. The goal of all of these simulations was to generate and evaluate long-term consistent datasets that would be suitable for epidemiological health impact assessment studies. We present and interpret the evolution of the levels and spatial distribution of pollutants during almost four decades, on global, European and city scales.

Introduction
Only few studies have estimated the past levels air pollution over longer time periods, commonly from a few years up to two decades. Previous investigations have not addressed the modelling of spatially and temporally high resolution concentrations in cities, regionally or globally over a period of several decades. However, reliable and self-consistent data on air quality is needed for an extensive period of time for conducting long-term health impact assessments.

Methodology and Results
The high resolution urban computations included the $PM_{2.5}$ emissions originated from vehicular traffic and those from small-scale combustion.

The simulations using the SILAM model were conducted in three spatial domains (Fig. 1). The model was driven by the European Interim reanalysis meteorological fields. The most suitable available long-term emission datasets were used, such as MACCity / ACCMIP, MEGAN and EDGAR.

The simulations included all main air quality parameters, optical density of the air, and also allergenic pollen species for the European and Fennoscandian domains.

The predicted concentrations were first evaluated by a comparison to available measured concentrations. E.g., the modelled concentrations of $PM_{2.5}$ in the Helsinki metropolitan Area agreed well with the measured data at four measurement stations, during 1999 – 2014.

Globally, the concentrations of $PM_{2.5}$ have substantially increased in India and China, and decreased in Europe and Northern America, from 1980 to 2015. The highest urban concentrations of PM2.5 occurred in the 1980's; these have since decreased to about to a half of the highest values (Fig. 2). The concentrations of ozone have also increased in China and India, and their global spatial distribution has changed substantially.

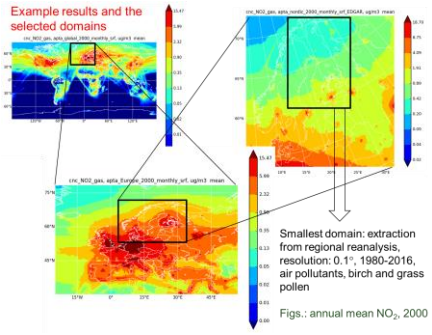

Fig.1. The selected larger scale domains: global, European and Northern European. This example figure shows the predicted annual average concentrations of NO_2 in 2000.

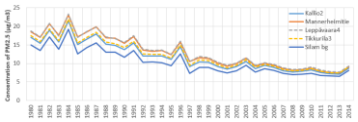

Fig.2. The predicted annual average concentrations of $PM_{2.5}$ at four stations in the Helsinki Metropolitan Area from 1980 to 2014, and the predicted regional background concentrations (SILAM).

Conclusions
The study has provided unique high-resolution concentration databases on global, European, Fennoscandian and urban scales. The urban scale data has already been successfully used for health impact assessments. The datasets will be continuously refined and updated, e.g., to include improved modelling and the data for the most recent years. It is also possible to make higher-resolution zoomed computations for any selected domain, based on the global or other domains. The data and results are openly available for health assessments or other kinds of research (on request from the authors).

Acknowledgement
This study has been part of the research projects NordicWelfAir, funded by Nordforsk, and APTA and ASTREX, both of these funded by the Academy of Finland.

EFFECTS OF INTERNATIONAL SHIPPING ON EUROPEAN AIR POLLUTION LEVELS

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Introduction

Ship emissions is a large, and so far poorly regulated, source of air pollution. Emissions are mainly clustered along major ship routes, both at open seas, and also close to shore and often densely populated areas. Major pollutants emitted include sulphur, NO_x and particles. Sulphur and NO_x are also major contributors to the formation of secondary fine particles ($PM_{2.5}$). In addition NO_x is a major precursor for ground-level ozone. $PM_{2.5}$ emissions (primary and secondary) from international shipping will in general have largest effects when emitted close to shore, as the residence time in the atmosphere is typically a few days or less. For ground level ozone this is only partially the case. Furthermore, NO_x will have a greater potential for forming ozone in pristine environments generally found at open seas than close to shore where the environment is often already rich in NO_x from land based sources.

Model calculations

This study is based on model calculations with the EMEP model (Simpson et al. 2012). See also http://emep.int/mscw/mscw_publications.html for more recent model updates. Here the model runs are made with ship emissions representative for year 2015. The study includes model sensitivity studies perturbing emissions from different sea areas as the Baltic Sea, the North Sea, the Mediterranean Sea (including the Black Sea) as well as emissions on a global scale. The 2015 ship emissions will be representative for the situation after the implementation of a stricter SECA (Sulphur Emission Control Area) in the North Sea and the Baltic Sea. Model calculations are also made with ship emissions in the North Sea and the Baltic Sea before the implementation of the SECA.

Model results

Figure 1 shows that ship emissions are a major source of ground level ozone at open seas. There are also marked contributions over the continents, mainly, but not restricted to, areas close to the main shipping lanes. The model calculations show that emissions from shipping is an important source of $PM_{2.5}$ in coastal regions in Europe, responsible for up to 5 – 10% of total $PM_{2.5}$ levels in several densely populated areas. For regions bordering the SECA sea areas (Baltic Sea and the North Sea) we show that PM concentrations have decreased as a result of the stricter regulations.

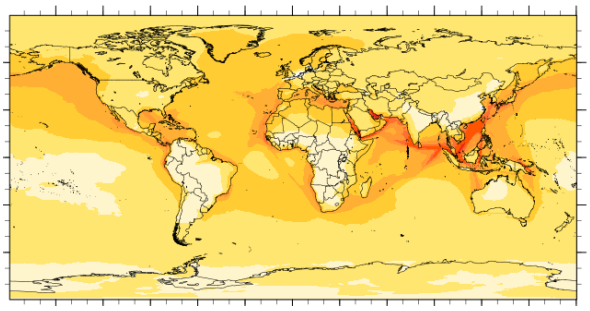

Fig.1. Effects of international shipping on surface daily maximum ozone in ppb

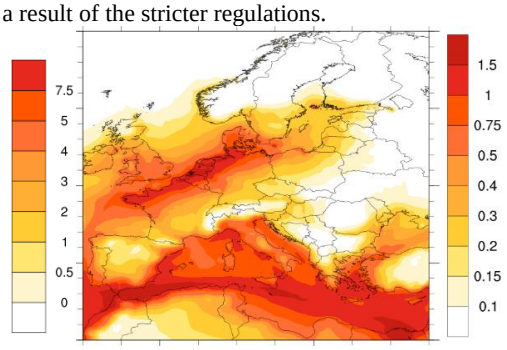

Fig2. Effects of international shipping on European $PM_{2.5}$ levels in ug/m^3

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VERTICAL AND HORIZONTAL EXPERIMENTAL DISPERSION OF DIESEL-RELATED POLLUTANTS WITHIN URBAN BLOCKS

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Summary

In the city of Barcelona, as in many other cities around the globe, traffic emissions are the most important source of PM and NO2 pollution. While exposure to traffic pollutants may be significantly reduced with the distance from the curb, the very dense urban architecture hampers such reduction. Moreover, the building height reduces significantly the dispersion of pollutants. We have investigated the horizontal variability of Black carbon (BC) (29 profiles) with distance from the curb, and the vertical variability of NO2 (28 profiles) and BC (4 profiles) with height from the road surface, given that a great share of people live and work at higher height than that of air quality network inlets. These inputs can be useful for assessing population exposure, air quality policies and for validating 2D and street canyon simulations.

Introduction

Most of EU population lives in areas exceeding WHO guidelines for atmospheric pollutants. Air quality monitoring networks are of course limited in spatial representativeness and also are located within 1.5- 4 m above ground (2008/50/EC). However in many cities, an important share of population live and work at buildings of 6-7 storeys where air pollutants concentrations may be significantly lower than at ground level. Another lack of knowledge is on the horizontal spatial variability of traffic-related air pollutants at progressive distance from the road, important information for improving the design of vulnerable receptors such as biking lanes, kindergartens, schools, day-care centres and hospitals, with the objective of reducing population exposure. In this study we present novel results on the vertical and horizontal variability of diesel-related pollutants (NO2 and BC) within urban blocks of Barcelona considering several road geometries in relation also to wind patterns.

Methodology and Results

The study consists of 3 different campaigns:

- 28 vertical profiles for NO2 characterizing 18 buildings. At each building we installed at least 1 passive dosimeter of NO2 (Gradko) at each floor, including ground floor and the roof during 2-4 weeks, Figure 1. The NO2 passive dosimeters were exposed during 2-4 weeks and their concentrations corrected after intercomparison with chemi- luminescence reference instrumentation at 5 monitoring stations in the city. Precision was evaluated by means of collocation of duplicates.
- 4 vertical profiles of equivalent black carbon (BC). The total duration of BC moeasurements was varying from 1 to 3 days for each profile. The 8 BC monitors were intercompared several times before and after the measurement campaigns obtaining the correction factor.
- 29 horizontal profiles of BC, from the road edge until a maximum distance of 250 m during 30 minutes. The BC monitors (micro-Aethalometers AE51 (Magee Scientific)) were located along a walking area or very a very low intensity traffic road.

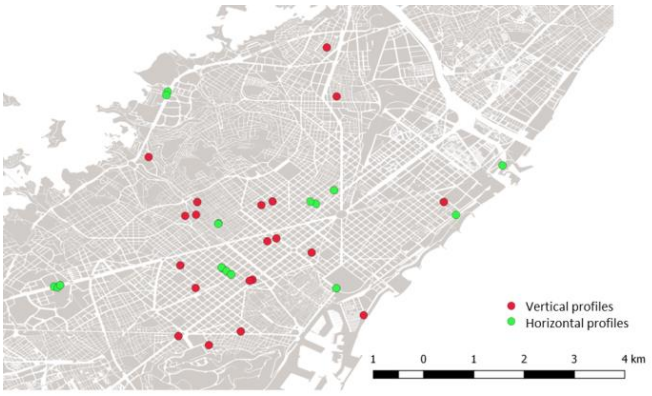

Fig.1 Map of BC horizontal profiles and NO2 and BC vertical profiles. At most locations, duplicated profiles were obtained.

We observed that the horizontal variability of BC is affected by several parameters such as vehicle intensity, meteorology and roads geometry (of both emission road and receptor road). This suggests that generally it is difficult to establish for a whole city the minimum safety distance from the road. However, a relationship is likely between vehicle intensity and the distance at which 50% reduction of BC is achieved.

Regarding the vertical variability of BC there is a clear negative trend with increasing height from ground, very similar among the four roads under study in spite of the large differences in terms of vehicle intensity and road geometry. The general pattern can be described as an exponential reduction implying a mean 12% reduction at 10 m height and 33% at 20 m height.

Regarding the vertical variability of NO2, this achieved as mean, only a 9% reduction at 10 m and 16% at 20 m height from the ground. This reveals that NO2 vertical dilution is significantly lower than for BC due to the partly secondary origin of NO2. Consequently urban differences in NO2 exposures are probably smaller than for BC.

Acknowledgement

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DECREASING CLIMATE CHANGE IMPACT – ONE MOLECULE AT THE TIME

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Summary
An example of the history of improving technology one molecule at the time will be presented. Halogenated organic compounds play an important role in atmospheric and environmental chemistry. There has recently been an extensive review of the atmospheric chemistry of halogenated organic compounds [i]. The most current understanding of sources, emissions, atmospheric concentrations and environmental sinks and fates will be presented. The chemistry associated with formation and loss of stratospheric ozone and processes related to halogenated organics is described and the contribution of halogenated organics to radiative forcing of climate change is discussed in context of the environmental impact of halogenated organic compounds.

Introduction
Chlorofluorocarbons (CFCs) are well-known for their ability to destroy stratospheric ozone and their potency as greenhouse gases They have had several uses, for instance as refrigerants, solvents, in foam blowing and in electronic cleaning. Having recognized their environmental and atmospheric impacts they were phased out and replaced by hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). Generally, the HCFCs and HFCs are more environmentally benign in that the HCFCs and HFCs have shorter atmospheric lifetimes than the CFCs, and that the HFCs do not contain chlorine substituents. However, they are both still long-lived greenhouse gases. Hydrofluoroolefins (HFOs) constitutes a recent class of alternative replacement compounds to the CFCs, HCFCs, and HFCs. They are more reactive in the atmosphere and thereby have a smaller impact on the environment. It is important to know the fate of these compounds before they enter large-scale production and are potentially released to the environment.

Methodology and Results
A series of CFC alternatives have been investigated using FTIR smog chamber techniques. Rate constants and chemical degradation mechanism were determined. The photoreactor is a 101.4 L quartz reactor surrounded by 8 UVA (Osram Eversun L100/79 with the main emission peak at 368 nm) or UVB (Waldmann F85/100 UV6, with a wavelength range of 280–360 nm) lamps, and 16 UVC lamps that are used to initiate the experiments. The reactor is interfaced with a Bruker IFS 66 v/s FTIR spectrometer. All spectra were obtained using 32 co-added interferograms with a spectral resolution of 0.25 cm^{-1} and optical path lengths of around 50 meters. All experiments were performed at 296±2 K and at a total pressure of 700 Torr air/N_2/O_2 diluent. The experiments were performed with Cl atoms, OH radicals or O_3. Cl atoms were produced by photolysis of Cl_2: Cl_2 + hν (UVA or UVB) → 2Cl. OH radicals were produced by the photolysis of CH_3ONO (methyl nitrite) followed by reaction with O_2 forming HO_2.

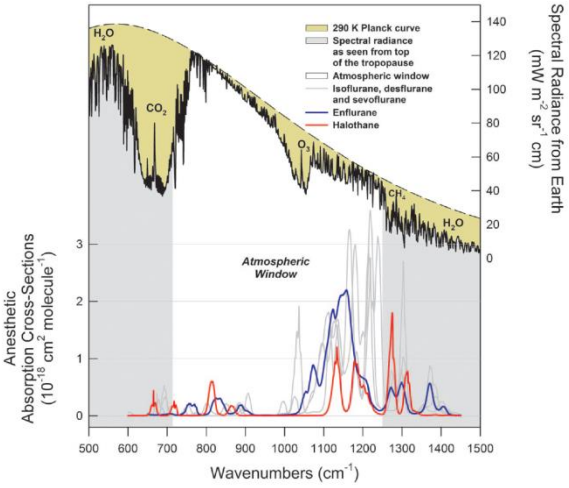

Fig.1 The Atmospheric Window and halocarbon infrared absorptions

Conclusions
Ozone depleting substances including CFCs have been controlled under the Montreal Protocol and its Amendments. It is hard to overstate the success of Montreal Protocol. Absent the Protocol, it has been estimated that the Antarctic ozone hole would have grown 40% by 2013, a deep Arctic ozone hole would have developed in 2011, the ozone layer worldwide would have thinned by ~15%, and the climate effect of net annual ODS emissions by 2010 would have been equivalent to ~10 Gt CO2/year. Replacements for CFCs have been developed and a large international research effort has been conducted to understand their atmospheric chemistry and environmental impacts. In general the atmospheric chemistry of CFC replacements is well understood. Indeed it can be argued that of all the classes of organic compounds, the atmospheric chemistry of halogenated organic compounds is the best understood. The source of the observed burden of trifluoroacetic acid in the atmosphere and hydrosphere is not understood. More research is needed to better understand the sources and sinks of perfluorocarboxylic acids and other halogenated persistent pollutants in the environment. As more CFC replacements are proposed (e.g., the recent interest in halogenated alkenes) their atmospheric chemistry and environmental impacts need to be evaluated by experimental and computational research before being adopted for large scale industrial use.

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IMPACT OF URBAN MORPHOLOGY ON AIR QUALITY: SPRAWL, COMPACT, CORRIDOR AND EDGE CITIES

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Summary
This modeling study aims to analyze air quality and to define the key drivers of the distribution and intensity of the emissions of air pollutants and greenhouse gases in urban planning scenarios. It relies on the set up of the OLYMPUS model, which calculates anthropogenic emissions from the activity and the mobility practices of individuals. It takes into account city-specific parameters such as morphology, population density and job centres distribution, road networks, public transport and energy consumption units, as well as climate parameters that influence the consumption of energy. OLYMPUS has been implemented for different types of urban organization. The results confirm that urban density, which is strongly correlated with the emitting urban fabric, plays a key role in the simulated air quality. However, we show that density is not the only emission control parameter of the urban fabric. Accessibility, connectivity and urban mix also play a role in the variability of emissions.

Introduction

One of the primary objectives of urban policies is to provide an environment that allows all stakeholders to benefit from the advantages of the urban lifestyle. They are based on the improvement of accessibility to services, and rely on a controlled development of the urban transport infrastructures. Territorial planning is based on many urban components such as housing, urban economy and transportation of goods and people. However, all of these activities have a major impact on air quality and threaten urban sustainability. Currently in France, the environmental challenges of urban planning are mainly focused on climate issues and on the implementation of decarbonisation policies. By reducing energy consumption, they are also intend to improve urban air quality. However, the role of the urban structure as a lever for the reduction of energy consumption remains to be clarified. The objective of our work is to characterize the impact of urban forms on energy consumption, and on the associated anthropogenic emissions. Here, we will focus on primary pollutant release from road transport and residential / institutional heating.

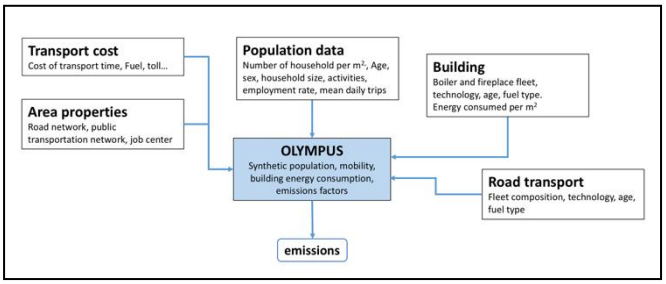

Figure 1: Flow diagram showing the OLYMPUS emissions operating

Methodology and Results

In this work, we tested the sensitivity of the emission model (OLYMPUS) to various urban morphologies. OLYMPUS is a modelling platform that generates a synthetic population of individuals for a given urban structure, defines the mobility of each individual in the city through an activity-based travel demand approach. OLYMPUS also models the road traffic within the city by taking into account the car fleet, the congestion on the road network and the transport of goods. It then generates the energy demand for domestic and building heating, throughout the simulated region, and from the unitary energy consumption of households and employment centres. Finally, OLYMPUS calculates the pollutant emissions from these activities, based on the EEA methodology. The urban form has an impact on the location of services, employment and households. It plays a key role in the mobility of populations, and consequently in the exposure of populations to the pollutants resulting from these travels. The IPCC sets out four key variables of urban form: density, mixed land use, connectivity, accessibility. Each of these variables has a different impact on energy consumption and, ultimately, on air quality in terms of emissions, dispersion and exposure. Four contrasting scenarios of urban structure were simulated with OLYMPUS: COMPACT (classical monocentric city), CORRIDOR (city based on privileged directions for transport), SPRAWL (spread city) and STARS (polycentric city). We studied their impacts on the urban emissions of pollutants.

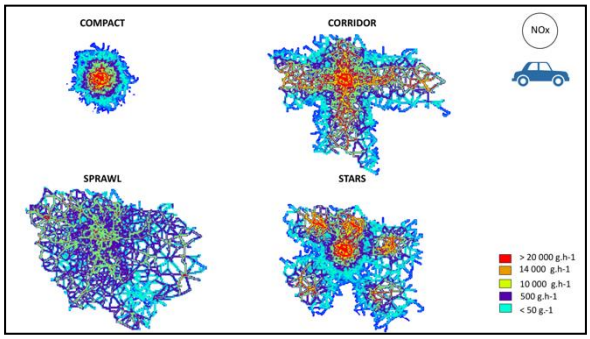

Figure 2: Road transport emissions of NOx under different

Conclusions

Urban density plays a key role in modelling the impacts of different urban forms, because it is strongly correlated with the emitting fabric. We note, in terms of mobility, that the scenarios do not provide large differences in public transport and car attractiveness. It would be interesting to simulate new academic scenarios offering a strong modification of the attractiveness of transport modes, in order to see the degree of attractiveness necessary for people to switch from one mode to the other, and which urban form best allow such a change. These elements could serve as a guide for the design of new cities, but also for the evolution of existing cities.

Acknowledgement
This work was performed using HPC resources from GENCI-CCRT (Grant 2017- t2015017232).

A MULTI-MODEL OPERATIONAL AIR POLLUTION FORECASTING SYSTEM FOR CHINA

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Summary

In this study we used an ensemble of nine chemistry transport models (CTMs) to provide operational forecasts of air quality in China for 3-5 days ahead (http://www.marcopolo-panda.eu/forecast/). The performance of the multi-model prediction system is evaluated using available datasets in China including ozone and particulate matter. The ensemble approach enhances the accuracy of the forecasts and shows improved statistical skills compared to individual model predictions. We discuss the different uncertainties affecting the performance of current air quality forecasting systems and the different approaches that can be used to reduce such uncertainties.

Introduction

In this study we present an ensemble model forecasting system implemented to provide daily forecast of air quality in China. This system has been conceived and developed in the framework of two EU-funded projects: PANDA and MarcoPolo (http://www.marcopolo-panda.eu/forecast/). We performed a detailed study of some of the recent haze events that occurred in China (e.g. Fig 1.) and evaluated the performance of the ensemble predictions over 37 Chinese cities. We will demonstrate the good performance of the ensemble forecasting system approach and discuss the uncertainties that affect current individual air quality forecasting systems. We will also present the MAP-AQ initiative which, as a future perspective, aims to develop a consortium of expert groups that coordinates and enhances research and services with the purpose of mitigating air pollution in developing countries such as in Africa and South America.

Methodology and Results

The ensemble model system includes nine global and regional chemistry-transport models. The regional systems follow a downscaling approach: global model forecasts provide initial and boundary conditions to regional model predictions. In this study, we show a comprehensive evaluation (e.g. Figure 1) of our modeling approach with in-situ observations of pollutants (O3, NOx and particulate matter) at several surface stations in China. The analysis of several haze events highlights the fact that individual models do not necessarily provide accurate estimates of air quality situations. The application of simple statistical parameters, specifically the calculation of mean or median values derived from a multi-model ensemble forecast, tends to reduce the influence of outliers and hence provides better quality and accuracy forecasts.

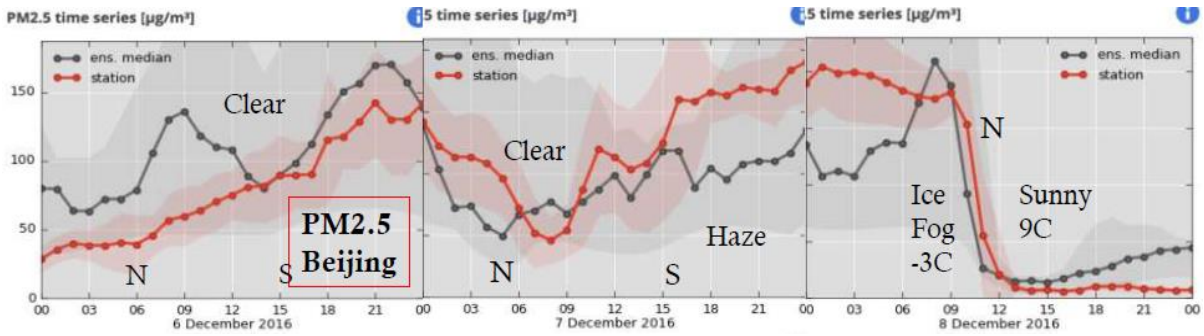

Fig.1 Observed (red) and ensemble median forecast (black) of $PM_{2.5}$ in Beijing for 6, 7 and 8 December 2016. Light red and grey are standard-deviation values

Conclusions

The combination of several air quality prediction systems into an ensemble, already experimented by the CAMS project in Europe, is a pragmatic approach that can be used to reduce the uncertainties that affect the performance of individual model predictions. Within the EU-funded PANDA and MarcoPolo projects, a multi-model forecasting system for air quality in China has been constructed using nine models. Interesting differences are found among the individual models involved in this study indicating the need to assess the relation between the performance of the models and the complexity of their chemistry and aerosol schemes. The multi-model ensemble approach increases generally the skill of the forecasts, in comparison with individual model predictions. The MarcoPolo-PANDA ensemble forecasting system has been operational since summer 2016 and provides operational air quality forecasts for 3-7 days ahead.

Acknowledgement

The authors acknowledge supported from the EU-funded projects PANDA and MarcoPolo. We acknowledge the ECCAD and MEIC teams for providing emission inventories.

IMPACT OF AFRICAN DUST ON AIR QUALITY OF SPAIN 2001-2016. IS IT ONLY DUST THAT MATTERS?

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Summary

We present here results of the occurrence of African dust over Spain in the last two decades, the impact on PM10 and PM2.5 levels, as well as a summary of major health effects deduced from cross studies using different air quality parameters. We will discuss what are the major patterns of dust outbreaks that may have relevant health effects, as well as the forecasting system that we implemented in Spain to alert air quality networks and most sensible population.

Introduction

Different regions of Spain are influenced by dust outbreaks with varying frequency and intensity depending on the distance to the north of Africa. During extreme episodes this impact may result in exceeding the PM10 standards for human protection.. Since January 2001 we report to the Ministry of Agriculture, Fishing, Food and Environment of Spain on the occurrence of these dust outbreaks over Spain. This includes forecasting and post-event evaluation of the impact on ambient levels of PM10 and PM2.5 of each episode. Furthermore we monitor levels of PM10, PM2.5 and PM1, as well as their chemical speciation and concentrations of ultrafine particles and black carbon (UFP and BC), at an urban, a regional and a continental background sites in and around Barcelona (NE Spain). In this study we evaluate the impact of dust outbreaks on PM10 and PM2.5 levels in different regions of Spain. Finally, we discuss on the possible patterns of the dust outbreaks with possible influence on the health impact of PMx.

Methodology and Results

Using a statistical method to quantify the African dust contributions to daily PM10, PM2.5 and PM1 levels (Escudero et al 2007, subsequently modified in (EC 2011) we evaluate the 2001-2016 time series of PM10 and PM2.5 concentrations of 25 remote air quality sites covering the whole Spanish territory to determine the mass contributions to annual and daily ambient PMx. Furthermore, we analyse also the 2009-2016 PM10, PM2.5 and PM1 chemical speciation time series from 3 monitoring sites (urban background of Barcelona, UB; regional background, RB at Montseny; and continental background, CB at Montsec) from NE Spain to evaluate the influence on the PMx composition and the impact of dust outbreaks on both mineral and non-dust-related PM components. Details of the chemical speciation analysis are reported by Querol et al (2001) and Minguillón et al (2012). Finally we review prior results and discuss the direct and indirect heath impact of African dust episodes. The annual mean African dust contribution to ambient PM10 levels ranged from 1 to 8 $\mu g/m^3$ (also from the NW region to the Canary Islands). Levels of PM2.5 and PM1 were also highly affected due to fine dust particles but also, as already described by Pandolfi et al (2014), by the increase of the anthropogenic PM load. The latter is attributed to i) the decrease of the height of the planetary boundary layer; ii) interaction of dust with gaseous pollutants favouring secondary PM formation; iii) co-transport of anthropogenic pollution with dust in air masses travelling over N Africa and crossing the Mediterranean. The results from the chemical speciation support that levels of Se, As, SO_4^{2-} and other anthropogenic components might reach the maxima during dust episodes when compared with the other atmospheric transport scenarios and atmospheric stagnation episodes affecting Barcelona.

Conclusions

Results indicate that, in addition to the marked increase of mineral dust, dust outbreaks favour the accumulation of locally emitted anthropogenic elements/species. Accordingly, it is not only mineral dust that matters for air quality during African dust episodes. Thus, when analysing health effects of PM during dust outbreaks it is convenient to evaluate the effects for the coarse and fine fractions and also for the mineral and anthropogenic loads of PMx.

Acknowledgement

The present work was supported by the Spanish Ministry of Agriculture, Fishing, Food and Environment and by the Generalitat de Catalunya (AGAUR 2015 SGR33, and Departament de Territori I Sotenibilitat).

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IMPROVED TOOLS FOR ASSESSING NO_2 EXPOSURE IN EUROPE

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Summary
This paper presents a methodology to assess NO_2 health impacts in Europe. In order to capture the steep gradients of NO_2 concentrations in the vicinity of NO_X sources like traffic, the QUARK model was developed. QUARK makes use of pre-computed "kernels" and allows to map annual averaged NO_2 concentrations at the spatial resolution of 100m for the whole of Europe.

Introduction
Currently, no adequate and commonly accepted methodology exists to assess the NO_2 health impacts at an EU-level. To a large extent this can be attributed to the level of detail required in the NO_2 concentration assessment due to the strong spatial gradients of NO_2 around roads. In addition, the uncertainty surrounding the NO_2 concentration response functions and the lack of auxiliary data such as EU wide traffic volumes contributes to this knowledge gap.

Methodology and Results
In a first part of the paper we present a sensitivity analysis of the major sources of uncertainty in such an EU-wide NO_2 health impact assessment. Amongst other we investigate the impact of the spatial resolution of the NO_2 assessment and the available concentration response curves (with special attention to the proposed cut-off in the HRAPIE CRF's).

Subsequently we present the QUARK model, a novel methodology to estimate the annual NO_2 concentrations for the whole of Europe at a resolution of 100m. In order to do so in a reasonable amount of time, we use a dispersion kernel method applied to the major source of local ground level NO_X emission in Europe: traffic. In QUARK, a list of NO_X dispersion kernels is pre-calculated using the IFDM Gaussian dispersion model for different road directions and different weather regimes in Europe. This gives rise to a database of standard patterns of NO_X concentration fields for line sources with a fixed unity emission. These kernels are then applied throughout Europe, multiplying the results with the effective emissions of each of the road segments. The latter are estimated using a downscaling of the 7x7 km² SHERPA NO_X emission dataset on the major roads, taken from Open Street Maps. The resulting NO_2 concentrations are joined, including corrections for emission double counting and chemistry, with the results of a CHIMERE simulation at 7x7 km². The final high resolution map is validated with AirBase monitoring stations and can be used to assess EU-wide NO_2 exposure at unprecedented spatial detail. The map is accessible via http://maps.atmosys.eu/eu-no2/ and an extract is presented in Fig.1. Since the QUARK methodology starts from traffic NO_X emission at road segments, it can also be used to investigate the impact of EU traffic policies. An example for a specific GAINS scenario is presented to demonstrate the capabilities of QUARK to translate an EU wide policy scenario down to concentration changes at street level.

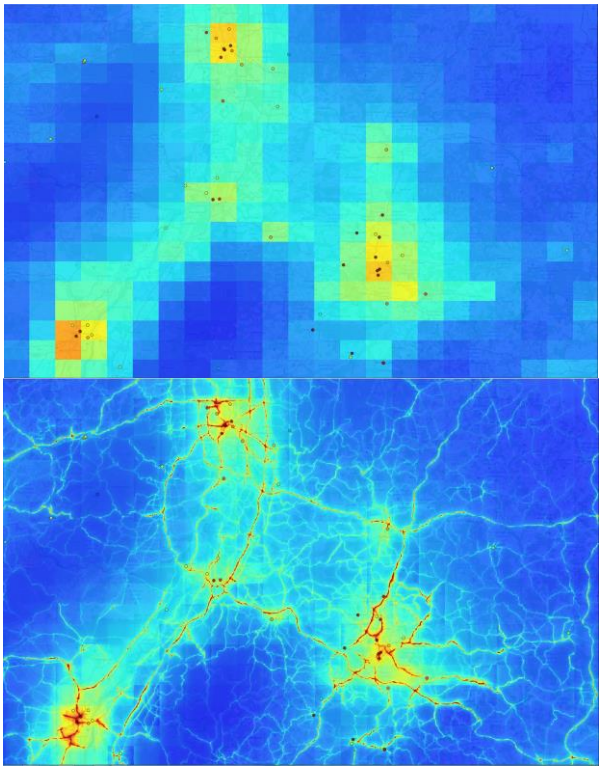

Fig.1 Extract of the NO_2 maps over Baden-Württemberg (Manheim – Stuttgart). The top panel shows the CHIMERE-NO_2 map, the bottom panel the QUARK map. Units are in in µg/m3, with equal colour scale for both panels.

Acknowledgement
This work has been performed in the frame of the DG-ENV service contract 070201/2015/SER/717473/C.3.

ARE METHODS TO PREDICT FUTURE AIR QUALITY CONCENTRATIONS RELIABLE ENOUGH TO MAKE POLICY DECISIONS?

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Summary

The modelling methods used to set policy measures in the UK and London do not make use of advanced modelling techniques, such as meso-scale models. However the modelling has been key to the recent introduction of national policy measures, primarily to ensure compliance with the EU Directive limit value for nitrogen dioxide. This paper reviews the modelling methods and highlights their deficiencies, which could lead to failures to meet the NO_2 limit value or a solution to air quality health concerns.

Introduction

In the past year a number of important policy measures have been introduced in the UK, to try to enable the country to meet the EU Directive annual limit value for NO_2.

Methodology and results

This paper reviews the measures proposed in these policy initiatives, mainly related to motor vehicles, primarily diesels, such as the introduction of Clean Air Zones in major conurbations, stricter road vehicle emission tests and the T-charge on older vehicles in London, with a future ambitious plan to phase out petrol and diesel cars altogether. It demonstrates that because of uncertainties in predicting future concentrations, measures designed to reduce NOx emissions may neither produce the anticipated reduction in NO_2 concentration, nor ensure compliance with the limit value nor lead to a significant reduction in the number of life years lost to air pollution.

The difficulty lies with the treatment of secondary pollutants. Official modelling, apart from a lack of transparency, takes an optimistic view of model validation, simplifies non-linearities especially when dealing with future emissions and does not fully treat source apportionment. This study introduces some simple diagnostics which enable simple comparisons to be made of the benefits of exposure reductions to NO_2 and $PM_{2.5}$ concentrations brought about by measures to reduce primary emissions. The diagnostics involve ratios of the NO_2 population exposure, total $PM_{2.5}$ population exposure and the population exposure to $PM_{2.5}$ arising from primary particulate emissions in a typical London street. The diagnostics provide a simple way of analysing the UK modelling methods for assessing the effect of policies to reduce emissions. This is a complementary approach to very detailed assessment models, for which the factors leading to the major uncertainties may be hidden or difficult to establish.

Conclusions

It is concluded that uncertainties in the methods for assessing future NO_2 and $PM_{2.5}$ concentrations in the UK are considerable and limit the reliability of the current, chosen policy options. The results are seen as a warning to policy makers.

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Air Pollution Sources and Emissions

A SOURCE APPORTIONMENT ASSESSMENT OF OZONE CONCENTRATION IN PEAK SUMMER EVENTS OVER SOUTHWESTERN EUROPE

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Summary
This study aims to quantify the contributions to surface ozone (O_3) concentration in the Iberian Peninsula (IP) from the main NO_x emission sectors within the region along with the external contributions (O_3 produced outside of the IP) during a pollution episode. The work applies the Integrated Source Apportionment Method (ISAM) within the CALIOPE air quality system at 4-km resolution which includes the bottom-up HERMESv2.0 emission model providing highly disaggregated emission fluxes. This study shows that besides the major external contribution towards IP, O_3 contributions from local/regional sources are decisive in the O_3 hourly peaks downwind of main NO_x hotspots in IP.

Introduction
The IP experiences severe tropospheric O_3 episodes during the summertime. Since the early 1980s a number of studies have advanced our knowledge on the dynamics of these episodes based on a comprehensive understanding of the synoptic and mesoscale circulation patterns. However, there is a lack of studies identifying the sources responsible for the high O_3 over the region, which is crucial to design adequate mitigation measures. Chemical Transport Models (CTMs) are tools to quantify the impact of sector-specific pollution at the surface of a receptor region. The simplest and most widely used source apportionment approach in CTMs is the brute force, but it can be computationally prohibitive if many emitters are of interest, and it is susceptible to numerical instability. Recently, CTMs include algorithms to track multiple pollutant sources along the whole pollutant's lifetime without altering the atmospheric conditions, which is vital for non-linear regimes (e.g. O_3).

Methodology and Results
We quantified the contributions to O_3 in the IP from the main NO_x emission sectors (see Fig.1a): energy production (SNAP1), manufacturing industries (SNAP34), road transport (SNAP7), non-road transport (SNAP8), and the chemical boundary (BCON) and initial (ICON) conditions. The experiment covers the IP during an O_3 pollution episode in July 21-31 2012. The ISAM O_3 tagging method (Kwok et al., 2015) is a mass balance technique that tags both O_3 and its precursor emissions from each source sector and calculates all the concentrations of O_3 ensuring mass conservation within one simulation. The results are grouped into ten O_3 receptor sub-regions (see Fig.1b). In all sub-regions the external contribution accounted for more than 45% of the O_3 under exceedances of the 120 μgm^{-3} threshold for the maximum daily 8-hour concentration (DMA8). Our analysis indicates that this external fraction is typically controlled by the downward mixing of O_3 upper layers transported from beyond the IP. The sub-regions involving the biggest cities in Spain (Central and NE IP) show the highest road transport contribution to O_3 (up to 40% in daily peak in events). Meanwhile in industrial regions (NIP, NW IP and GV) SNAP1 and SNAP34 contribute to ozone up to 11%. Overall, the non-road traffic is a contributor as significant as the road transport in all sub-regions (10-19%).

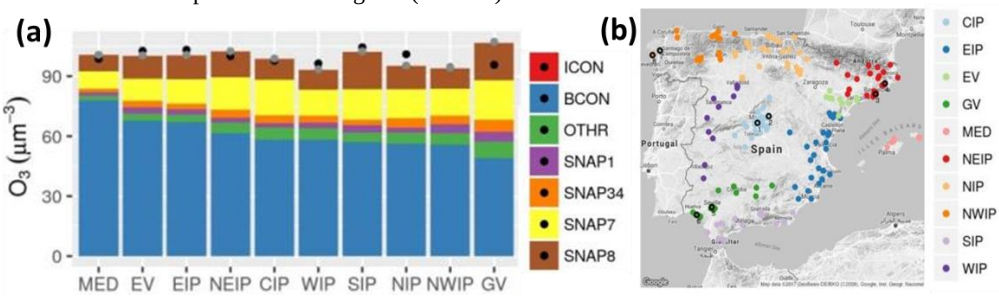

Fig.1 (a) Daily mean contribution of tagged O_3 during exceedances of the observed 120 μgm^{-3} for DMA8 O_3 averaged by (b) identified receptor regions. Black and grey dots represent observed and modelled daily mean O_3 concentration during exceedances of 120 μgm^{-3} of the DMA8.

Conclusions
O_3 over IP is not only of a local or regional origin, but hemispheric. Long-range transported O_3 from beyond IP domain is the main contributor to the daily mean O_3 concentration. In addition, during high O_3 events BCON is added to relevant local and regional anthropogenic contributions, which are decisive in the O_3 hourly peaks downwind of main NO_x hotspots in IP.

Acknowledgement
This study is supported by the Spanish Ministry of Economy and Competitiveness under the PAISA project (CGL2016-75725-R) and granted with computing resources of the "Red Española de Supercomputación" at FinisTerrae2 in CESGA.

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MULTIVARIATE STATISTICAL METHODS APPLIED ON ORGANIC MARKER SPECIES AS AN EFFECTIVE TOOL IN SOURCE IDENTIFICATION STUDIES AT A LOCAL SCALE

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Summary

The aim of the study is to demonstrate application of multivariate statistical techniques such as principal component analysis (PCA) and hierarchical clustering on principal components (HCPC) on organic pollutant species as an effective and reliable tool in source identification studies at a local scale. Analytical technique PyGC/MS was used to identify organic species in PM_{10} samples. HCPC produced three clusters of measurements which were clearly characterized by the predominant source of pollution at the measurement sites: plastic manufacturing sources; wood combustion and no specific source (background). Use of the HCPC was, thus, justified in the organic pollutant species based identification of the pollution sources.

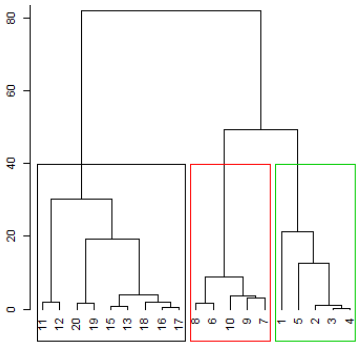
Introduction

Source identification of the ambient air quality is a matter of serious concern. The concept of marker species is based on the use of a single pollutant as a tracer of a specific source. Organic markers provide appropriate source representation while the method does not require advanced calculations and has a relatively low uncertainty (only measurement error included). However, due to its limitation, it can oversimplify real results in some cases (Oakes et al., 2014). Plenty of studies used multivariate statistical methods in air pollution studies and source identification, only few studies have employed clustering techniques (e.g. Austin et al., 2012); moreover, combination of principal component analysis followed with hierarchical cluster analysis on principal components was not used on organic marker species in air pollution studies so far. The aim of this study was to investigate spatial changes in pollutant mixtures at a local scale.

Methodology and Results

Four sampling sites located in city Napajedla (representing all potential pollution sources) in the Zlín region (SE Czech Republic), were chosen in this study. The city's industrial sector is represented by plastics processing and manufacturing, and also by mechanical engineering. PM_{10} samples were collected during autumn 2016 at all sampling sites simultaneously, five times for 72 hours, and Py-GC/MS method was employed in organic compounds detection. 52 organic marker species was selected for data analysis, and PCA followed with HCPC were performed. The first principal component distinguished two groups of measurements – sites affected plastic manufacturing sources opposed to those affected by other sources (traffic, home combustion), the second PC distinguished two groups of individuals of other sources – home combustion / traffic opposed to background. HCPC performing on the first five components produced three main clusters: Cluster 1 was consisted of individuals representing measurements from plastic manufacturing sources, the group was characterized by high measured concentrations of compounds *bumetrizole*, *bis(tridecyl)phthalate* and *mono(2-ethylhexyl)phthalate* (all markers of manufacture and processing of plastics); Cluster 2 consisted of individuals representing measurements from the background site, the group was characterized by high concentrations of compounds: *sitosterol* and *estratrieon*; Cluster 3 consisted of individuals representing measurements from the site affected mainly by biomass combustion, the group was characterized by high concentration of compounds *oleanal* and *lutidin* (markers of wood combustion).

Fig.1 Resulting HCPC dendrogram



Conclusions

The use of organic marker species in multivariate statistical methods can properly distinguish main air pollution sources between sampling location even at the small urban scale. Identifying which organic compounds are the most significant for each cluster (location) allows a better understanding of air quality in the study area, thus the model is applicable in source identification studies.

Acknowledgement

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POTENTIAL SOURCES OF PM_{10} IMPACTING THE HAUTS-DE-FRANCE REGION OVER A 5-YEAR PERIOD (2009-2013) IDENTIFIED BY RECEPTOR MODELING: INFLUENCE OF PRECIPITATION, AIR MASS ALTITUDE, LENGTH OF BACKWARD TRAJECTORIES AND THE USE OF A WEIGHTING FUNCTION

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Summary
Potential emission source areas of PM_{10} impacting the Hauts-de-France (HdF) region in northern France were investigated for the 2009-2013 period by means of the Concentration Field (CF) receptor model, using daily mass concentration of PM_{10} at 12 sampling receptor sites and 72-h air mass backward trajectories calculated with HYSPLIT model. The results showed a significant influence from areas located in central Europe (e.g. Czech Republic, Slovakia and Hungary). However, these potential source areas were associated with trajectories not frequently impacting the HdF region. A sensitivity analysis based on precipitation and altitude led to more realistic potential source maps. Moreover using trajectories frequently impacting the HdF region through a weighting function showed significant influence from nearer source regions (e.g. the city of Paris, Benelux and west of Germany). Comparison of these results to the EMEP regional emission inventory showed accordance for many areas and discrepancies for others. This work highlights the need for such a receptor-oriented approach (e.g. CF) which uses measurement data as input in order to evaluate and improve emission inventories and CTM models.

Introduction
The HdF region located in north-western Europe is subjected to frequent high-pollution PM_{10} episodes where the European daily limit value of 50 µg m^{-3} for PM_{10} is often exceeded. High levels of PM_{10} were found to be associated with adverse impacts on human health as they contain many toxic and carcinogenic compounds. In order to reduce the impact of air pollution on human health, investigation of potential source areas impacting the region of study is necessary to identify local and regional sources. To address this issue, geographical origins of PM_{10} have been investigated for a five-year long period (2009-2013) using 12 receptor sites representative of the whole area, including a sensitivity analysis in order to study the impact of long, medium and short range trajectories.

Methodology and Results
Daily PM_{10} values for the period of 2009-2013 were collected from Atmo HdF. For the CF analysis, the residence time of each air parcel was used to identify areas that could be responsible of high PM concentrations at the receptor sites through air mass backward trajectories. 72-h backward trajectories were calculated by means of the PC-based version of HYSPLIT model every 6 hours at an ending altitude of 500 m. CF multi-site maps were calculated using Zefir (Petit et al., 2017) on both annual and seasonal bases with the use of many sensitivity tests: influence of precipitation and altitude threshold limit, use of a weighting function for the investigation of medium-range trajectories, and selection of short-range trajectories distant by 500 km from the receptor site to highlight the influence of nearer sources. The multi-site CF maps showed an influence from Central Europe for long-range trajectories but associated with air masses rarely impacting the HdF region. For medium-range trajectories, an influence from nearer areas (e.g. Benelux and west of Germany) was revealed whereas when short trajectories were considered, an influence from the local sources of the HdF region and the Paris megacity was emphasized. Seasonal variations of CF maps showed that impacting sources were closer to the HdF region during the winter and fall when primary emissions from local combustion sources were at their maximum, and more distant sources during spring and summer, likely linked to secondary processes (e.g. nitrate- and sulfate-rich and organic aerosols). Comparison of these results to the EMEP regional emission grid maps averaged over the same period showed accordance for many areas and discrepancies for others. Discrepancies which could be related to uncertainties of both approaches are going to be evaluated and discussed as a part of this work. Nevertheless, the comparison highlights the importance of such an approach to evaluate and improve emission inventories and chemistry transport models.

Conclusions
In this study, potential source areas maps were investigated for the HdF region for the period of 2009-2013 and showed an influence from both intra and extra-regional sources. The study highlighted also an influence from long-range transport from Central Europe in particular leading to maximum levels of PM_{10}.

Acknowledgement
This work was supported by the CPER Climibio project and the labex CaPPA. The authors acknowledge the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport and dispersion model used in this publication.

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AIR QUALITY AND POLLUTANT EMISSIONS IN THE MOSCOW MEGACITY

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Summary
Observational data obtained at 35 stations in 2005-2014 have been used to estimate the air quality in Moscow.
Spatial and time variations of the key air pollutants over Moscow have been revealed.
Annual CO, NOx, SO_2, and CH_4 emissions from Moscow and the Moscow agglomeration have been assessed.
Time variations and trends of annual emissions reflect changes in the urban infrastructure.

Introduction
In Moscow, the development of an up-to date network for monitoring atmospheric composition got under way in the late 1990s. In 2010, this network included 35 stations. Data on surface NO, NO_2, CO, SO_2, CH_4, and PM_{10} concentrations measured from 2005 to 2014 have been used in studying the characteristic features of their distribution over the city and their time variability. Their seasonal and interannual variations, as well as 10-year trends, are closely related with variations in the urban infrastructure and weather conditions. The emission fluxes of CO, NOx, SO_2, and CH_4 and their integral emissions for Moscow have been estimated using multiyear measurements of their concentrations, vertical air temperature and wind stratification. The weekly cycles obtained by the method of superimposed epochs and the inverse Fourier transforms of the average in Moscow data characterize variations in surface concentrations of urban air pollutants during the average week for 10 years. Additionally the characteristics of CO Total Column and AOD over Moscow and outskirts obtained using ground-based OIAP RAS and AERONET observations as well as orbital AIRS, MOPITT CO and MODIS AOD observations were analyzed for improvement of weekly and seasonal variations of anthropogenic emissions.

Results
Trends of pollutants concentrations and emission fluxes reflect changes in Moscow infrastructure (Fig. 1;Table 1).

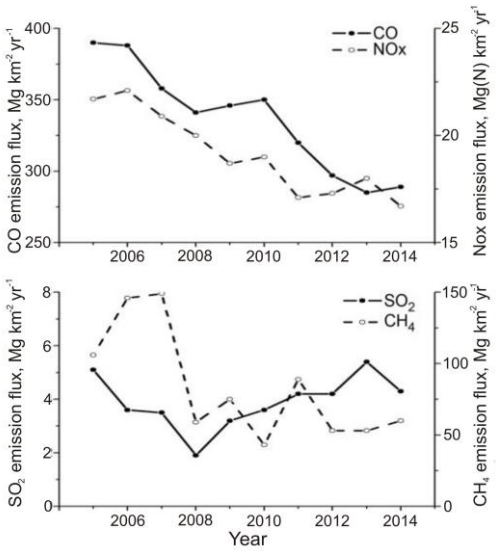

Fig.1. Annual mean anthropogenic emission fluxes of CO, NOx, SO_2, and CH_4 for Moscow megacity between 2005 and 2014.

Table 1. Emissions trends of air pollutants for Moscow from 2005 to 2014 (% yr-1).

Pollutant	CO	NOx	SO_2	CH_4
Trend	-1.9±0.3	-1.7±0.4	+3.3±2.3	-7.8±3.1

The CO emissions from Moscow megacity coincide with their EDGAR v4.2 inventory values interpolated to the territory of Moscow. However, the EDGAR v4.2 values of NOx, SO_2, and CH_4 significantly exceed their calculated values. This is, to a large degree, associated with the fact that, in this inventory, the contributions of metallurgy and chemical industries, methane escape during natural-gas transportation and distribution, house heating, and some other sectors are overestimated. The emissions of CO, NOx, SO_2, and CH_4 have also been calculated for the Moscow agglomeration, which includes towns and enterprises located within a radius of approximately 75 km.

Conclusions
Emission estimates obtained for Moscow and Greater Moscow make it possible to do more correct comparisons with other cities and different inventory data. The annual means of integral emissions from Moscow differ only slightly from other megacities in the world.

Acknowledgement
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GREEN BIOMASS OFFERS GREY FUTURE FOR AIR QUALITY

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Summary
Extraordinary levels of air pollution, surpassing 300 µg m^{-3}, and exceeding WHO $PM_{2.5}$ guidelines with 1 in 5 winter days were observed in a moderately-sized European city (Dublin, Ireland) and are attributed to emissions from residential solid fuel – specifically peat and wood, often promoted as '*slow renewable*', '*low-carbon*', '*carbon-neutral or even 'green'* biomass. Using sophisticated fingerprinting techniques, we unexpectedly found a staggering 70% of the PM_1 pollution arose from <4% consumption of solid fuel (0.2% wood and 3.6% peat) in contrast to 94% oil. Using this advanced approach, we can better inform emissions reductions policy to ensure the most appropriate air pollution culprits are targeted. Our results suggest that even modest increases in consumption of current 'green' marketed fuels will have a disproportionate impact on the frequency of extreme pollution events and our endeavors towards cleaner air since matching the calorific benefit of liquid fuels, the solid fuels emit ~5 (for peat) to ~17 (for wood) times more pollution.

Introduction
Particulate matter (PM) is well known to have adverse effects on human health, both in terms of mortality rates and reduced lifespan (Pope and Dockery, 2006). The World Health Organization (WHO) recommends a daily $PM_{2.5}$ (with an aerodynamic diameter less than 2.5 micrometers) limit value of 25 µg/m^3 (EPA,2010) not to be exceeded. However, it is noted that there is no identifiable threshold below which $PM_{2.5}$ would not pose a risk to. Thus, source apportionment technique (e.g., ACSM-PMF) is widely employed to characterize the pollution sources in an ultimate goal of informing a policy to reduce PM pollution.

Methodology and Results
A pilot national network was deployed in Ireland with the aim of enabling source apportionment of organic matter using real-time online aerosol mass spectrometers (see AEROSOURCE web site for more detail; www.macehead.org). The ACSM provides separation and quantification of organic aerosol species using Positive Matrix Factorization (PMF) and, prior to deployment in the transboundary network, ACSM was initially used to fingerprint specific residential solid fuels (wood, peat, and coal) which were used to constrain PMF. Two extreme pollution events on the night of 19th November 2016 (P1) and 22nd January 2017 (P2) with a 30-minute PM_1 average of ~300 µg/m^3 were found to be mainly caused by solid fuel burning (Fig. 1) during the night. In contrast, secondary OOA is dominant during the day.

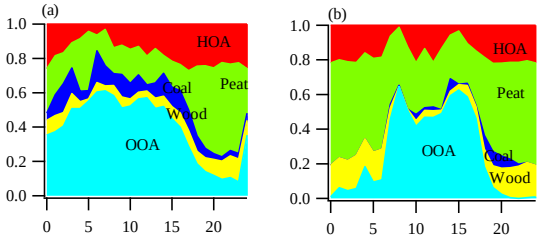

Fig.1 The average diurnal cycle of the relative contribution of ACSM-PMF resolved factors (i.e. HOA (hydrocarbon-like organic aerosol), peat, coal, wood, and OOA (oxygenated organic aerosol) during (a) P1; and (b) P2.

Conclusions
Despite the minor fraction of modern solid fuels (wood and peat, ~4%) used for heating, their poor combustion efficiency is responsible for the extraordinary high PM_1 concentrations (~70% of the total PM).

Acknowledgement
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THE INFLUENCE OF SHIPPING EMISSIONS ON POLLUTANT CONCENTRATIONS IN THE BALTIC SEA REGION

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Summary
The aim of this study is to quantify the influence of emissions from ships sailing the Baltic Sea on concentration levels of the air pollutants NO2, PM2.5 and Ozone. Transport and chemical transformation of the emitted species were simulated with the chemistry transport models CMAQ, SILAM and the EMEP model. This study focuses on evaluating the shipping influence with the CMAQ results and compares these both with the results of the other models and with observational data.

Introduction
While land-based emissions of nitrogen oxides (NOx) in Europe have steadily decreased over the past two decades due to stringent air quality regulations; emissions from ship traffic in the North Sea and Baltic Sea have been increasing over the same time period. In the atmosphere, nitrogen oxides are transformed through photochemical processes into more water soluble gaseous and particulate species which are eventually removed by deposition. The atmospheric deposition of nitrogen-containing species is an important contribution to the input of nutrients into the Baltic Sea and to land ecosystems. The results from this model study will be maps of nitrogen deposition from shipping to the Baltic Sea and maps of the ship contribution to air pollution (NO2, O3, PM2.5) and nitrogen deposition in the Baltic Sea region.

Methodology and Results
The CTM CMAQ (Byun and Schere, 2006) was applied on a 4km x 4km Lambert conic conformal grid. Meteorological fields to drive the chemistry transport module were calculated with the climate version of the COSMO weather forecast model (Rockel et al. 2008). Anthropogenic emissions of all relevant sectors except for ship traffic were created with Sparse Matrix Kernel Emissions model for Europe (SMOKE-EU, Bieser et al. 2011). Simulations were done for the full year of 2012 to represent the present-day situation. Ship emissions from (Ship Traffic Emission Assessment Model) STEAM (Jalkanen et al., 2012), which uses ship position data of the Automatic Identification System (AIS) network, were gridded to the respective model's grid resolution.
Photochemical ozone production due to NO2 from ships increases O3 levels in areas >100 km away from the major ship routes. On the other hand, Ozone titration in the shipping lanes was about 7 ppbV in the CMAQ and EMEP simulations, while this effect was less pronounced in the SILAM results. Shipping emissions are responsible for 40-70 % of the particulate nitrate during the summer months. An increase of annual nitrogen depositions of up to 178 kg/ha (with CMAQ) could be seen along the coastlines, however with a large discrepancy between the models.

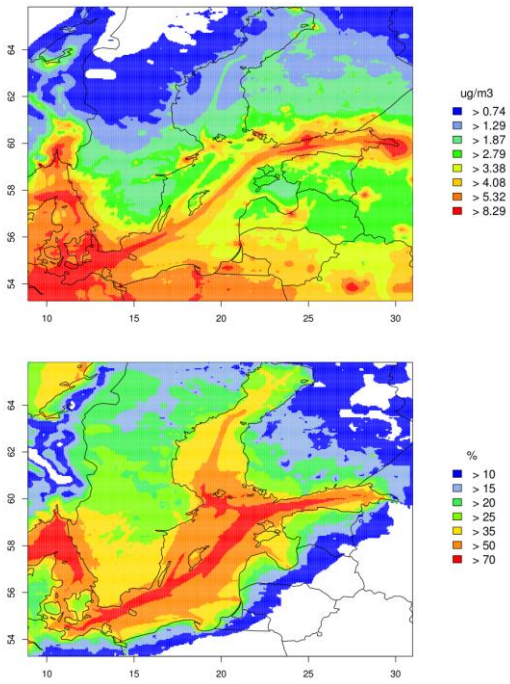

Fig.1 Annual mean NO2 concentrations (top) and the relative contribution by ships (bottom).

Conclusions
Shipping emissions in the Baltic Sea calculated with a state-of the-art ship-emissions model were used to simulate the annual air Quality in the Baltic Sea region with three different regional scale air quality models. Results show that for many of the coastal areas emissions from ship engines are the only significant source of air pollutants like NOx. Hence, shipping is the main contributor to ambient NO2 concentrations over the Baltic Sea and at coastal sites (Fig. 1).

Acknowledgement
This research (CMAQ and SILAM simulations) is part of the SHEBA project funded by BONUS.

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THE IMPACT OF EMISSIONS FROM SHIPS IN THE GOTHENBURG AREA ON URBAN SCALE AIR QUALITY AND HUMAN HEALTH

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Summary

Ship emissions in and around ports contribute to local air pollution in port cities and are therefore of interest for urban air quality management. In the frame of the BONUS SHEBA project (Shipping and the environment of the Baltic Sea Region, www.sheba-project.eu) the impact of emissions from ships on local air pollution in the city of Gothenburg (Sweden) for year 2012 has been studied. The city-scale air quality was simulated with the coupled meteorological and Chemical Transport Model (CTM) TAPM to investigate impact of the local and regional shipping activities. The modelled concentrations of ozone, $PM_{2.5}$ and NO_2 were used to calculate human exposure and to determine the effect of shipping on human health within the city.

Methodology

For the study of the air quality in Gothenburg, the meteorological domain was set-up with 30x30 km area and two different resolutions, (1) 500 m and (2) 1000 m. The CTM domain was nested in the domain of the meteorological model which was set-up with 93x93 grid cells of 250x250 m. TAPM used hourly boundary concentrations for the CTM domain derived from results of the regional simulation of the Baltic Sea Region of air quality model CMAQ with 4x4 km resolution (as performed within the BONUS SHEBA project).

The gridded shipping emissions were calculated with the activity-based STEAM model (Jalkanen et al., 2012) on 250x250 m resolution. Model runs for 2012 with all emission sources (shipping, road traffic – linear sources, other sectors – area and point sources) were performed as well as runs without shipping emissions to determine the effects of local shipping emissions on the overall air quality. A model run without shipping emissions was also performed using boundary concentrations from a CMAQ run that excluded the Baltic Sea and North Sea shipping to determine effects of the regional shipping emissions on urban air quality. In addition, every scenario was simulated with 500 m and 1000 m meteorological field resolution, to identify impacts of a higher resolution in CTM runs.

To access the health impacts, the human exposure was calculated using the modelled concentrations of air pollutants associated to shipping and gridded population density in Gothenburg. The health impacts of the exposures were calculated using ALPHA2 model (Holland et al., 2013). The TAPM simulations were evaluated for NO2 and PM2.5 for three monitoring stations of the Gothenburg measurement network.

Results and conclusions

Spatial maps of concentrations of and population exposures to NO_2 and $PM_{2.5}$, related to the local shipping, show the biggest impact in the harbour area (local shipping contribution to $PM_{2.5}$ concentrations shown in figure 1a). The relative contribution of the ship emissions to the overall air pollution is highest for NO_2 where the shipping can contribute by up to 30% close to the harbour. It is also more pronounced in summer months, when the concentrations of air pollutants from other sources are lower.

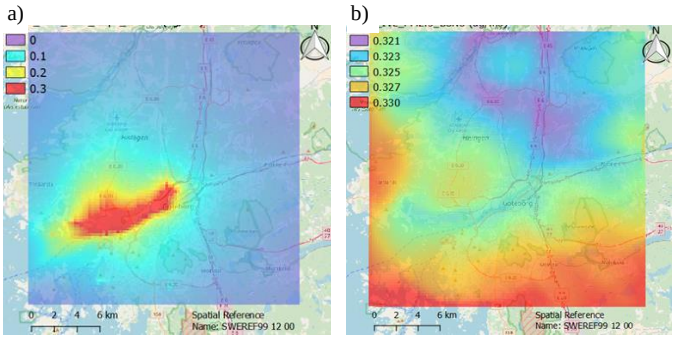

Fig.1 Contribution of (a) local shipping emissions and (b) regional shipping emissions toPM2.5 concentrations in the city of Gothenburg calculated with the TAPM model.

Shipping emissions in the North and Baltic Sea outside the model domain affect concentrations of air pollutants in Gothenburg in a rather homogeneous way, this partly due to the fact that the boundary concentrations are averaged on each side of the TAPM domain (regional shipping contribution to $PM_{2.5}$ concentrations shown in figure 1b). On average, the pollutants transported via the model boundary can contribute as much to the air pollution from shipping as the more local emissions. For ozone the impact of both local and regional shipping is a decrease of concentrations and exposure.

The comparison of all runs with just a change in the meteorological field resolution has shown only small differences in the modelled concentrations of air pollutants.

Acknowledgement

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ASSESSMENT OF DISCREPANCIES BETWEEN BOTTOM-UP AND REGIONAL EMISSION INVENTORIES

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Summary
This study shows the capabilities of a benchmarking system to identify inconsistencies in emission inventories, and to evaluate the reason behind discrepancies as a mean to improve both bottom-up and downscaled emission inventories. We have compared and evaluated fine scale bottom-up and regional emission inventories (i.e. EC4MACS, TNO_MACC-III, EMEP-GNFR, 2017) downscaled to the same areas. The comparison shows significant discrepancies in nitrogen oxides (NO_x) and particulate matter ($PM_{2.5}$ and PM_{10}) when evaluating both total and sectorial emissions. We will present the results and lessons learned when assessing two main sectors, on-road traffic and residential combustion.

Introduction
The quality of emissions is crucial as it will determine to a large degree the accuracy of air quality models. The quality of emission inventories relies on the quality of the activity data and emission factors, that define the emission intensity, and on the spatial distribution. Emission inventories are developed at local, regional and national scales, with methods that very much depend on the purpose, emission source intensity and input data availability. Different methods are being used to estimate and allocate emissions. Some methods, known as bottom-up, are based on data at high spatial resolution (e.g. building point, road link) and thereafter aggregated to a coarse scale (e.g. regional or national level). Regional emission inventories are often based on downscaling processes using ancillary data (e.g. population, land use), refereeing to those as "top-down". Several studies conclude that bottom-up may contribute with more accurate emission data and more realistic spatial distribution of emissions than top-down methods (Guevara et al., 2016; López-Aparicio et al., 2017).

Methodology
For the comparison of bottom-up and downscaled emission inventories, we used the Δ-Emis tool (Guevara et al., 2016; Thunis et al., 2016). Δ-Emis is an IDL-based tool designed to screen and benchmark emission inventories, and especially to support the comparison of bottom-up and top-down emission estimates at city, regional and country scales. The tool was designed in the framework of FAIRMODE; the Forum for Air Quality Modelling created for exchanging experience and results from modelling in the context of the Air Quality Directive (AQD). The FAIRMODE network intends to support model users at administrative levels in their policy-related model applications by establishing tools, databases and methods to enhance harmonization and promote good modelling practices among Member States.

Results
An assessment carried out at local scale in Norwegian cities shows that regional emission inventories underestimate urban NO_x and PM_{10} traffic emissions by a factor up to 2 and 4, respectively, when comparing with bottom up emission inventories. The bottom-up NO_x traffic emissions are based on the actual traffic volume at the road link and detailed information about the vehicle fleet composition, and result to be higher than the NOx emissions downscaled from national estimates based on traffic flow at the road link and population data. We have also identified important discrepancies in $PM_{2.5}$ emissions from wood burning for residential heating among all the inventories. The discrepancies are associated with the assumptions made for the allocation of emissions. TNO_MACC-III is in agreement with BUP emission inventories, EC4MACs inventory slightly underestimate PM emission from wood burning, and the new EMEP-GNFR at 0.1° underestimate PM emissions by a factor of 5 to 10 in several Norwegian cities.

Conclusions
The discrepancies found between emission inventories may have significant implications for their subsequent use in air quality models, exposure assessments and/or the evaluation of policy measures. The spatial disaggregation of emissions based on GIS methods and physical ancillary data does not always capture the geographical differences that are important for emission processes, and especially at urban scale. The benchmarking of inventories has proved to be essential for the better understanding and improvement of emission inventories.

Acknowledgement
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COMPARISON OF A NEW EMISSION INVENTORY FOR THE NORDIC COUNTRIES AND GLOBAL INVENTORIES

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Summary

We developed a comprehensive Nordic air pollution emission inventory at 1 km x 1 km spatial resolution. The inventory covers NOx, SOx, NH_3, CO, NMVOC, BC, OC, TSP, PM_{10} and $PM_{2.5}$ emissions for 1990-2014. In this paper, the inventory was compared to regional and global emission inventories: TNO-MACCIII and ECLIPSEv5a.

Introduction

In order to assess the complex behaviour of air pollutants in the atmosphere chemical transport models have been developed. In recent years the models have been developed for large domains at high spatial resolution to enable reliable health impact assessment. An important part of the modelling and a source of uncertainty is spatially resolved emission data. In this paper we introduce a new Nordic emission inventory at high spatial resolution. The inventory was compared to regional (TNO-MACC_III; Kuenen et al., 2014) and global (ECLIPSEv5a; Klimont et al., 2017) emission inventories for 2010, both in terms of total emissions as well as the spatial distribution of the emissions.

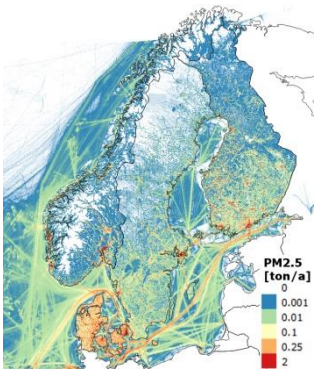

Fig.1 Gridded PM2.5 emissions for 2014 from NWA

Methodology and Results

National emission inventories in Finland, Sweden, Norway and Denmark were used to develop the Nordic inventory (NWA) at 1 km x 1 km spatial resolution, including most important single polluters as point sources. Iceland was included in the inventory, but was omitted in this comparison. In addition, shipping emissions were based on Finnish Meteorological Institute's STEAM model (Johansson et al., 2017).

For most pollutants the differences between the three inventories in total emissions were within 20%. However, sectoral emissions showed larger disparities. In small scale combustion there was variation in the emissions especially in BC, OC and NMVOC emissions. NWA had the lowest emissions for all pollutants, with 35% lower BC and 54% lower OC than TNO, and 57% lower NMVOC than ELCIPSEv5a. The $PM_{2.5}$/PM_{10}-ratio of traffic and machinery emissions for NWA was 0.43, but for TNO 0.73 and ECLIPSEv5a 0.70. One explaining factor was the traffic dust emissions, in which NWA had much smaller $PM_{2.5}$ fraction based on measurements in Nordic conditions.

Spatially $PM_{2.5}$ emissions from TNO were similar to NWA, although in Finland the NWA emissions were weighted more into rural areas. The ECLIPSE emissions were correlated more with population density than NWA. In small scale combustion TNO $PM_{2.5}$ emissions were more weighted to cities compared to NWA in Finland, whereas in Sweden TNO had lower weighting in Stockholm and more in other cities compared to NWA. For spatial distributions NWA used national data that took into account the local and regional characteristics.

Conclusions

While overall emissions were similar between the inventories, there were large sectoral differences. The discrepancies were especially found in small scale combustion and traffic dust, where regional differences are remarkable. Therefore, to reduce the uncertainties in larger scale inventories regional characteristics should be incorporated in a more detailed way.

Acknowledgement

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CONCENTRATIONS AND EMISSION FACTORS OF TRAFFIC ORIGINATED NANOCLUSTER AEROSOLS

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Summary

This study showed that a significant fraction of particle number of urban ambient air belonged to nanocluster aerosol particles (NCA, particle size range of 1.3–3.0 nm). This NCA was emitted by traffic. The emission factors of the NCA for traffic were $2.4 \cdot 10^{15}$ $(kg_{fuel})^{-1}$ in a roadside environment, $2.6 \cdot 10^{15}$ $(kg_{fuel})^{-1}$ in a street canyon, and $2.9 \cdot 10^{15}$ $(kg_{fuel})^{-1}$ in an on-road study throughout Europe. In engine laboratory experiments with a modern diesel engine, the emission factors of exhaust NCA varied from $1.6 \cdot 10^{12}$ $(kg_{fuel})^{-1}$ to $4.3 \cdot 10^{15}$ $(kg_{fuel})^{-1}$. The NCA emissions of traffic directly affect particle concentrations and human exposure to nanosized aerosol in urban areas, and potentially affect the condensational particle growth events observed in urban atmosphere.

Introduction

Traffic is known to emit significant amounts of primary particles, semivolatile compounds contributing the amount and properties of particles in diluted exhaust, and secondary aerosol precursor gases. Exhaust particles emitted by traffic have relatively complicated physical and chemical characteristics and they cover a large particle size range. Several studies have shown that the traffic originated particles affect air quality and human health in urban areas. This study extends the characterization of traffic emission to cover the smallest particles of traffic environments, called as nanocluster aerosol (NCA), i.e., the particles in a size range of 1.3–3.0 nm.

Methodology and Results

Atmospheric aerosols were studied in three experiments covering a wide range of environments: stationary measurements at the roadside of a main road in a semiurban area in Helsinki, Finland, stationary measurements in a street canyon environment in Helsinki, and a long-distance on-road study through the Western Europe using a mobile aerosol laboratory. These measurements were fulfilled by experiments in engine laboratory where the particle emissions of a modern heavy-duty diesel engine equipped with a diesel oxidation catalyst, a diesel particle filter, and a selective catalytic reduction system were studied at three engine load conditions. In the engine experiments, the exhaust was sampled using a partial flow sampling and dilution system shown to reproduce the real-world exhaust nanoparticle formation. In all the experiments, the NCA measurements were performed using combinations of Particle Size Magnifier (PSM, Airmodus Oy) and CPCs. CO_2 concentrations were measured parallel with the NCA measurements in order to determine the emission factors of the NCA. NCA measurements were reinforced by measurements with other instruments.

In stationary measurements in roadside environments, the NCA concentration depended significantly on the wind direction; when the wind was blowing from the road toward the monitoring station, the NCA concentrations exceeded 10^5 cm^{-3} in the semiurban environment and 10^4 cm^{-3} in the street canyon environment. In the semiurban roadside environment, the NCA represented 20–54% of the total particle concentration in ambient air. The NCA concentrations correlated with simultaneously measured CO_2 concentrations, indicating that the NCA was originated from combustion. Engine laboratory experiments supported this observation; especially at high engine load the NCA had a significant contribution to the total particle number concentration of the exhaust sample. When determined from ambient air measurements, the NCA emission factors varied from $2.4 \cdot 10^{15}$ $(kg_{fuel})^{-1}$ to $2.9 \cdot 10^{15}$ $(kg_{fuel})^{-1}$, while in engine experiments they varied from $1.6 \cdot 10^{12}$ $(kg_{fuel})^{-1}$ at 50% engine load to $4.3 \cdot 10^{15}$ $(kg_{fuel})^{-1}$ at 100% engine load.

Conclusions

Traffic emits high numbers of nanocluster aerosols into the urban atmosphere. This finding significantly updates the current understanding of atmospheric aerosol in urban areas and demonstrate that in urban air, significant fraction of extremely small

Acknowledgement

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DECREASING TRENDS IN DIRECT EMITTED NO2/NOX RATIO IN DENMARK, GERMANY, SWEDEN AND UK - IMPLICATIONS FOR A NECESSARY UPDATE OF EUROPEAN EMISSION MODELS

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Summary

This study aims to quantify the resent trends in directly emitted NO_2/NO_x ratios from road traffic, based on roadside measurements from Denmark, Sweden, Germany and U.K. The observations show similar trends with a peak in the years 2008-2010 in the range of 15%-20% and a subsequent decrease to about 10%-15% in 2014/2015.

The commonly used emission models (e.g. COPERT / EMEP-EEA emission inventory guidebook) would lead to much higher ratios of 20%-25% in 2014/2015 and cannot reproduce this unexpected decrease in NO_2/NO_x ratios.

This study suggested an updated set of NO_2/NO_x ratios for the most recent EURO technologies based on vehicle emission remote sensing including an assumption about decreasing ratios for recent EURO classes due to aging of the catalytic converters.

Introduction

Many European cities still struggle with high NO_x and NO_2 concentrations. The expected decrease in NO_2 was delayed due to increasing share of directly emitted NO_2 and the failure of Diesel light duty vehicles meeting the emission norms under real world driving conditions (also aggravated by "Dieselgate").

While vehicle emission factors for NO_x are widely measured and well established in emission database, only few data exist on the NO_2/NO_x ratios especially for recent EURO classes. However, the correct assumption about NO_2/NO_x ratios is crucial for street-scale air pollution modelling, widely used for forecast and scenario calculations.

Lately, comprehensive remote sensing data from London indicate that the increasing trend in NO_2/NO_x ratios, observed since the late 1990ies has unexpectedly reversed after about 2010 (Carslaw 2016). This paper analyses roadside measurements from Denmark, Sweden, Germany and U.K. for their trends in NO_2/NO_x ratios and compares these with estimates from emission models.

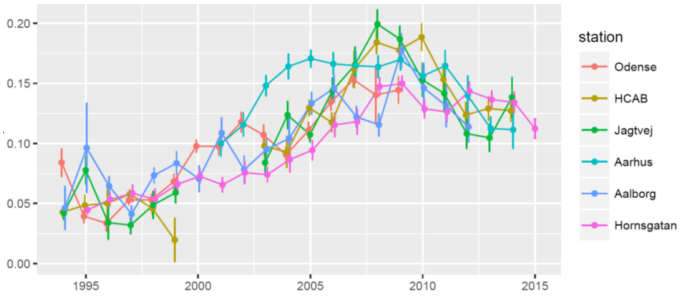

Fig.1 Trend in NO2/NOx at Danish and Swedish street stations

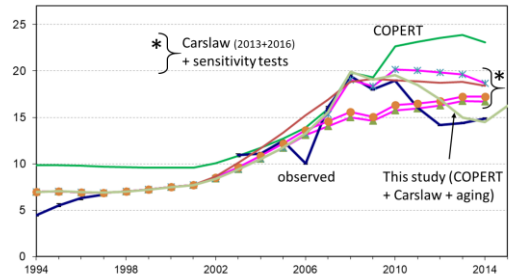

Fig.2. Observed and modelled NO2/NOx ratios (%) at HCAB.

Methodology and Results

We use two methods to estimate the directly emitted NO_2/NO_x ratios. Firstly, using a linear regression between ΔOx and ΔNOx with Ox =NO2 + O3 and "Δ" indicates the difference street and background concentration. Secondly, using a linear regression between Δ NO2 and ΔNOx that only requires one O3 measurement at the background station to filter for low O3 concentrations (e.g. < 10 ppb) in order to avoid in influence of the NOx-O3 chemistry. Fig.1 shows the estimated development of the NO_2/NO_x ratios for Danish and Swedish streets, revealing the maximum in 2008-2010 and the subsequent reduction similar trends are observed in U.K. and Germany.

The EMEP-EEA emission inventory guidebook gives NO_2/NO_x ratios as function of vehicle category and EURO-technology. The obtained trend in NO2/NOx based on a detailed fleet composition for a street in Copenhagen (Ketzel 2008, Ellermann 2015) is shown in Fig.2 (marked with COPERT). An overestimation compared to measurements is clearly visible. A bit lower NO2/NOx ratios are obtained for an updated set of vehicle category depending NO2/NOx ratios based on remote sensing reported in Carslaw (2013, 2016).

Conclusions

The "EMEP-EEA emission inventory guidebook" needs an update on direct NO2/NOx ratios for different vehicle categories and EURO classes. We propose an update of the NO_2/NO_x ratios for different vehicle types and EURO classed based on remote sensing including assumptions about aging of the catalytic converters ("This study" in Fig.2). With the update we are able to reproduce the peak in NO2/NOx ratios in 2008/2010 and subsequent decrease.

Future trends in NO2/NOx ratios for new vehicle technologies should be closely observed. The results of this paper indicate the decrease in NO2 emissions and NO2 concentrations in the future.

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A COMBINED EMISSION MODELLING APPROACH TO ESTIMATE ROAD TRAFFIC EXHAUST EMISSIONS AT URBAN SCALE

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Summary
The purpose of this work is to develop a combined emission modelling approach in order to explicitly predict the effects of the traffic congestion on the estimated emissions at urban scale, combining thus the advantages of an instantaneous emission model and an average-speed emission model. The current work highlight the potential of integrate a macroscopic transportation model with a combined emission model to provide enhanced high-spatially resolved input data for urban air quality modelling, in response to local needs and priorities.

Introduction
Currently, around 90% of European city dwellers are still exposed to high levels of air pollutants and road transport is a large contributor to this (EEA, 2015). Therefore, there is an increasing need to estimate road traffic emissions at urban scale as accurately as possible. Average-speed approach is extensively used for quantification of on-road vehicle emissions, since they can efficiently be applied to larger areas and required data are commonly available. However, since such models cannon reflect driving conditions, instantaneous emission models present a more complex approach combining information about instantaneous speed and acceleration to provide a more detailed description of emissions. Nevertheless, instantaneous models are particularly useful for microscale simulations, requiring a significant amount of detailed input data. Therefore, compiling a realistic traffic emission inventory is ultimately complex due to the large uncertainty levels regarding emission models. Considering this, a combined emission modelling approach that explicitly take the traffic congestion into account to provide accurate high-spatially resolved road traffic emissions at urban scale is proposed in this work and applied to a medium-sized Portuguese city (Coimbra). The performance of the modelling approach has been evaluated through air quality data from an experimental field monitoring in order to assess the reliability of the emission data.

Methodology and Results
Two approaches to calculate road traffic emissions were implemented and compared in this work: an instantaneous emission model and an average-speed emission model, in order to improve the characterization of PM10 and NO_x emissions from road transport in a complex urban area. For this purpose, GPS based vehicle trajectory data were collected (1 sec. resolution) for different time periods (peak and off-peak hours) in order to characterize the transport activity data required by each emission model. A comparative analysis between the two emission models was performed to evaluate the magnitude of the difference (absolute and relative) in estimated emissions and main variables affecting such difference, taking into account different traffic conditions (congested and non-congested flow conditions). Moreover, based on such comparison per link unit, emission functions for each Euro emission class of passenger cars were re-calculated and enhanced in order to clearly predict the effects of driving conditions on road traffic emissions, particularly in morning and afternoon peak periods. Information from a macroscopic transportation model (traffic volume and average speed) was combined with different congestion indicators to characterize the transport activity data and driving conditions for the entire urban road network, required by the proposed emission model. Finally, an atmospheric dispersion model was used in order to assess the reliability of the emission data. The spatial distribution per link unit of the road traffic emissions estimated by the different approaches are compared and discussed for different traffic conditions. Based on different validation statistical metrics, the performance of the proposed numerical modelling system is discussed against air quality data from an experimental field monitoring deployed at a city "hot-spot" during two distinct periods (20th to 24th June 2017 and 20th September to 16th October 2017).

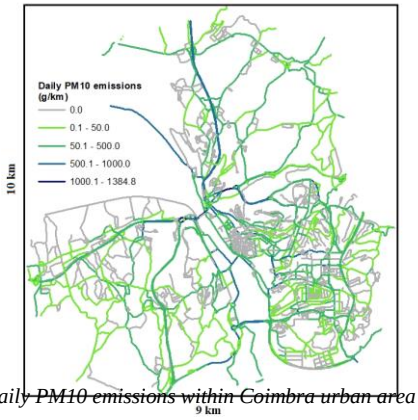

Fig.1 Daily PM10 emissions within Coimbra urban area

Conclusions
This study proposes a combined emission modelling approach at urban scale aiming to reflect the effects of the traffic congestion on the estimated road traffic emissions, without compromising the equilibrium between data availability and quality of input data. Also, the potential of the proposed combined emission model to provide enhanced high-spatially resolved road traffic emission, as required for urban air quality modelling, is demonstrated, presenting thus as key component of a decision-support tool in response to local needs and priorities.

Acknowledgement
This work was supported by TRAPHIC project (PTDC /ECM-URB/3329/2014 - POCI-01-0145-FEDER-016729) and by Foundation for Science and Technology (Post Doc. grant of D. Dias (SFRH/BPD/118168/2016) and the Ph.D. grant of N. Pina (PD/BD/128048/2016)).

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NEW OPEN SOURCE EMISSION PROCESSOR FOR AIR QUALITY MODELS

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Summary
A structure of a new emission processor for the chemical transport models is described. Processor is based on free software (PostgreSQL, PostGIS, Python) and is not bound to any predefined fixed input file formats, where possible. Its source code will be made available for public after the end of the funding project.

Introduction
Among air quality models, chemical transport models (CTM) require the most elaborated emission inputs – annual emissions of main species need to be disaggregated in time and space and chemical speciation has to be applied. CTMs also usually work with huge amount and various types of sources (anthropogenic point, area, and line sources from different data providers, biogenic sources, etc.). The only widely used open source emission processor for CTMs is SMOKE (CMAS, 2017). Its main advantage is that it can be readily used with NWP model WRF and chemical transport models such as CMAQ or CAMx. Although SMOKE has been applied for Europe many times, its application with non-US data is quite complicated since it is designed for US-specific inputs. Therefore a new emission processor was developed, which is flexible and easily configurable for users using different types of input data and also different NWP and CTM models.

Structure of the emission processor
Emission processor (EP) is based on free software (PostgreSQL, PostGIS, Python) and has a modular design which allows users to add their own modules. Structure of the EP can be divided into four main layers:
Inputs preprocessing – EP has to ingest heterogeneous primary information about the emissions. The role of this phase is to consolidate and unify the structure and format of emission inputs. Emission processor currently accepts two file formats of the input data: GIS shapefiles and text files. In case of text files, the spatial information can be provided in a separate GIS shapefile (useful if multiple emission inventories have the same spatial distribution) or can be read directly from the text file in case of point or regular grid sources based on its predefined parameters (e.g. in case of TNO MACC emissions). Each input file or emission inventory is accompanied by the supplementary file, which holds information on the type of the input file, its geometry and coordinate system, type of emission sources (area/point/line), names of columns that contain necessary data (e.g. stack parameters), and their units. Names of the source categories can be user-defined. Data are processed to unified format and stored in a PostGIS database. The same emission inventories can be used for different scenarios, therefore no further preprocessing is done at this stage.
Scenario setup – first the grid is created. EP can prepare emissions in any known predefined or user-defined coordinate system and its usage is not limited to a regular grid – it can generate emissions for any polygons. According to the configurations, emission inventories are imported and during the import user-defined filters and masks are applied. Optionally missing stack parameters are filled in. Configuration also decides which module implementation will be used in case of multiple implementations of particular submodule – e.g. different calculations of plume rise based on the availability of meteorological data and/or stack parameters.
Emission processor core is a key part of the toolchain where the disaggregation of emission totals takes place. The central task is the processing of spatiotemporal factors for the disaggregation and consequent chemical speciation. The temporal factors range from static profiles stored in database to less or more dynamic profiles which can be computed by complex models (e.g. for local heating or agriculture). Time variation of emissions based their continuous measurement is also possible to use. Specialized external models are invoked – e.g. for the biogenic emissions.
Postprocessing – the data are aggregated according to the user requirements. The results are then transformed to desired data format. Currently outputs for CAMx and CMAQ chemical transport models are the option. But users can define their own output file formats. Various visualizations and reports are also the part of this phase.

Conclusions
New emission processor for chemical transport models has been developed. It has been successfully used in combination with the CAMx model for the assessment of impacts of traffic reduction scenarios in Prague, Czech Republic. Its source code will be made publically available after the end of the funding project (i.e. in 2018).

Acknowledgement
This work was supported by the grant of the Technology Agency of the Czech Republic under the project TA04020797.

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CMAS, 2017: Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System – official website of the model. WWW: https://www.cmascenter.org/smoke/

OLYMPUS: AN URBAN EMISSIONS MODEL CENTERED ON INDIVIDUAL.

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Summary
OLYMPUS is a modeling platform that generates a synthetic population of individuals, defines the mobility of each individual in the city through an activity-based travel demand approach. The model also models road traffic within the city by taking into account congestion on the road network. The model also incorporates a module that addresses the energy demand of the territory by considering the unit energy consumption of households. The road traffic emissions, as well as the combustion emissions from the residential and tertiary sectors are calculated using the COPERT emission factors and the EEA methodology, respectively. The comparison of emissions with the Paris regional inventory shows a small discrepancy of emissions mainly related to the representation of the transport of goods and to inter-urban mobility.

Introduction
In the current environmental context which places great emphasis on the emerging concept of sustainable cities, it is necessary to consider the emissions of air pollutants that are associated with energy consumption and climate change concerns. To do this, the fundamental pillars of the development of a sustainable city governance - the economy, the social and the environment - have to be taken into account. The main objective of the OLYMPUS modelling platform is the representation of present, prospective or hypothetic air pollutant emissions of a city, based on population activity.

Methodology and Results
OLYMPUS is composed of 6 calculation modules, grouped into 3 main tasks, as presented in Figure 1. The GAIA module generates a synthetic population composed of agents characterized by their age, gender, principal activity and situation in a household. OLYMPUS provides the road transportation database by considering household choices, trip generation based on zonal attractions, trip distribution, modal split and route choice. The THEMIS module defines the accessibility and attractiveness of the different parts of the city, as well as average time travels. The Activity-Based Travel Demand module called MOIRAI computes the daily activity patterns of all agents. In parallel, the model computes the building energy demand by taking into account household energy consumption per square meter, dwelling size of the household and energy mix of the city. And the emission module VULCAN calculates pollutant emissions, both from road transport and small combustion heating systems, as presented in Figure 2.

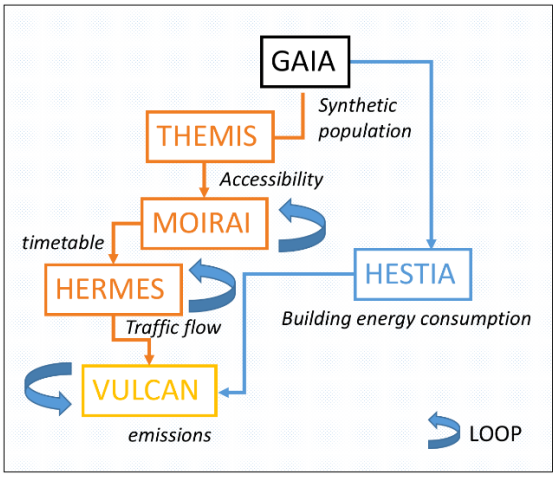

Figure 2 : OLYMPUS modules

Conclusions
The Paris megacity was the field of evaluation for OLYMPUS. The results obtained with the model where compared to the local emission inventory AIRPARIF and to the regional inventory EMEP. It demonstrates a solid representation of the emission resulting from individual and collective activities in the Paris region, though we had to make rude approximations concerning the transport of goods and the inter-regional mobility. The lack of constraint data on heating systems also induces uncertainty on the emissions from the residential sector. Such limitations of the current version of model have to be considered in future work. It would be interesting, subsequently, to introduce additional socio-economic segregation parameters (e.g. household income) and their impact on mobility choices.

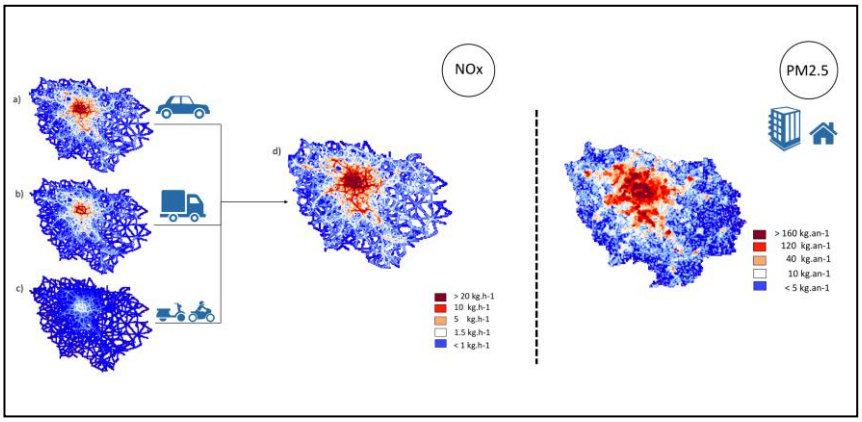

Figure 2: Spatial distribution of emission modelled by VULCAN - On the left NOx emissions from road transport - Right PM2.5 emissions from the residential and tertiary sector

Acknowledgement
This work was performed using HPC resources from GENCI-CCRT (Grant 2017- t2015017232).

EMISSION MODELS FOR FUGITIVE PARTICULATE MATTER IN HOT-DRY ENVIRONMENTS

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Summary
This study aims to develop an effective and accurate emissions inventory for fugitive Particulate Matter (fPM) sources, representative of the arid and semi-arid regions. Field measurements, lab analysis and emissions modelling were carried out to develop a comprehensive understanding of the fPM behaviour with a focus on loose soils from construction sites and non-exhaust traffic induced emissions.

Introduction
Airborne Particulate Matter (PM) has become a global concern due to the health risks linked with its exposure (Kumar et al. 2014). Over the recent years, several studies agreed that a large amount of PM10 in dry-arid environments (i.e. North Africa, Middle East, and Central Asia) come from loose crustal material, tyre and brake markers, and dust resuspensions (Saraga et al., 2017), which are classified as fugitive (non-controlled) sources. Despite the efforts invested in developing national and regional emission inventories, the information on fugitive emissions remains sparse compared to the large number of sources that produce them. More importantly, the exiting inventories were developed for typical soils and climate conditions of North America and Europe. Thus, we were alerted to develop a similar knowledge for dry and hot environments.

Methodology and Results
Two field studies were conducted at a construction site and a major road in the city of Doha, Qatar to collect source related information, real time measurements of ambient size-resolved PM and meteorological components. On-site meteorological measurements and source related data were used to model the dispersion of fPM from the loose soils at the construction site using the Fugitive Dust Model (FDM) in an iterative manner. The results were fitted to a power function, which expresses the wind velocity dependence, and were analysed along with the observed data to evaluate the exiting models, and develop new ones more representative of the studied area and climatic conditions. Power factors fitted to the data were showed good adjusted R^2 that varied from 0.13 for the smaller particles and up to 0.69 for the larger ones (Hassan et al., 2016). Fig. 1 shows the impact of barren lands (loose soils) over the city of Doha modelled by CALPUFF, where 95th percentile of daily PM10 >200 µg.m^{-3} inside the areas, >70 µg.m^{-3} at 500m away, >50 µg.m^{-3} at 1.5km away and >20 µg.m^{-3} everywhere else. PM10 and PM2.5 samples were collected at a major roadside using PTFE filters. Lab analysis of the collected filters is currently ongoing to determine the elemental composition of the samples. Source apportionment modelling will be performed to identify the contribution of different traffic sources (i.e. brake, tyre and road abrasion, dust resuspension) as well as the other sources affecting the area.

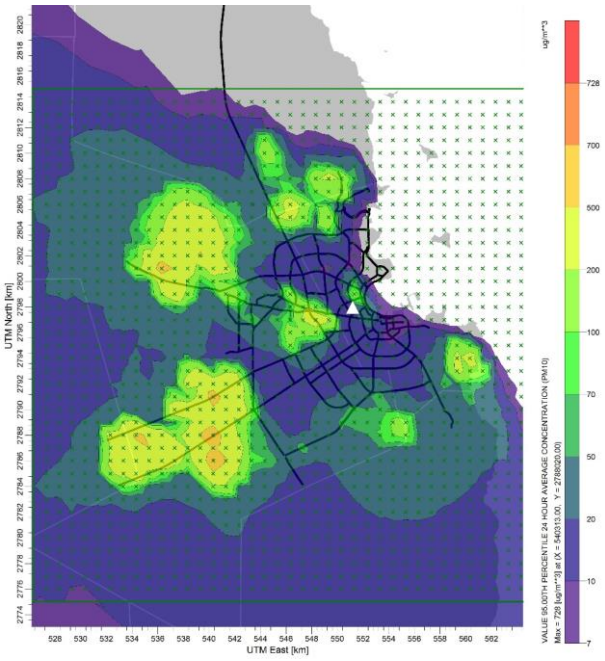

Fig. 1 A contour map shows the impact of loose soils over the city of Doha (CALPUFF)

Conclusions
Loose soils and traffic are major sources of fPM in arid regions. This study provides developed models that can be incorporated into particulate matter emission inventories to improve the assessment of health and environmental impacts.

Acknowledgement
This work was made possible by the NPRP award [NPRP 7 - 649 - 2 - 241] from the Qatar National Research Fund (a member of The Qatar Foundation). The statements made herein are solely the responsibility of the authors.

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METHOD FOR DEVELOPMENT OF HIGH-RESOLUTION EMISSIONS FROM RESIDENTIAL WOOD COMBUSTION

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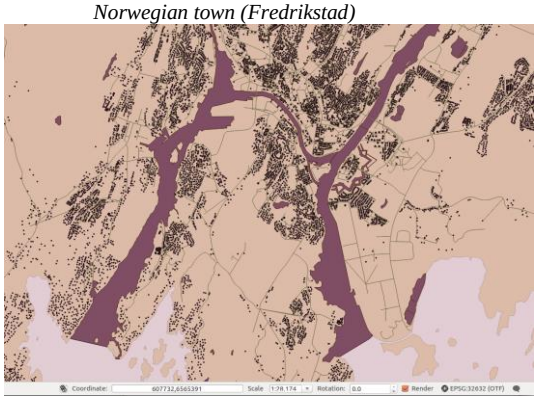
Summary
We will present the results from a newly developed emission model for residential wood combustion (RWC) at high spatial resolution (250 x 250 meters). The model has been developed for Norway and is based on fireplace information on a building point scale, regional consumption of fuelwood and emission factors dependent on the combustion technology from Seljeskog et al. (2017). The novelty of the method is the high level of detail in the input data and the distribution keys developed for the spatial distribution of emissions. Emissions are given with hourly time variation that is dependent on heating demand based on outdoor temperature at an injection height based on housing types in the grid.

Fig.2 Location of all registered fireplaces in a Norwegian town (Fredrikstad)



Introduction
Emission from RWC is of concern for urban air quality and climate change. The particulate composition of aerosols that originates from wood burning are organic carbonat (OC) and black carbon (BC), a short-lived climate pollutant. Emissions from RWC are dependent on firewood consumption, water content of the wood and on the burning efficiency of the wood stove appliance. The impact on air quality is in addition dependent on the emission altitude, atmospheric conditions and removal efficiency. In Northern European countries, the contribution from RWC to high particulate matter concentrations is pointed it out as one of the largest contributor to pollution episodes in winter. RWC have large temporal and spatial variations within a city and carries large uncertainties. Therefore it is essential to develop emission inventories with a high level of both spatial and temporal resolution.

Methodology
Data collection is a crucial step in environmental research and following technological advances and societal changes new methods are evolving. We have applied a web-crawling tool to mine openly available data on real estate transactions, which contain details on both primary and supplementary heating sources. The resulting dataset contains the geographical location of all transacted dwellings and indicates the heating source and whether or not a wood stove exist, the type of building and also include pictures that can be used to differentiate stoves and fireplace technology type. Where available, this is combined with geo-reference data on fireplaces per buildings from the fire-departments at the municipality (Fig. 1). The outcome from this data processing is a buildings "wood burning potential". For areas where accurate data are lacking, regional proxies are used based on statistics of housing in the area and the share of residential heating sources, obtained from the e.g. the web-crawling database. Regional wood consumption is then distributed to individual houses with wood stove based on the wood heating demand of buildings in a 250 m grid. Usage times of the wood stove is subsequently defined to be dependent on the need for heating defined by the outdoor temperature (Stohl et al.,2013). Emission factors are then applied after the ratio of wood stove type for each grid and emission altitude defined by the building type height. This emission inventory is build up with a cost efficient methodology and establishes a well-structured database for the update of urban to national emission inventories.

Results
We will present the results obtained with this method, together with an assessment of and comparison to other existing methods. Different methods for the spatial allocation of emissions involve large discrepancies on both the geographical allocation of emissions and the total emission intensity for the region of interest. The outcomes from our study contribute to the development of methods for the accurate gridding of emission. A further step will be to validate the resulting consumption distribution against self-reported residential consumptions, and the resulting emissions against observations of concentrations in a pilot study over a limited residential area.

Acknowledgement
The work in this study is funded by the Norwegian Environmental Agency through the MetVed project. Research for this work was done with the financial support of the Research Council of Norway through the iResponse project (247884/O70).

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MODELING EMISSIONS FOR 3D ATMOSPHERIC CHEMISTRY TRANSPORT MODELS

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Summary
This contribution reviews the most widely used emission inventories on global and regional scale and looks into the methods used to make the inventory data model ready. Shortcomings of using standard temporal profiles for each emission sector are discussed and new methods to improve the spatio-temporal distribution of the emissions are presented. An outlook for new ways to improve model ready emission data, for example by using external data bases about road traffic or satellite data for rapidly changing land use, is also given.

Introduction
Poor air quality is a threat for human health in many parts of the world. In order to assess measures for emission reductions and improved air quality, three-dimensional atmospheric chemistry transport modeling systems are used in numerous research institutions und public authorities. These models need accurate emission data in appropriate spatial and temporal resolution as input. Atmospheric concentrations of pollutants as well as their deposition depend not only on the emitted amount but also on place and time of the emissions used for the model calculations. Emission inventories, both regional and global ones, typically provide annual emissions of specific substances on a predefined grid. Often, this grid is of coarser resolution than the model grid and the temporal resolution is not higher than monthly. This requires further processing of the emissions in order to produce sufficiently resolved data sets.

Methodology and Results
Emission models like US EPA's SMOKE (Houyoux et al., 1998) or its spinoffs SMOKE for Europe (Bieser et al., 2011) and SMOKE-PRD (Wang et al., 2010) were developed for the purpose of creating "model-ready" emissions. They use methods that depend on the emission sector and the additional data available for the disaggregation of the inventory data, e.g. land use and population density data.
Point source emissions need to be treated in a special way because the emission height may often be significantly above ground level. In addition, the exhaust gas leaves the stack with a certain exit velocity and at a temperature far above the ambient temperature. This is either taken into account using pre-calculated emission heights for certain SNAP sectors (e.g. from Bieser et al., 2011a) or through inline plume rise calculations. Recently, new methods for the tempo-spatial distribution of emissions from specific sectors like agriculture, residential heating and traffic have been developed. For agricultural emissions, detailed information about animal densities, types of barns and meteorological conditions are considered (e.g. Backes et al., 2016, Hendriks et al., 2016). The distribution of emissions from residential heating also makes use of meteorological conditions (e.g. Aulinger et al., 2011, Mues et al. 2014). Temporal profiles of traffic emissions can be improved using traffic counts (e.g. Menut et al., 2012). For international shipping, bottom-up methods that use ship activity data offer high spatial and temporal resolution of the emission data (Jalkanen et al., 2009, 2012, Aulinger et al., 2016).

Conclusions
Emission data from available inventories need to be further distributed in time and space in order to feed them into 3D CTMs. A number of methods have already been developed that can be used for this task. However, there are options for improvements in the future. The temporal and spatial allocation of emissions could involve large data sets that exist but have not been used for emission modeling up to now. Emissions from traffic could be improved if the real variability of the traffic including traffic jams and the composition of the fleet could be considered. Emissions from agriculture can be made more accurate if application dates and amount of fertilizers would be reported. Emissions from industry and power plants could also be reported in more detail than today and subsequently be used in emission models. In addition, satellite data could be of great benefit, e.g. to better determine biogenic emissions. Spatial distributions of plant type, plant growth and leaf area, exact dates for blooming periods, harvesting, and leaf stripping, might be taken into account.

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IMPACTS ON AIR QUALITY DUE TO AVIATION EMISSIONS

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Summary
One year of air quality data obtained at Zagreb Airport has been analysed to assess the level of air pollution due to air traffic. Air transportation growth has rapidly increased over the years and notable influences of aviation emissions on local and regional air quality as well as on climate are identified. The environmental impacts of atmospheric emissions from aircraft have been addressed in two separate ways; aircraft pollutant emissions occurring during the landing and take-off (LTO) phase (local pollutant emissions), and the non-LTO phase (global/regional pollutant emissions). Aircraft pollutant emissions are an important source of pollution and directly or indirectly harmfully affect human health and ecosystems. In this work harmonized methodology for emissions estimation as well as recent estimated emissions for Croatia will be presented in relation to European and global trends. The WRF-Chem model is applied with modified aviation emissions to calculate local air concentrations of CO_2, PM_{10}, NOx, O_3 and SO_2 around the Zagreb airport in Croatia. The EMEP model is used to estimate the background contributions with several different emission scenarios. The management of air quality must include major sources within the urban area and the application air quality models is essential in identification of environmental impacts.

Introduction
Aircraft emissions are of growing importance and concern worldwide. This concern is mostly related to their impacts in the stratosphere and their growing contribution to greenhouse gas emissions (Carslaw et al., 2008). However, increased aircraft movements are also of concern to air pollution issues close to airports. At Zagreb Airport there is a specific concern over the concentrations of nitrogen dioxide (NO2) and meeting international standards for ambient NO2 concentration. An important consideration therefore is the development of a good understanding of the sources that contribute to local concentrations of NOx.
Zagreb Airport is approximately 10km south of the center of Zagreb. In existence since 1962, the airport is surrounded with a mix of commercial and residential areas; residential areas located to the south-east are most affected by the current activities and planned development.

Methodology and Results
Main sources of air emissions from the airport operations include exhaust gases from aircraft, vehicle movements and stationary sources, such as power generators and venting from fuel storage tanks. Emission were determined based on aircraft type (ICAO) emission factor and Tier 1 methodology for LTO cycles. Air pollution simulations were conducted using WRF-Chem, CMAQ and EMEP models. Concentrations of NOx and PM10 were taken as reference parameters. Based on the modelling it is expected that the limit values for NOx and PM10 will be exceeded immediately along the runway but be within acceptable Croatian and IFC limits in the surrounding area for both phases. Given the trend to tighten emissions criteria in the aviation industry, it is to be expected that there will be technological advances in the form of emissions reductions from new aircraft engines. Simulations with WRF-Chem are conducted for August 2015 and surface NO_2 and O_3 concentrations are provided.
During nighttime NO_2 concentrations are transported from E and SE to measuring locations.
During the day NO_2 concentrations are transported from NE. Measurements (bivariate polar plots) show that the highest concentrations ~ 35 $\mu g m$-3 are transported from the W while minimum concentrations ~ 5 $\mu g m$-3 are transported from E directions. High ozone concentrations are transported from E and NE while minimum concentrations are from W.
WRF-Chem model simulates very well the wind direction but underestimates the measurements of NO_2 and O_3.

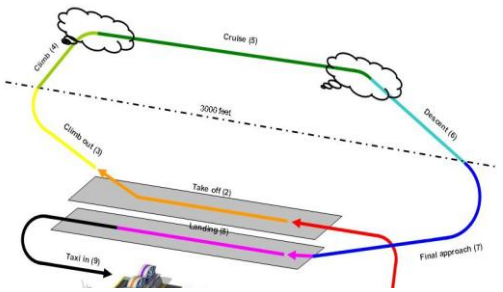
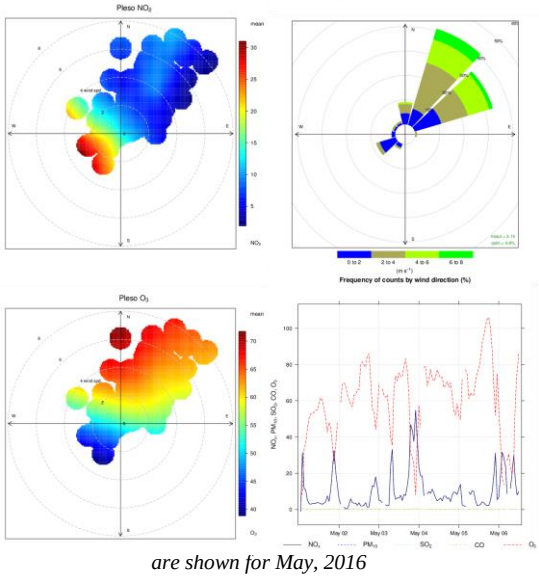


Fig.1 LTO cycles used for emission determination.



are shown for May, 2016

Conclusions
Bivariate polar plots of NO_2 measurements show high airport contributions. WRF-Chem simulates well the transport of NO2 and O3 concentrations, but underestimates the magnitude of concentrations. Contribution to NOx concentrations from aviation is ~ 30 % according to CAMx.

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Carslaw et al 2008.; 'Near-Field Commercial Aircraft Contribution to Nitrogen Oxides by Engine, Aircraft Type, and Airline by Individual Plume Sampling, Environmental Science and Technology

CITY BUS EMISSIONS IN REAL OPERATION

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Summary

This study shows the differences in the particle and NO_x emissions between the Euro VI and EEV emission level city busses. The case, where EEV level buses are equipped with new after treatment systems (DPF+SCR) is also studied. The decrease in emissions was found to be significant from EEV to Euro VI level in PM_1, BC and NO_x. Retrofitting of EEV busses reduces particle mass emissions significantly, but not necessarily NO_x emissions. This indicates that if a retrofit is installed, NO_x levels should be measured in real operation.

Introduction

Diesel engines are known particle and NO_x emitters. In city bus applications these emissions occur in populated areas affecting the air quality. To improve air quality, strict emission limits have been introduced for vehicles, which force manufacturer to use new complicated emission control technologies including particle filtrations and catalytic NO_x removal. These limits are tested in laboratory conditions. However, the real emissions may significantly differ from these laboratory values. To investigate real emissions, we measured particulate emissions from city busses during their normal operation with a mobile laboratory and characterized emission from EEV and Euro VI level city busses as well as from EEV city busses, which were retrofitted with new exhaust after treatment systems consisting of a particle filter and an SCR. These systems were supplied by two different manufacturers.

Methodology and Results

The city bus measurements were conducted in part of the Helsinki region bus line 550. The measurement route was approximately 2.9 km long, lasted 10 min and included 6 bus stops. In total of 32 individual measurements were conducted for 5 different bus types. The mobile laboratory was used to sample bus exhaust plume, and emissions were analysed in real time with various aerosol instruments as well as CO_2 and NO_x analysers. CO_2 concentrations were used to define emission factors for the pollutants. The bus particle number emission factor, including solid and liquid particles (D > 3 nm), were approximately $1 \cdot 10^{15}$/kg_{fuel} and did not depend on the bus type. The PM_1 emission factors were on average 0.21 g/kg_{fuel} for EEV busses and 0.07-0.10 g/kg_{fuel} for Euro VI busses and retrofits (see Fig. 1). The black carbon emission (BC) factor was 0.12 g/kg_{fuel} for EEV and 0.05-0.06 g/kg_{fuel} for Euro VI and retrofitted busses. The PM_1 and BC concentration were close to the ambient background level for Euro VI and retrofitted busses, and the given values represent the upper threshold. The NO_x emission factors varied significantly, and were 21 g/kg_{fuel} for EEV and below the detection limit for Euro VI. Some retrofitted busses produced NO_x at similar levels with the EEV class, and some at a similar level with Euro VI (see Fig. 1).

Conclusions

Euro VI emission level and retrofitted bussed were observed to emit significantly less particle mass than EEV. NO_x emissions from the Euro VI busses were low, compared to EEV busses. Thus, the Euro VI level is a significant improvement over the EEV. Retrofit systems operated variably in terms of the NO_x. We observed NO_x levels comparable to Euro VI but also high NO_x emissions were observed. Pirjola et al. (2016) noticed in a similar study, that busses equipped with an SCR may emit high NO_x concentrations in normal operation. Thus, if older busses are retrofitted with new after treatment systems, especially with SCR, the operation of these systems should be confirmed in real world.

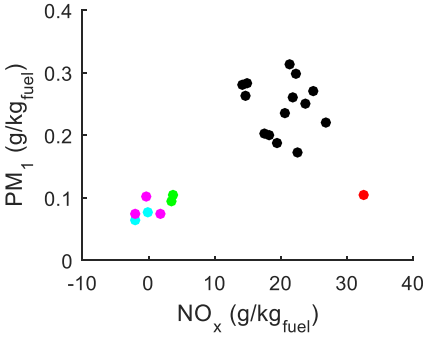

Fig.1 Real-world PM_1 and NO_x emission factors for different city busses: ***EEV****,* ***Retrofit A****,* ***Retrofit B****,* ***Scania Euro VI*** *and* ***Volvo Euro VI****.*

Acknowledgement

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ASSESSMENT OF BLACK CARBON CONCENTRATIONS AND EMISSION SOURCES IN CURITIBA, BRAZIL

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Summary

NOx, PM2.5 and black carbon (BC) levels were assessed in the Paraná state capital Curitiba, a city known for its effective urban planning where industry and transit traffic are separated from the residential and commercial areas of the city. The focus on BC emissions was motivated by its strong impact on health and its contribution to global warming. Through a monitoring and modelling campaign it was possible to determine local BC emission factors for public transport and private vehicles, which were then used to map the citywide concentrations and to estimate total emissions. The strong increments of BC levels inside street canyons in Curitiba show the dominant role of road traffic exhausts.

Introduction

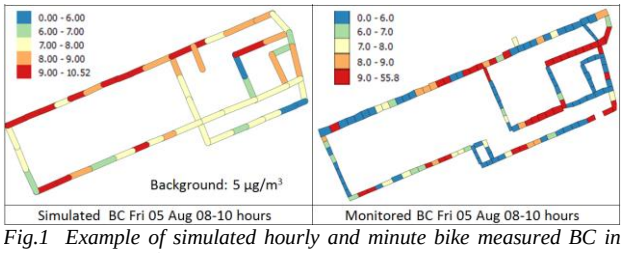
Black carbon in urban air is a good tracer of combustion particles, which have shown to produce adverse health effects and they also, on a regional scale, contribute to climate warming. Within the framework of a bilateral agreement between Brazil and Sweden concerning environmental protection, a cooperation project has been running since 2015 to assess the emissions and ambient levels of particles – including black carbon - in the city of Curitiba, Brazil. The first phase included a monitoring and modelling campaign to determine local emissions and map the spatial distribution of NOx, PM2.5 and BC, especially focusing on the impact of road traffic exhausts. Despite being the hometown for the Bus Rapid Transport (BRT) system, Curitiba has the highest motorization rate in Brazil, 528 cars per 1000 inhabitants.

Methodology and Results

Emission inventories including fixed and mobile sources were set up for Paraná state (1x1 km^2 grids) and for the city of Curitiba (line and point sources). A monitoring campaign was conducted to measure PM2.5 and BC inside street canyons, using a fixed station at street level and monitors deployed on retrofitted bicycles. Urban background monitoring of PM2.5 and BC was performed at one station in the city centre (roof level) and at a residential station. For NOx passive samplers complemented the data obtained by the operational Curitiba monitoring network. Dispersion modelling was performed on three scales using a) a regional dispersion model CCATT-BRAMS covering the Paraná state, b) a standard Gaussian model (Airviro) implemented over Curitiba and c) the Danish OSPM model for the street canyon comparisons with measurements. Emission factors for buses were taken from the European traffic emission model HBEFA and for the private vehicles the European Environmental Agency (EEA) handbook was used.

Simulated and measured NOx showed comparable levels at the fixed street canyon station, while PM2.5 and BC emissions were strongly (up to 5 times) underestimated due to misrepresentative vehicle emission factors. The emission factors were subsequently adjusted to fit the street canyon measurement data.

The urban background concentrations of BC were rather uniform over the city, with average concentrations of 2.0-2.5 µg/m^3, of which about half originated from local traffic exhausts. Within street canyons the average concentrations were above 5 µg/m^3, with hourly peak values regularly reaching 10 µg/m^3. The BC emissions from traffic in Curitiba were estimated to 17-18 tons/year from public transport and 370-380 tons/year from private traffic.



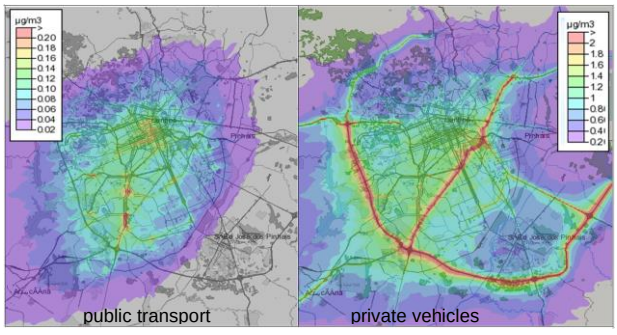


Fig.1 Example of simulated hourly and minute bike measured BC in street canyons of the Curitiba city centre (top). Average wintertime impact on BC levels in Curitiba from public transport and private vehicles (right, please note different colour scales).

Conclusions

Urban background BC levels in Curitiba were rather homogenous with a wintertime mean concentration around 2.0-2.5 µg/m^3, but with considerably higher concentrations in trafficked street canyons, reflecting the dominating role of traffic exhaust emissions.

Acknowledgement

This bilateral cooperation between Sweden and the Curitiba municipality, the regional environmental agency in Paraná and the federal universities UFPR, UTFPR and UFPel has received financial support from the Swedish Ministry of Environment and Energy. We acknowledge the technical support received from the Curitiba municipality and also its open data policy, which allowed the creation of the emission inventories and other input required for the assessment.

CONTROLLING THE EMISSIONS OF AND POPULATION EXPOSURE TO PRIMARY PM2.5 FROM RESIDENTIAL WOOD COMBUSTION AND VEHICULAR NON-EXHAUST SOURCES IN 2030 IN FINLAND

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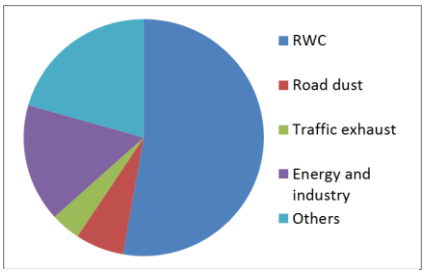
Summary
The largest potential to mitigate the emissions of primary fine particles (PPM2.5) in the future will be on sources that are currently not systematically regulated, such as residential wood combustion (RWC) and road dust. In this study, it was found that the effects of the feasible emission reductions were greater for RWC than for road dust in Finland. It would be technically possible to substantially reduce the population exposure to PPM2.5 originating from both source categories.

Introduction
At present, RWC and vehicular traffic are the largest sources of PPM2.5 emissions in Finland. By the year 2030 traffic exhaust emissions will be considerably reduced due to introduction of efficient control technologies in vehicles, while the emissions from RWC and vehicular non-exhaust, i.e. road dust, will remain largely untouched. This paper introduces estimates of emission control potentials at various ambition levels and their impacts on resulting population exposure.

Methodology and Results
According to the projections of the latest Energy and Climate Strategy of the Finnish Government, RWC and road dust will contribute to 53% and 6% of the total PPM2.5 in 2030 (Fig. 1). Emission reduction potential for RWC was estimated at 0.11 to 4.3 Gg/a, or 0.6% to 25% of the total Finnish PPM2.5, depending on the ambition level (Table 1). The lowest ambition level includes only information campaigns about proper stove use targeted to 28 main Finnish urban agglomerates. Adding a national sauna stove regulation would increase the reduction potential to 2.1 Gg/a. The most stringent level includes politically less feasible measures: end-of-pipe filtration to small-scale house boilers and regional combustion bans in the main urban areas. Road dust scenarios showed a lower reduction potential, including street cleaning and dust binding measures (0.039 Gg/a) and restrictions to studded tire use (0.040 - 0.23 Gg/a), with a maximum of 0.28 Gg/a, or 1.6% of the total Finnish PPM2.5.



Others include mainlv diffuse dust sources

Fig.1 Division of PPM2.5 emissions to main sources in Finland in 2030

To assess the impact of emission reductions on population exposure (population weighted concentration PWC), the emissions were spatially assessed at 250 m grid resolution. The dispersion of PPM2.5 was estimated using linear source-receptor matrices based on Gaussian UDM-FMI model (Karvosenoja et al. 2011). The largest potential to reduce PWC was by the introduction of sauna stove regulation and urban RWC ban. The ΔPWC / ΔEM ratio demonstrates the highly variable relative efficiency of emission reductions to decrease population exposure, the efficiency being considerably higher for measures targeted to urban areas.

Table 1 Emission and population exposure reduction potential in RWC and road dust

Sector, Emission control measure	Emission EM (MgPM2.5 a^{-1})	Pop. exposure PWC (ng m^{-3})	EM reduction ΔEM *	Pop. exposure reduction ΔPWC *	ΔPWC / ΔEM
Residential Wood Combustion					
RWC Baseline	9104	642			
InfoCampaign	8992	616	112	26	0.23
InfoC+SaunaRegulation	7023	485	1969	131	0.07
InfoC+SR+ESP in boilers	5468	441	1556	45	0.03
MFR: InfoC+SR+ESP+urban ban	4792	235	676	206	0.30
Road dust					
Road dust Baseline	1033	187			
Street Cleaning & Dust Binding	995	171	39	16	0.40
Studded Tires 20% in cities	993	170	40	17	0.42
Studded Tires 20% all country	767	136	226	34	0.15
MFR: Clean&DB+ST20all	749	129	18	7	0.40

* ΔEM and ΔPWC are calculated for each step from previous ambition level, except for the Studded Tire scenario

Conclusions
Potential to mitigate the emissions and harmful impacts of PPM2.5 remain in RWC and road dust sectors. Feasible measures to considerably reduce population exposure include RWC information campaigns, sauna stove regulation and studded tire restrictions. The results can be used to support national and local policy making to improve air quality and human health.

Acknowledgement
This study was funded by the Academy of Finland in the project Environmental impact assessment of airborne particulate matter: the effects of abatement and management strategies (BATMAN) and supported by Nordforsk project NordicWelfAir.

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AN ATTEMPT OF VALIDATION OF INDUSTRIAL POLLUTANT RELEASE BOTTOM UP INVENTORIES AT SILESIA, POLAND

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Summary
One of the important sources of air pollution and greenhouse gases is mining industry together with oil refinery. Silesia Upper Coal Basin comprise of 29 mines and 2 refineries accompanied by large steel industry and energy sector facilities. The area was directly investigated with mobile platforms under the MEMO2 project resulting of spatiotemporal map of particular sources with 3D concentration of methane, carbon dioxide, PM2.5 and PM10. Gaussian modelling applied for validation of bottom up estimates indicated large discrepancies between reported and modelled values basing on measurement results.

Introduction
The presented work was launched with the main objective of providing a comprehensive assessment of gas and aerosol pollutant fluxes into the atmosphere during the period 2015-2017, associated with the Upper Silesian Coal Basin (USCB). The Upper Silesia region is located in southern Poland and constitutes a unique example in Europe of the impact over two centuries of heavy industry (coal, lead and zinc mining industry, steelworks, machine building industry) and dense urbanization on the land-use evolution. With 19 interconnected cities, approximately 3.5 million inhabitants, and 29 active coal mines, it presents the most heavily transformed landscape in Poland.

Methodology and Results
Mobile platform was built over the 4x4 car equipped with Picarro 2201-i CRDS analyser, Dustrak optical PM analyser, 2D sonic anemometer, GPS and power system allowing for 24h of continuous work. The first investigation rides were aimed on determination of background values and hotspots with highly enhanced concentration. Subsequently, the path of the mobile platform formed closed curve around particulate emitters, wherever existing road and off-road conditions were accessible for passage. Plumes of interesting substances were identified (isotopic signature was a helpful tool in this case) and route passed through them at different distance from the source allowing to fit the Gaussian model to minimise the weight function representing residuals of model-measurements difference. In case of methane the mine ventilation shafts fluxes reported by facilities had to be increase by 350% to achieve concentrations measured by mobile platform, occasionally reached 120ppm. Even estimates obtained from EDGAR 4.2 FT database , which are much higher than values reported by E-PRTR database was not fully in agreement with estimates basing on measurements.
PM 2.5 and PM10 concentrations were usually extremely high and highly changeable in respect to the atmospheric dynamics. In winter season night values were enriched in compare to the background values by more than two orders of magnitude and locally reached 750 µg/m3.

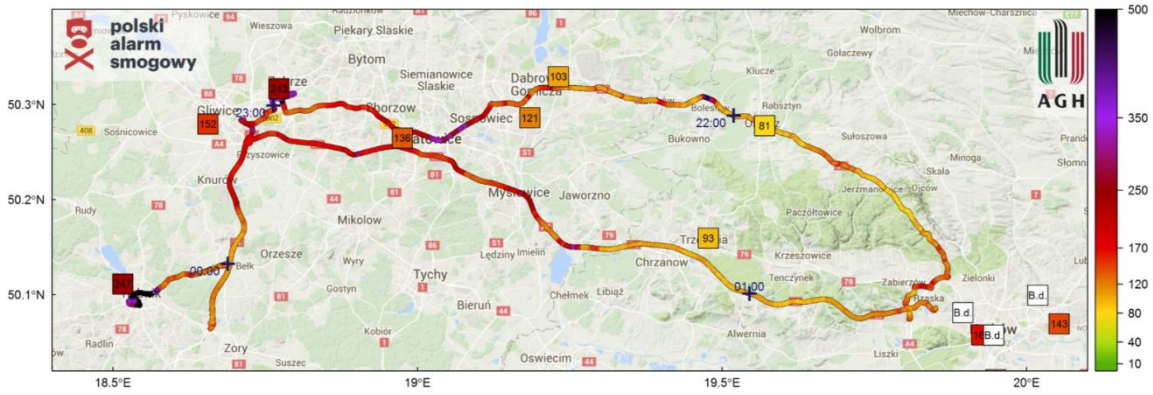

Fig.1 Example of Silesia PM10 record form mobile platform, performed in winter 2016

Conclusions
The reported by industry values of emission rates of all kind of pollutant have great social impact and awareness of verification possibilities should be increased leading to reporting of reliable values, which now are highly uncertain.

Acknowledgement
This work was supported partially by EU H2020 MSCA ITN Project Memo^2 (project num. 722479). Authors would like to acknowledge also partial support obtained from AGH – University of Science and Technology statutory work. Measurements of particulate matter as well as optical analyser was funded by Krakowski Alarm Smogowy.

EMISSION OF PM10 AND COARSE PARTICLES FROM "SILENT" ASPHALT

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Summary
Emission of PM10 and coarse particles from a silent asphalt of type ABD11 was compared to a reference pavement ABS16 during three spring seasons (Feb – May) in 2015, 2016 and 2016. It was found that the emission of coarse particles from the silent asphalt was about 40 % lower than the reference asphalt the first season. During the second season the emission of coarse particles from the silent asphalt was about 15 % lower than the reference and during the third season it was around 5 % higher that the reference site. The results strongly indicate that emission of coarse particles has increased throughout the three years of measurements.

Introduction
Non-exhaust emissions of particulate matter (PM) from road traffic are a significant air pollution problem in many areas and especially in Scandinavian countries where studded tyres and winter maintenance including sand and salt are used. Road traffic is also the cause for high noise levels close to major roads and highways. One measure to reduce the noise levels is to change the pavement. However any change in the pavement characteristic might also change the emission of particles.

Methodology and Results
On a 1.4 km long stretch on the highway E4 north of Stockholm was silent asphalt of type ABD11 placed in 2014. A measuring campaign has been ongoing close to this and a reference stretch with asphalt ABD 16 for three spring seasons (Feb – May) in 2015, 2016 and 2016 and will continue 2018 and 2019. Traffic number at the sites were up to 100000 veh/day and the average speed about 100 km/h. The concentrations at the two sites showed very high correlations indicating that both stations are similarly affected by particle emissions from the road. Only daytime periods with dry road surface and wind direction from the road towards the stations were analysed. Comparison of the emission of coarse particles (PM10-PM2.5) from the asphalt were done by comparing the PMcoarse/NOx ratio between the two sites, were the NOx levels have been adjusted according to the emission factors based on HBEFA 3.2. During the first season (spring 2015) was the PM10 levels (and PMcoarse) about equal at the two sites (Figure 1). However during the second season (spring 2016) were both PM10 and PMcoarse higher at the silent asphalt site compared to the reference site and they increasing even further until the third season (2017). At the same time were the NOx levels higher at the silent asphalt site for all years but the ratio compared to the reference site did not show any significant trend, Figure 1.

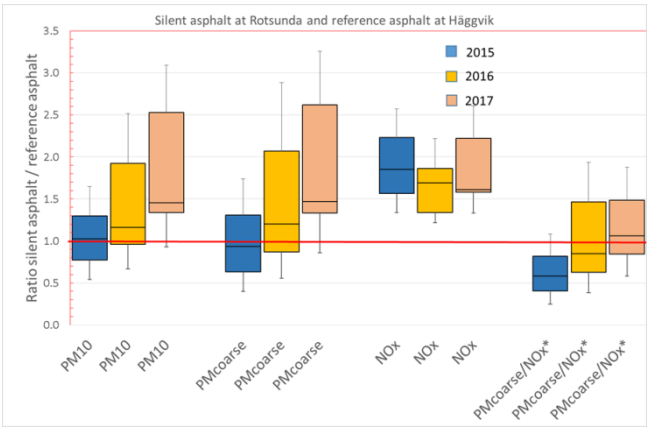

Fig.1 The ratio between pollutants at the silent asphalt and the reference site. The black line is the median, the coloured box the 25th and 75th percentile and the vertical bars the 10th and 90th percentile. The NO_x^* levels are adjusted according to emission factor.

Emission of coarse particle based on the comparison between the PMcoarse/NOx ratio between the sites showed that the emission of coarse particles were about 40 % lower at the silent asphalt compared to the reference during 2016 (first season). During the second season was the emission of coarse particles from the silent asphalt about 15 % lower than the reference and during the third season it was around 5 % higher that the reference site. The results strongly indicate that emission of coarse particles has increased throughout the three years of measurements.
The pavement structure in the silent asphalt contains more pores than the reference asphalt. One reason could be that the cleaning has been insufficient and that the surface therefore has collected more particles that in spring are available for resuspension. Another potential cause is that the surface structure of the silent asphalt has changed due to the traffic (worn and compacted), which might have increased the particle emissions

Conclusions
It was found that the emission of coarse particles from the silent asphalt was about 40 % lower than the reference asphalt the first year. During the following two seasons has the emission of coarse particles from the silent asphalt increased significantly and was during the third season even 5 % higher that the reference site. The results strongly indicate that emission of coarse particles from the silent asphalt has increased significantly during the three measured seasons. The continuation of the project for two more seasons will tell if the emissions of non-exhaust particles will continue to increase. The result is important when considering using silent asphalt as a measure for decreasing noise levels along highways.

Acknowledgement
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SOURCE APPORTIONMENT OF PM2.5 IN BEIJING DURING THE APHH-BEIJING CAMPAIGN

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Abstract

Beijing still experiences severe haze episodes during winter season. There is still uncertainty in identifying major sources of PM2.5. It is also very important to understand how sources change with time as it has significant temporal variation. As part of the winter campaign of the APHH-Beijing project, a joint effort and collaboration between scientists from U.K. and China, online measurements were made during November to December 2016. In this study, major and trace species of PM2.5 were measured in an urban site in Beijing with 1-h resolution for ions by an in-situ gas and aerosol composition monitor (IGAC), Sunset EC and OC, and multiple metals by the Xact 625 ambient metal monitor.

Our results show that during the study period, organic matter was the major component of fine particulate matter, followed by sulfate, nitrate, and ammonium. Online speciation data were applied in the PMF model to identify major sources of PM2.5. The most significant episode occurred during December 15-22, 2016, lasting for almost 8 days. During the last stage of the episode, inorganic components especially sulfate, nitrate, and ammonium showed a continuous increase, while carbonaceous aerosol and metals did not, suggesting that it was mainly due to secondary formation from local sources during the later stage. It was found that PM2.5 during the episodes were mainly from secondary, while the remaining primary particles were primarily from coal combustion, vehicular emission, and industry. In contrast, biomass burning and dust were relatively minor sources. However, it is noticed that major sources of PM2.5 could vary from episode to episode, even during the same season.

The source apportionment results from this study were integrated with results from footprint analysis and the Nested Air Quality Prediction Modeling System (NAQPMS) to understand the regional transport and source regions. These results were compared with chemical signatures from receptor measurements. A distinct chemical profile and signature was found when cold front approached from Northwest with strong wind, when PM2.5 concentration in Beijing was usually low. Our analysis showed that in some cases episodes could form through transport from southern regions first, followed by accumulation from local sources, adding to the increased level that was observed during the process of episode.

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MONITORING LONG-TERM AND LARGE SCALE DEPOSITION OF AIR POLLUTANTS BASED ON MOSS ANALYSIS

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Summary

A brief historical review is given on the development and milestones of the moss biomonitoring technique used to study atmospheric deposition of trace elements, nitrogen, persistent organic pollutants (POPs) and radionuclides of technogenic and natural origin in Europe. The relevance of these studies to the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP) is emphasized. Examples of the long-term activity of the ICP Vegetation (International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops) established in 1987 are given to illustrate the tendencies in behavior on a large scale of air pollutants such as heavy metals, nitrogen and persistent organic pollutants. In agreement with the long-term strategy of the LRTAP Convention to enhance participation and to improve air quality in Eastern Europe, the Caucasus, Central Asia, and South Eastern Europe, efforts to extend the moss survey to former republics of the USSR such as Armenia, Azerbaijan, Georgia, Moldova, Kazakhstan, and Tajikistan were successfully undertaken. Around 15 teams were formed in Russia to cover moss sampling in Northern and Central Russia, Western Siberia, and the Far East of Russia (Kamchatka and Sakhalin). All in all, 39 countries participated in the 2015-2016 moss survey. Analytical methods and approaches to data interpretation are reviewed.

Introduction

The Convention on Long-range Transboundary Air Pollution (LRTAP) was the first international legally binding instrument to deal with problems of air pollution on a broad regional basis. It was signed in 1979 by 34 Governments and the European Community (EC) and entered into force in 1983. Besides laying down the general principles of international cooperation for air pollution abatement, the LRTAP Convention set up an institutional framework bringing together research and policy. The LRTAP Convention focusses on acidifying and eutrophying air pollutants, ground-level ozone, heavy metals, persistent organic pollutants (POPs), particulate matter (PM) and black carbon. In 1987, the International Cooperative programme Programme on Effects of Air Pollution on Crops (ICP Crops) was established as a subsidiary body of the Working Group on Effects (WGE) under the United Nation Economic Cooperation Europe Convention on Long-range Transboundary Air Pollution (UNECE LRTAP). It mostly focused on assessing the impacts of ground-level ozone on crops and (semi-)natural vegetation. In 1999, the ICP Crops was renamed as the International Cooperative Programme on the Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation).

Methodology and Results

The idea of biomonitoring goes back to the XIX century when Nylander (1866) used the abundance of lichens as a measure for air pollution effects. Mosses and lichens accumulate heavy metals and other compounds very efficiently because of their large specific surface, slow growth and lack of cuticle and a developed root system. They serve mostly as passive biomonitors to provide an indication of the pollutant impact at the ecosystem level. Among the pollutants, heavy metals (and trace elements) are of special attention. One of the main aims of the European moss survey is also to establish temporal trends in heavy metal concentrations in mosses (Frontasyeva et al., 2016). **Heavy metals** can be toxic to both humans and wildlife, damaging terrestrial and aquatic ecosystems. Element concentrations in mosses for As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, V, Zn, Al, and Sb are reported to the LRTAP Convention under the auspices of the ICP Vegetation. Although implementation of air pollution abatement policies developed under the LRTAP Convention have resulted in a decline of the exceedance of **nitrogen** critical loads across Europe since 1980, terrestrial N enrichment continues to be a serious threat to European ecosystems. In the 2010 European moss survey, selected POPs were determined in mosses for the first time in some selected countries. For the 2015 survey, it was suggested to extend the pilot study conducted in 2010 to other countries and to focus on PAHs, PCBs, polybromodiphenylethers (PBDEs), dioxins, and perfluorooctane sulfonic acid and its salts (PFOS), but other POPs could also be included if there is a national interest. The latest extension of the moss biomonitoring programme incorporates determination of **radionuclide** atmospheric deposition that seems extremely important because of nuclear accidents such as the Chernobyl (1986) and Fukushima (2011) ones. Finally, mosses as natural planchets are a useful tool for determination of deposition of **cosmic dust**.

Conclusions

The moss survey has been applied successfully over the past 25 years to indicate spatial patterns and temporal trends of heavy metal deposition across Europe. For the majority of metals, concentrations in mosses have declined in recent decades; however, hotspots of high heavy metal deposition remain, particularly in parts of Eastern Europe. Hence, increased monitoring of heavy metal deposition in those countries in the future should be further stimulated and is of huge importance. Developments in recent years have shown that mosses can be used to indicate areas at risk of high nitrogen deposition too. Initial studies have confirmed that mosses can also be used as monitors of atmospheric deposition of persistent organic pollutants (POPs), radionuclides and cosmic dust. Hence, the aim is to extend monitoring of these substances in mosses in the future.

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POPULATION EXPOSURE TO SHIP EMISSIONS IN HARBOUR CITIES OF THE BALTIC SEA

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Summary
Ship emissions in ports can have a significant impact on local air quality in harbour cities. In terms of health issues due to air pollution, international shipping is a major source for health damages throughout Europe (Brandt et al. 2013). This study aims to investigate impact of the local shipping activities on the air quality of three harbour cities at the Baltic Sea. The city-scale chemistry-transport model CityChem - EPISODE was used to calculate hourly 3-dim. concentrations fields of multiple pollutants, including ozone, nitrogen oxides and volatile organic compounds. The modelled annual average concentrations of $PM_{2.5}$, SO_2 and NO_2 were used to calculate human exposure. People living in areas close to the ports were found to be exposed most, highlighting the need for in-port mitigation strategies such as onshore power supply.

Introduction
In the frame of the BONUS SHEBA (Sustainable Shipping and the Environment of the Baltic Sea region) project, the impact of emissions from ships in harbours on the local air pollution in the harbour cities Rostock, Riga and the urban agglomeration Gdansk-Gdynia for year 2012 was determined. Based on annual average concentration of NO_2, $PM_{2.5}$ and SO_2 calculated by the CityChem - EPISODE model (Karl, 2017), exposure maps for the three cities were produced.

Methodology and Results
Ship emissions from STEAM for the port cities were generated based on the Automatic Identification System (AIS) and activity based-emission factors, considering emissions at berth and on sea. They are spatially distributed on a 250 x 250 m^2 grid according to the ship routes inside the harbour area and have an hourly time resolution. SO_2 emissions from ships are in accordance with a fuel sulphur content of 1 % permitted in 2012. Emissions from residential heating, power generation, industry, commercial combustion and solvent use were obtained from local authorities. The prognostic meteorological model TAPM was applied to compute meteorological and wind flow fields. Hourly 3-dim. boundary concentrations from a simulation with CMAQ over the Baltic Sea on 4 km horizontal resolution were used to constrain the regional background. Chemistry-transport modelling was performed with CityChem - EPISODE for Rostock, Riga (400 m grid res.), Gdansk-Gdynia (1000 m grid res.) (Map in Fig. 1). Exposure calculations were done using population density maps from EUROSTAT. The FAIRMODE Delta Tool version 5.4 was used for evaluation of the model results for the air quality. Hourly modelled concentrations were compared to observations at 9 monitoring stations in Gdansk-Gdynia, 4 stations in Rostock and 2-3 stations in Riga. Contribution of shipping emissions to annual average concentration levels of NO_2, $PM_{2.5}$ and SO_2 are shown in Fig. 2. In Riga, the ship contribution to PM2.5 was very low because traffic emissions are the dominant source. Population exposure to NO_2 due to emissions from shipping was particularly high in areas surrounding the ports.

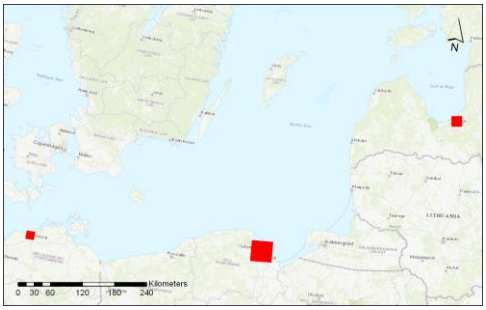

Fig.1 Map of the Baltic Sea with the harbour

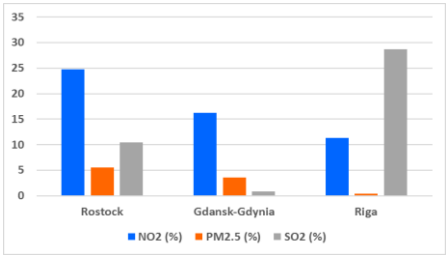

Fig.2 Ship contribution to annual average NO_2, $PM_{2.5}$ and SO_2 on spatial average.

Conclusions
Ship emissions in harbour cities are mainly from emissions during ships at berth and manoeuvring. Although the highest pollution due to shipping is at sea, the population exposure shows a high influence of shipping in the highly populated areas downwind of the port areas. This emphasizes the need for emission reduction measures in the port such as onshore power supply of ships at berth.

Acknowledgement
BONUS SHEBA project has received funding from BONUS (Art 185), funded jointly by the EU, Innovation Fund Denmark, Estonian Research Council, Academy of Finland, Forschungszentrum Jülich Beteiligungsgesellschaft mbH (Germany), National Centre for Research and Development (Poland) and Swedish Environmental Protection Agency.

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FILLING DATA GAPS FOR A BETTER UNDERSTANDING OF IMPACT OF AIR POLLUTION ASSOCIATED WITH RURAL RESIDENTIAL ENERGY USE IN CHINA

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Emissions of solid fuel consumption in residential sector are among the major sources of air pollutants in China and many other developing countries. Air qualities of both ambient and indoor environment in these countries are affected by the emissions from households leading to significant adverse health impacts. Unfortunately, emissions from residential sector have been overlooked, leading to large data gaps in this sector for a full understanding of overall health impact of air pollution. It was noticed that biomass fuel consumption data from International Energy Agency (IEA), originally from Chinese Agricultural Census, might fail to catch rapid rural residential energy transition in China during last two to three decades, resulting high uncertainty in emission inventories of major air pollutants, which are widely used in all modeling exercises. To fill this data gap, we conducted a nationwide survey to collect energy mix data for 34,489 households using detailed activity questionnaires and fuel weight data for 1670 households It was demonstrated that the rural residential energy mix and consumption changed rapidly when clean cooking fuels and electricity increased from 8% to 59% and heating energy from 2% to 15% from 1992 to 2012, resulting in a significant reduction of air pollutant emissions. These results are very different from those from IEA in both absolute quantities and temporal trend. In addition to other factors such as coal production and grain production, per capita income is the leading driving force causing such changes. Energy use in residential sector varies among seasons mainly due to heating needs. Unfortunately, only annual energy consumptions are officially reported. To quantify seasonal trends of residential energy consumption for modeling purpose, a space-for-time substitution method was proposed based an assumption that the factors affecting spatial and temporal variation of residential energy use are identical. As a result, a set of models developed based on spatial data were able to be applied to predict seasonality of residential electricity and fuel consumption. The last, but not the least data gap is emission factors (EFs). Most EFs used in the literature are measured in laboratory in developed countries. We have conducted a series of field measurements in rural China and demonstrated that the EFs measured in China are much higher than those reported for developed countries and data from laboratory chamber tests with better oxidation condition can underestimate the EFs significantly. Using the data from our residential energy survey, seasonal model, and field EF measurements, influences of residential energy transition in rural China on emissions and population health were evaluated.

Air Quality Management for Policy Support

FURTHER DEVELOPMENT OF AIR QUALITY CONTROL PLANNING AND AIR QUALITY MONITORING IN ULAANBAATAR THE CAPITAL OF MONGOLIA

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Summary

1.38 million Mongolians, half of the Mongolian population, are living in the capital Ulaanbaatar. The main air pollution problem is in this city the strong winter time smog with very high particulate matter concentrations. Thus, Ulaanbaatar counts as the worst polluted capital city of the world. The dust is coming mainly from the ger areas with their yurtes and little huts where in around 185.000 traditional stoves raw coal and wood is burned producing strong smoke. Results of measurements from several projects and records from monitoring stations are presented showing the serious air pollution problem. To support further improvement of the air quality situation the German Environment Agency developed in cooperation with the National Agency for Meteorology and Environmental Monitoring of Mongolia a project particularly considering the air pollution dispersion under local climatic and orographic conditions.

Introduction

Ulaanbaatar is the capital city of Mongolia. From its 1.38 Million inhabitants a great part is living around the modern city in the so called ger areas with their yurts (Mongolian: gers) and little huts where in individual stoves mainly raw coal and some wood is burned. These approximately 185 000 stoves produce in winter months strong smoke exceeding the WHO guidelines for PM and SO_2 of several amounts, see Fig. 1 and Table 1. Based on measurements within several projects and records from monitoring stations Ulaanbaatar counts as the worst polluted capital city of the world (World Bank 2011). The ger areas are located in a valley north of Ulaanbaatar and at surrounding slopes of the city. During night under inversion conditions the cold air formed at the slopes flows down and transports the smoke into the city so that not only the ger areas themselves are polluted but also the city which is supplied with remote heat from power plants located outside and not affecting the city.

Fig. 1. Smog in the ger areas of Ulaanbaatar (Foto: G. Baumbach

Present Results and Further Project

In Ulaanbaatar 10 permanent operating air quality monitoring stations are installed, 6 of them operated by the "National Agency for Meteorology and Environmental Monitoring of Mongolia", 4 operated by the "Environmental Agency of the Municipality of Ulaanbaatar". Results of measurements are presented showing the serious air pollution problem and negative health effects (R. W. Allen 2013). To support further improvement of the air quality situation the German Environment Agency developed in cooperation with the National Agency for Meteorology and Environmental Monitoring a project particularly considering the local air pollution distributing conditions. For that purpose staff members of administrations and institutions on national and municipal level will be advised to enhance the analysis of existing data sets. In addition to existing monitoring programs, a modelling approach will be developed in order to allow the Mongolian experts to estimate the source apportionment of airborne concentrations as well as the influence of local climatic and orographic conditions on the pollutant dispersion.

Table 1. Comparison of PM concentrations between city center and ger areas in Ulaanbaatar (World Bank 2011)

Indicaded ranges for annual average PM concentrations in Ulaanbataar, June 08 – Mai 09:

Area	PM_{10} µg/m³	$PM_{2.5}$ µg/m³	Exceedance: Ratio to AQSs	
			Mongolian:	WHO
Central city areas	150–250	75–150	3–6	7–15
Ger areas	350–700	200–350	7–14	17–35

Acknowledgement

This project is financed by the German Federal Environment Ministry's Advisory Assistance Programme for environmental protection in the countries of Central and Eastern Europe, the Caucasus and Central Asia and other countries neighbouring the European Union.

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INVESTIGATION OF THE INFLUENCE OF CARBURETOR MOTORCYCLES REPLACEMENT BY ELECTRICALLY CHARGED MOTORCYCLES DUE TO LEZ IMPLEMENTATION ON TEHRAN AIR QUALITY

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Summary
Tehran air pollution is a severe environmental concern. Different policies and solutions are pursued to control the pollutants level and thus to improve the air quality level. Some of the policies include traffic restrictions that create a serious challenge for citizens and some of them are related to substituting the old fleet generation by newer ones from the aspect of environmental criteria. Low Emission Zone (LEZ) is a well-known environmental policy by which traffic of specific category of vehicles within a predetermined region is banned. In this study the influence of Tehran LEZ implementation, in which traffic of carburettor motorcycles is banned and just electrically charged ones can enter the LEZ region, is investigated. Tehran Air Pollution Forecasting system (apfs.tehran.ir) was used for impact evaluation of this policy on Tehran air quality in the period of 12 to 31 December which was the longest polluted episode in 2015.

Introduction
In recent years, particulate matters, especially those with a diameter less than 2.5 micrometers (PM2.5) have been established as criteria pollutants in Tehran. According to the latest Tehran annual air quality report, there were 88 reported days of unhealthy conditions due to PM2.5 and 6 days related to PM10) during March 20, 2016 to March 20, 2017.
Air quality modelling tools have been widely used to investigate effects of implementation of various traffic related scenarios such as change in fleet composition and traffic restriction policies on overall air quality indicators. (Cai and Xie [1], Xing et al [2]). Shahbazi et al [3] investigated the effect of odd-even day traffic restriction policy on Tehran air quality using WRF/CAMx modelling tools. This study, investigates the impact of LEZ implementation on Tehran air quality, using Tehran Air Pollution Forecasting system (apfs.tehran.ir), in which carburettor motorcycles is banned entering LEZ region and just electrically charged ones are allowed.

Methodology and Results
In order to investigate the effect of implementing LEZ for motorcycles on the pollution emission, two different scenarios were considered. The base case, in which carburettor motorcycles are allowed to enter LEZ and the scenario that this motorcycles fleet in the LEZ (LEZ region is considered same as OETR zone in [3]) is replaced with electrical ones. In order to calculate pollutant concentrations, Tehran Air Pollution Forecasting system (apfs.tehran.ir) including combination of WRF and CAMx models [4] was applied over Tehran modelling domain for the autumn time episode of December 12 to 31, 2015. Total exhaust emission of motorcycles in Tehran in the modelling episode for CO, VOC, NOx, SOx and PM estimated to be 6448, 1695, 167, 2 and 59 tons, which after implementing LEZ reduced by 36, 39, 34, 36 and 36% respectively.
Spatial distribution of PM 2.5 concentration for the base case and the change due to LEZ implementation are presented in Fig. 1

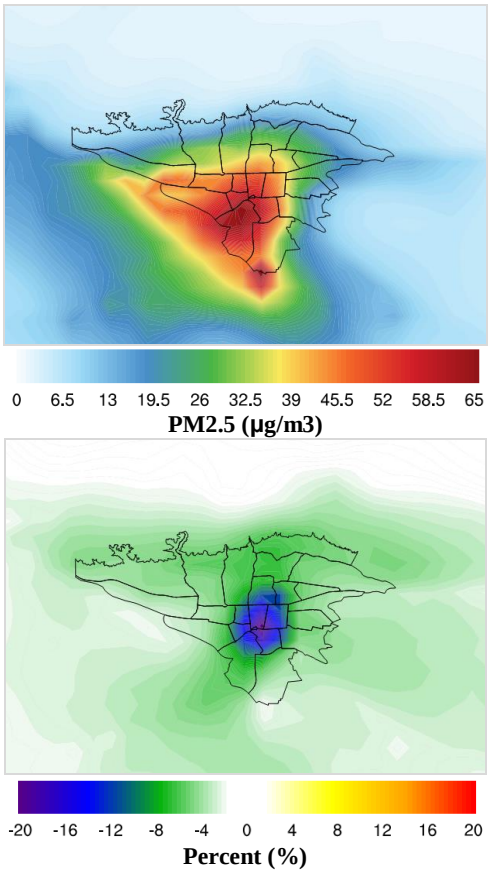

Fig 1. Spatial distribution of average PM2.5 concentration (up) and percent change due to LEZ implementation (down) over Tehran during December 12-31, 2015

Conclusions
In this study emission and concentration reduction in a highly polluted episode from December 12 to 31, 2015 in Tehran were investigated due to LEZ implementation on motorcycles fleet. Mobile sources emission inventories for both scenarios including base case and LEZ are estimated using the same approach presented by Shahbazi et, al 2017 [3] and used in CAMx model to calculate pollutant concentrations.
The results show that exhaust emission of motorcycles in the study episode for CO, VOC, NOx, SOx and PM reduced by 36, 39, 34, 36 and 36% respectively. The maximum concentration reduction of PM2.5 occurred in the central zone of Tehran which reduced by 20%.

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ESTABLISHMENT OF A USER FRIENDLY URBAN AIR QUALITY SCENARIO ASSESSMENT SERVICE USING COPERNICUS - CAMS DATA FOR BRATISLAVA

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Introduction

Traffic is a key contributor to air pollution in urban environments. Many cities across Europe are taking drastic measures reduce traffic emissions or improve air quality for their residents. Optimisation of such air quality management plans usually requires elaborate scenario evaluations using dispersion models to calculate the impact of the altered traffic configuration or flows on the concentration levels and population exposure. Due to the complexity of these tools, the abundance of input data required and the technical/scientific skill of the consultants running the models, traceability of results of such impact assessments is often a problem, sometimes leading to disputes in high profile cases.

Methodology and Results

Inspired by this need for harmonisation of traffic-related EIAs, VITO developed a centralised online web service called ATMOSYS-planning offering a standard set of pre-processed input data (meteo, background concentrations, fleet composition, road network, baseline traffic intensities…), easy scenario definition and setup of model parameters. At its core, the FASTRACE traffic emission model is combined with the IFDM Gaussian dispersion model (Lefebvre et al, 2011) including an emission double counting correction scheme.

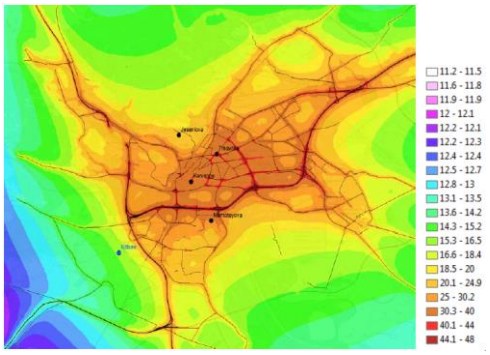

Fig.1 ATMOSYS-CAMS 2015 NO_2 annual average assessment (reference scenario).

In the frame of an ECMWF Copernicus CAMS 95f service contract, the ATMOSYS - Planning tool was further developed and coupled to CAMS background and meteo information. The resulting ATMOSYS - CAMS planning tool was deployed over the city of Bratislava, Slovakia, where the coupling between the urban dispersion modelling chain and the CAMS background & meteo data was evaluated using local monitoring data for 2015. The ATMOSYS-CAMS assessment showed a very good spatial correlation against the (limited number of) available measurement stations. The R^2 was 0.99 with a model BIAS of 1.38 µg/m^3 (5%) and RMSE of 2.12 µg/m^3 (8%). An analysis of diurnal cycles between model and observations revealed still room for optimisation, though overall results were satisfactory. Results for PM_{10} however showed poorer agreement with the observations indicating that some emission sources (residential heating and resuspension) are lacking in the local source database, which focussed entirely on the traffic contribution. Nevertheless, as a proof of concept, the results do indicate the usability of the Copernicus CAMS data for urban air quality planning in the absence of local background concentration estimates.

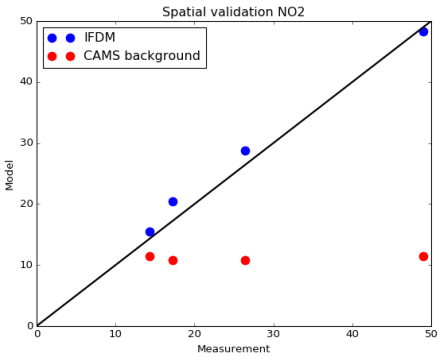

Fig.2 Spatial validation of the 2015 annual average using local measurement data.

These offline results were subsequently transferred and made available for scenario assessment in the ATMOSYS-CAMS web application for further distribution among the EIA experts in Slovakia, underlining the need for harmonisation in environmental impact assessments.

Conclusions

The evaluation showed excellent spatial agreement for NO_2 concentrations with measurements indicating that the CAMS air quality data can be a useful source of urban background & meteo data to drive local scale traffic-related EIA's. The CAMS data allows the ATMOSYS planning tool to be deployed over regions with limited capacity in terms of air quality modelling.

Acknowledgement

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CFD MODELLING OF THE IMPACT ON THE NO_X REDUCTION THROUGH A PHOTOCATALYTIC COATING COVERING AN ENTIRE NEIGHBORHOOD: A HYPOTHETICAL CASE STUDY

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Summary
Nowadays, photocatalytic materials are being researched as a possible mitigation strategy to reduce NOx concentrations in urban areas. These materials are activated in the presence of sunlight and act as a sink of NO concentration in air. The deposition effect of NO in air due to the photocatalytic materials in an urban area is here evaluated through a computational fluid dynamics (CFD) model.

Introduction
The effectiveness of the photocatalytic materials in outdoor conditions is increasingly researched and the NO removal due to the deposition on these materials in full-scale street canyons have been analysed in some studies (Pujadas et al., 2017; Sanchez et al., 2017). The aim of this contribution is to simulate the NO deposition and study its impact on air due to the application of photocatalytic materials on all surfaces of a real urban scenario. To that end, the photochemical reactions linked to the NO_x-O_3 photostationary state are considered in the model, and the effect of the materials is represented by means of a deposition velocity. The deposition velocities are different depending on the photocatalytic coatings applied on the surfaces: roads, pedestrian areas (on sidewalk) and the walls of buildings.

Methodology and Results
The selected urban area corresponds to a neighbourhood of the city of Alcobendas (Madrid, Spain) where previous related studies took place in the framework of the project LIFE MINOx-STREET. The CFD domain is around 1500m x 1000m x 160m and the polyhedral mesh consists of 2.3 million of grid points with a resolution progressively increasing from 6 m at the boundaries to 1 m close to the buildings and the ground. For the prevailing wind directions of this area, several wind speeds in neutral atmospheric conditions are considered to evaluate its influence on the NO removal by deposition. With the purpose of evaluating the maximum impact of the photocatalytic materials, all surfaces inside the research area (orange in Fig. 1) are assumed photoactive, covering around 1 km^2.The values of the deposition velocities for each coating are 0.005 m s^{-1} on roads, 0.01 m s^{-1} at pedestrian areas and 0.004 m s^{-1} at walls and roofs of buildings.

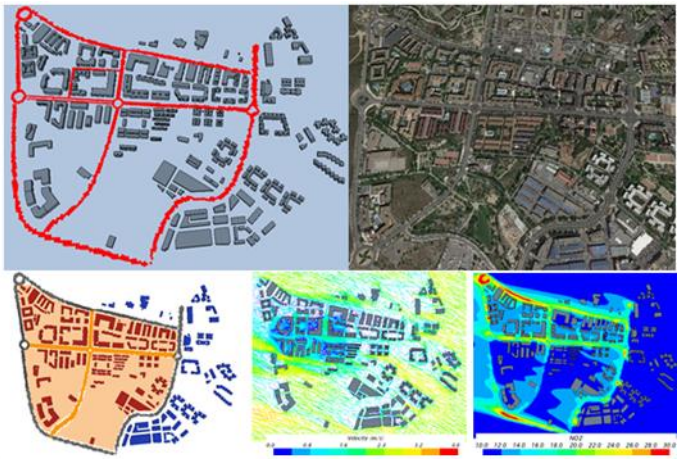

Fig.1 (above) The computational domain and the real geometry from Google Earth. (below) The research area implemented with photocatalytic materials (orange colours) and the flow pattern and the NO_2 concentration at pedestrian level (3 m above ground level) for SE wind direction.

The application of these materials over the whole neighbourhood is very expensive, and it is therefore crucial to evaluate the efficiency beforehand through numerical modelling. The effect on the NO reduction due to the photocatalytic materials is evaluated by comparing the modelled NO concentration with and without the deposition effect. The results show that the amount of NO removal is dependent on the atmospheric conditions and is unevenly distributed in the domain. The largest impact is found close to the surface and it decreases with distance. Note that the results show an upper limit of the impact because all surfaces are considered photoactive, while in reality shadowing reduces its effect.

Conclusions
The main conclusions derived from this study is that to see a significant reduction of NO levels in a real urban scenario, photocatalytic materials must be applied on large areas (at least a neighboured). Moreover its impact is strongly dependent on wind conditions and flow patterns in the streets, solar radiation and the distance from the surface.

Acknowledgement
This study has been supported by European Project LIFE MINOx-STREET (LIFE12 ENV/ES/000280) with the contribution of the LIFE financial instrument of the European Union. Authors thank Extremadura Research Centre for Advanced Technologies (CETA-CIEMAT) for allowing us to use its computing facilities for the simulations. CETA-CIEMAT belongs to CIEMAT and the Government of Spain and is funded by the European Regional Development Fund (ERDF).

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MODELLING THE EFFECT OF ELECTRO MOBILITY ON THE AIR QUALITY IN HAMBURG

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Summary
Road traffic is a cause of noise and emits various pollutants with direct negative effects on human health. Since its binding introduction in 2001, the annual limit value of 40 µg/m^3 for NO_2 has been regularly exceeded at all traffic monitoring stations in Hamburg. Although annual average NO_2 concentrations at the traffic stations have declined in the last decade, the situation continues to be problematic. Four scenarios for traffic development were designed to investigate the effect of introducing electro mobility on the air quality in the inner city of Hamburg. Results from city-scale chemistry-transport simulations show that fast transition to electric vehicles can greatly improve the air quality in the inner city of Hamburg in 2020, avoiding the need for driving bans for gasoline and diesel cars.

Introduction
The effect of electro mobility on air quality of cities has been a controversy in recent years. Electric cars are not "zero-emission" vehicles because the charge of its batteries must be generated in electrical generation plants that produce emissions to air. The air quality situation with respect to NO_2 in 2012 (Fig. 1) shows area-wide exceedance of the annual limit value in the inner city of Hamburg. The air quality in Hamburg for 2020 was simulated using the CityChem - EPISODE model (Karl, 2017). As reference, a base case (BASE) was set up based on projected traffic emissions for 2020 according to the Hamburg air quality plan 2017 (HAQP). Four different electro mobility scenarios for the year 2020 were designed.

Methodology and Results
Traffic emissions were modelled as line sources for the entire road network of Hamburg. Other urban emissions in 2020 were calculated based on the totals given in the HAQP using the spatial distribution of the gridded emissions from Umweltbundesamt (UBA). The prognostic meteorological model TAPM was applied to compute meteorological fields and wind flow fields for 2012, which were used for 2020. Electro mobility scenarios: (1) EPLAN - introducing electro mobility according to the HAQP, including e.g. the installation of 1000 charging points and privileges for electric car owners. (2) EFAST - in addition, subsidies for changing to electric cars with the target: 20 % of inner city trips by electric cars and buses. (3) EMAX_R - theoretical scenario where passenger cars and buses in the inner city of Hamburg will be 100 % replaced by electric vehicles. Power supply of electric cars with regenerative energy. (4) EMAX_F - same as EMAX_R, but electricity supply through coal-fired power plants inside Hamburg. Emissions of NO_X in 2020 for EPLAN, EFAST, EMAX_R and EMAX_F were reduced by 41, 92, 685 and 412 kt/year, respectively, compared to BASE. The air quality situation in the inner city of Hamburg improves considerably in 2020 when compared to 2012, mainly due to the introduction of Euro VI vehicles, however exceedances of the annual limit value still occur. EPLAN results in a minor additional reduction of NO_2 levels compared to the base case. With EFAST, exceedances are prevented with the exception of busy crossroads. In EMAX_R and EMAX_F scenarios, the NO_2 levels in the inner city are reduced below the annual limit value. NO_X emissions from the electricity production in EMAX_F mainly impact the areas outside of the inner city. Levels of PM_{10} are almost unaffected by the introduction of an electric vehicle fleet because the majority of traffic-emitted PM_{10} is from non-exhaust sources such as tyre and break abrasion.

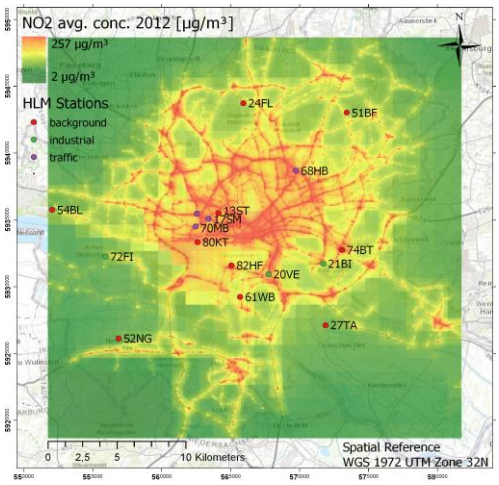

Fig.1 Map of annual average NO_2 in Hamburg (2012). Location of traffic stations indicated as purple dots.

Conclusions
Electro mobility could be an adequate measure to improve air quality in the inner city. The immediate target to reduce NO_2 at traffic stations below the annual limit value can be achieved when the change to electric cars happens faster than suggested by the HAPQ. This could be achieved with incentives for buying electric cars and by introducing a congestion charge for diesel and gasoline cars. However, to bring PM_{10} levels down the increased use of public transport has to be promoted.

Acknowledgement
This work was supported as part of the project SMURBS (Smart Urban Solutions for air quality, disasters and city growth) funded under ERA-PLANET (www.era-planet.eu).

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AIR QUALITY ASSESSMENT OF RETROFITTING SCRT ON URBAN BUSES IN COPENHAGEN

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Summary
This study aims to estimate the effect of retrofitting of SCRT on about 300 urban buses in Copenhagen. The Danish Environmental Protection Agency implemented this policy measure as part of an Air Quality Action Plan for NO_2 in Copenhagen to contribute to compliance with the air quality limit value for NO_2. The estimation of the effect is based on an analysis of the development of measured concentrations at fixed measuring stations, and on air quality model calculations based on, among others, information from the Sealand traffic company (Movia) about buses with and without reprofitted SCRT. SCRT reduces both the emissions of nitrogen oxides (NOx) and particles which are harmful to health. The model calculations assumes that SCRT reduces the emissions of NOx and particles from each bus with 90%. Based on the analysis of trends in the measurements it was not possible to isolate an effect of SCRT on urban buses in Copenhagen. However, model calculations for 98 selected streets in Copenhagen show that the concentration of NO_2 is reduced by 1.0 µg/m^3 on average due to retrofitting of SCRT on 300 buses for 2015. More detailed analyses were conducted for H.C. Andersens Boulevard and Jagtvej in Copenhagen, where there are fixed measuring stations. NO_2 concentrations are reduced by 1.3 µg/m^3 for H.C. Andersens Boulevard and 1.2 µg/m^3 for Jagtvej.

Introduction
The annual air quality limit value for NO_2 is 40 µg/m^3 and is exceeded at the fixed measuring station at H.C. Andersens Boulevard in Copenhagen. In 2015, the annual mean was 48 µg/m^3. The Danish Environmental Protection Agency has prepared an Air Quality Action Plan for Copenhagen in 2015 with the objective to ensure that concentrations of NO_2 in Copenhagen will comply with the limit value as soon as possible. One of the main elements of this plan is to retrofit SCRT on about 300 urban buses in Greater Copenhagen. Retrofitting of SCRT was carried out during the period from September 2015 to March 2016. The company Amminex has delivered the SCRT that are based on a technology that applies ammonia as injected into the exhaust as a gas as opposed to normally as a liquid (urea). This is more efficient in reducing NOx emissions especially under urban driving conditions with relatively low exhaust temperatures. SCRT is a combination of a SCR-catalyst and particulate filter, which together reduce the emission of both NOx (sum of NO and NO_2) and particles. SCR stands for Selective Catalytic Reduction (NOx) and T for Trap (i.e. particle filter).

Methodology and Results
The estimation of the effect is based on an analysis of the development of measured concentrations at fixed measuring stations, and on air quality model calculations for 2015. Model calculations are based on a regional air quality model (the Danish Eulerian Hemispheric Model-DEHM), an urban background model (Urban Background Model – UBM), and a street air quality model (Operational Street Pollution Model – OSPM). The calculations are carried out for 98 selected busy streets in Copenhagen. The streets of H.C. Andersens Boulevard and Jagtvej are also included where more detailed analyses were carried out as these streets have fixed measurement stations.

Based on the analysis of trends in the measurements it was not possible to isolate an effect of SCRT on urban buses in Copenhagen probably due to large variations in meteorology affecting the variations in concentrations.

However, model calculations for 98 selected streets in Copenhagen show that the concentration of NO_2 is reduced by 1.0 µg/m^3 on average due to retrofitting of SCRT on 300 buses.

SCRT reduces the total particle emissions from all road traffic on H.C. Andersens Boulevard and Jagtvej with 1.4% and 4%, respectively, and with 28% and 54% for PM exhaust emissions of buses (urban buses and tourist coaches). This corresponds to a reduction in particle concentration of 0.02 µg/m^3 and 0.03 µg/m^3 for H.C. Andersens Boulevard and Jagtvej, respectively. This is marginal in relation to the measured $PM_{2.5}$ and PM_{10} levels in 2015. Concentrations at H.C. Andersens Boulevard and Jagtvej are 18 µg/m^3 and 17 µg/m^3 for $PM_{2.5}$ and 30 µg/m^3 and 26 µg/m^3 for PM_{10}, respectively.

Conclusions
Retrofit of SCRT on existing urban diesel buses (Euro III, IV and EEV) reduces NOx and PM exhaust emissions with about 90% thereby making them equivalent to the Euro VI standard. On average modelled NO_2 concentrations were reduced by 1.0 µg/m^3 for 98 selected streets in Copenhagen where 300 buses were retrofit and the number of modelled exceedances of the annual air quality limit value for NO_2 was reduced from 9 to 5 exceedances for the 98 selected streets in 2015.

Acknowledgement
The Danish Environmental Protection Agency funded the study.

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SPEED LIMITATION IN METROPOLITAN AREA OF BARCELONA: IMPACT ON AIR QUALITY

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Summary
In 2007 the regional government of Catalonia adopted a measure limiting the maximum speed on the access roads to the metropolis. The speed reduction took effect on January the 1st, 2008. In this paper we analyse the data series of the main atmospheric pollutants according to the CITEAIR guidelines, that is O3, NO2, PM10, PM2.5 and we study the effectiveness of the that measure in accordance with the objective of improving air quality and so reducing pollution. It is concluded that an improvement is achieved in average AQI value and specially in the case of PM2.5.

Introduction and Objectives
There are different indices for expressing the quality of atmospheric air; in most cases do not have a reference scale and refer to air pollution rather than its quality. In this work we use de AQI* index defined by Gibergans-Báguena et al (2017), which has the advantage of having a reference scale of 0 (zero quality) to 100 (optimum quality, pure air).
The main objective of this work is to analyse the data series 2005-2008 of air pollutant concentrations in Barcelona, to study whether there is significant variation (statistically) before and after January the 1st, 2008.

Methodology and Results
The air quality index AQI* (see references) is based on the concept of log-contrast, defined by Aitchison in 1986:

$$LC = \sum_{i=1}^{m} a_i \log(x_i), \quad \sum_{i=1}^{m} a_i = 0$$

From this concept, applying Compositional Data Analysis methods the air pollution index (API) is defined as:

$$API = 0.0267\left(c_{O3}^{0.2}\, c_{NO2}^{0.3}\, c_{PM10}^{0.25}\, c_{PM2.5}^{0.25}\right)^{1.25}$$

where concentrations of air pollutants are expressed in µg/m^3. Finally, the air quality index (AQI*) is computed as:
AQI* = 100 − API
Similar expressions are obtained to express individual API (and so AQI) for each air pollutant.
In Fig.1 the maximum and minimum of individual AQI* and global AQI* are plotted. Significant differences can be appreciated. The global AQI* in 2005-2007 period is 96.97; the global AQI* in 2008-2012 period is 97.79. The minimum AQI* in 2005-2007 period is 90.24; the minimum AQI* in 2008-2012 period is 95.48. The maximum AQI* in 2005-2007 period is 99.14; the maximum AQI* in 2008-2012 period is 99.18.

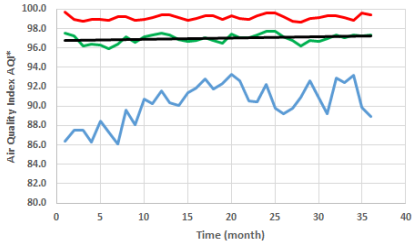

Fig.1 AQI* (green), MaxAQI(red), MinAQI(blue) in time series 2005-2007.

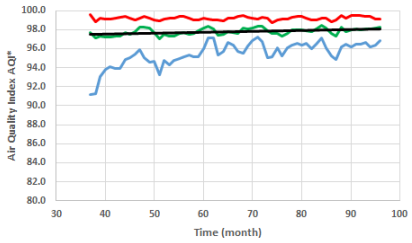

Fig.2 AQI* (green), MaxAQI(red), MinAQI(blue) in time series 2008-2012.

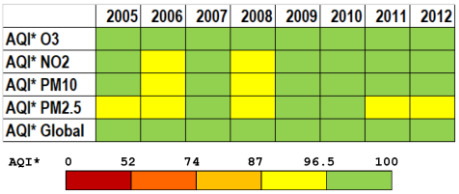

Fig 3. AQI colour code of air pollutants and global.

Comparing Fig.1 and Fig.2, a reduction of variance can be seen; also a most regular profile of values in the 2008-2012 period comparing with the 2005-2007 period. In Fig.3 colour code for average yearly values are illustrated. Also significant differences can be seen in both periods.

Conclusions
(1) Air quality in Barcelona is good (green colour) in the period 2005-2012; global AQI* in 2005-2007 period is lower than global AQI* in 2008-2012, so there is an improvement in global air quality. (2) The number of years with AQI in the yellow zone has decreased very significantly since the first year of speed limitation, making the measure seem adequate to improve air quality in Barcelona. (3) The air quality index for particles PM2.5 presents some years in yellow zone, that is, additional measures are required to reduce concentration of this type of particles.

Acknowledgement
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THE POTENTIAL IMPACT ON AIR QUALITY OF ENERGY SAVING MEASURES BY CITIES OF THE COVENANT OF MAYORS INITIATIVE

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Summary
In 2008, the European Commission launched the Covenant of Mayors initiative, to encourage local authorities to implement sustainable energy policies within their territories. Signatories of the Covenant of Mayors initiative agree on a common objective of a minimum 20% reduction of the Greenhouse Gas emissions by 2020, in comparison with their 1990 emissions (or the closest subsequent inventory year with reliable data) and have to present a Sustainable Energy Action Plan containing the measures intended to reach the target. This study is a first attempt to evaluate how the major efforts made by European local authorities in the frame of the Covenant of Mayors initiative will also affect air pollution levels in the participating cities.

Introduction
Recognising the key role of cities and towns in the fight against climate change, and following the adoption of the 2020 EU Climate and Energy Package in 2008, the European Commission (EC) launched the Covenant of Mayors (CoM) initiative, to encourage local authorities to implement sustainable energy policies within their territories. The CoM network proposes to its signatories a common objective of a minimum 20% reduction in Greenhouse Gas (GHG) emissions by 2020 in comparison with the 1990 levels (or the closest subsequent inventory year with reliable data), a common platform for building a Sustainable Energy Action Plan (SEAP) and a common model for monitoring the GHG emissions related to energy consumption. In the past, air quality (AQ) and climate change (CC) policies have usually been treated by different communities. Recently, efforts have been made at international / European level to implement air quality and climate policies in an integrated manner (Amann et al., 2011), but this integrated approach is still far from being adopted at the local/urban scale (Viaene et al., 2016). This paper contributes to the topic by examining for the first time the issue of co-benefits and trade-offs between AQ and CC policy actions under the Covenant of Mayors initiative.

Methodology
The measures contained in SEAPs aim to achieve the final goal of GHG mitigation by either decreasing energy consumption (Energy Saving measures: ES), or by increasing renewable energy production at the local level (Renewable Energy Production measures: shortly REP), or a miture of both (MIX measures). SEAPs translate each measure into GHG emission reductions, but provide no information about the parallel impact on Air Quality (see Figure 1). A key challenge in moving from a qualitative analysis to a more quantitative estimate of the Air Quality Benefit (AQB) is that of putting a scale on the vertical axis of Figure 1. In this study the AQB indicator of energy saving measures applied in selected CoM cities is computed using the SHERPA model (Thunis et al., 2016) and compared with the expected GHG emission reduction to provide a quantitative evaluation of the co-benefits these energy saving measures.

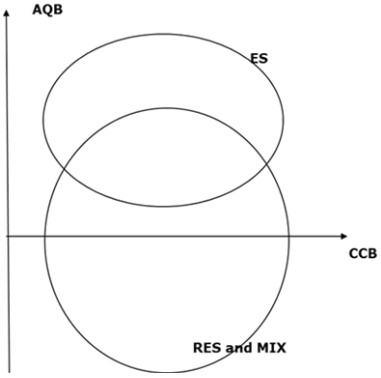

Fig.1. Qualitative representation of Air Quality Benefit (AQB) and Climate Change Benefit (CCB) of different kinds of SEAP measures. ES means 'energy savings', while RES describes 'renewable energies production'.

Conclusions
The main result of this study is the robust demonstration of the existence of climate and air quality co-benefits of energy saving measures for the cities involved, which are among the largest ones in the CoM initiative. AQ co-benefits for energy saving measures have been shown to depend on the size of the city in which the measure is implemented, yet no evidence was found that cities affected by higher pollution level tend to implement energy saving measures resulting in higher air quality co-benefits. Potential health benefits linked to the selected energy saving measures have been also quantified and shown to be non-negligible in comparison to the overall effect on public health of the current air pollution in Europe. We believe that the results presented in this study can be of inspiration to CoM signatories and other administrators to better exploit the AQ co-benefits of their planned mitigation measures and furthermore to raise awareness of the possibility that AQ impact of renewable energies production measures can be negative, as well as positive.

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REMOVAL OF PARTICLES ORIGINATING FROM TRAFFIC BY VEHICLES IN MEGACITIES THROUGH ACTIVE ON-BOARD FILTRATION UNITS

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Summary
This paper aims at discussing an innovative and cost efficient near source option for the reduction of air pollution caused by exhaust emissions control by vehicles. After the successful major clean-up of air pollution in industry by many branches and in many regions of the world the absolute and relative role of vehicle emissions is huge. Pollution of air is followed by pollution of rainwater runoff, which is really hard to control due to its diverse as well as diffuse characteristics. Following the principle that the party responsible is liable for the damages an innovative approach for clean-up by vehicles is presented. Besides the ongoing efforts of controlling emissions all vehicles should be equipped with an active filtration unit that will clean the air. The common air-filters only for inside the vehicles are absolutely not sufficient as all men and women exposed to traffic should be protected alongside with avoidance of water pollution. Such technology would be readily available through simple legislation.

Introduction
Increased particle pollution leads to severe health issues (Pope and Dockery, 2006 and many more) and will have to be addressed with more than just stricter exhaust emission standards. Emissions by vehicles in various forms are a major cause of air pollution in cities and beyond. This paper suggests the introduction of active agents of pollution removal relative to traffic and near to source. While exhaust treatment has severe limitations and does not address tire particles and all other sources of air pollution in and near roads, vehicles can not only be the source of pollution but also part of the solution. While all combustion driven vehicles are equipped with air-filters to protect the engine from particles all vehicles could become equipped with additional or integrated air-filters to clean up the air. The beauty of this concept is that vehicles would do the air treatment relative to traffic and the cost is on those using vehicles. Even though electric vehicles do not emit through combustion they also cause emissions by tire abrasion.

Methodology and Results
This study is building on statistics of air pollution that is caused by traffic in general and relative to traffic density in diverse climatic and geographical conditions specifically. Comparison was done between different methods of air treatment:

1.) Active roadside filtration units (ARF)
2.) Passive roadside filtration units (PRF) based on biological filtration
3.) Active vehicle based filtration units (AVF)

With respect to technical feasibility small motorbikes where excluded – proper legislation can convert those to electric transportation on a very short timeframe and with very high efficiency especially for 2-stroke engines.
It could be shown that the air treatment by vehicles themselves in and as part of the traffic was by far the most efficient both in particle reduction potential and in economic terms. However, a high percentage of equipped vehicles was assumed, which can be achieved by adequate legislation. Furthermore it was assumed that such filtration units can be designed with standard engineering and down to those particle sizes, which are responsible for the health issues. It was assumed further, that regular exchange of filters can be enforced while costs and efforts are within reasonable limits. This is even more reasonable because inflicting health problems on fellow humans and more specifically to the very vulnerable children is a severe issue. In a recent survey it could be shown, that a vast majority of drivers in a German city where more than willing to contribute to air quality. The percentage of positive attitude was highest among people with young children. The effects of these measures are relative to traffic density; however filters will just be less loaded than but can easily get clogged by dust pollution caused by land erosion. Additional energy demand for the AVF has to be calculated with the development of such units.

Conclusions
While vehicles cause most of the pollution problems for air-quality and rainwater runoff vehicles can be turned into a solution within a relatively short adaptation period. Active Vehicle based Filtration units (AVF) can make those that will be equipped in this way air-cleaners that move nearest to the source of pollution in all denser traffic. Most efficient is the introduction of AVF in Megacities.

Acknowledgement
The idea for this research originates from the entrepreneur and author Vladimir Megre, Siberia, Russia. Funding by TUHH.

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Air Quality Measurements and Process Studies

STUDIES OF SEMI-VOLATILE HYDROCARBONS IN DIESEL EXHAUST AND AMBIENT AIR

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Summary

The findings to date of the FASTER project (Fundamental Studies of the Sources, Properties and Environmental Behaviour of Exhaust Nanoparticles from Road Vehicles) are described. These include the characterisation of the semi-volatile compounds in sub-100 nm particles in diesel exhaust, laboratory studies of the vapour pressures of n-alkanes, field measurements of the number, size distribution and composition of sub-100 nm particles, and concentration of the associated vapour component, and the development of street canyon and neighbourhood scale models.

Introduction

Diesel exhaust particulate matter is an intense subject of research not only because of its direct toxicity but also because of its substantial semi-volatile component which is subject to evaporation as particles move away from their source releasing vapours which oxidise to form a greater mass of secondary organic aerosol. The sub-30 nm particles comprise largely condensed organic matter which has been sampled and characterised in detail within this project. In addition to measurements in the engine laboratory, other aspects of the behaviour of such particles in the atmosphere are described.

Methodology and Results

The ERC-funded FASTER project is studying many aspects of the semi-volatile organic matter associated with particle emissions from automotive diesel engines. The various facets of the project include the following:

- Collection of particulate matter and associated vapour emissions from a diesel engine using fuels of differing quality and different engine oil lubricants, sampling both before and after a diesel oxidation catalyst and a diesel particle filter (Alam et al., 2016a).
- Chemical analysis of the semi-volatile content (comprising mainly hydrocarbons of C_{12}-C_{35}) using 2-dimensional gas chromatography with Time-of-Flight Mass Spectrometry detection (Alam and Harrison, 2016; Alam et al., 2016b).
- Laboratory measurements of the vapour pressures of relevant n-alkanes.
- Field experiments in London in which the evolution of particle size distributions as air advects from a busy roadside into an urban park and mixes upwards to an elevated sampling point are measured.
- Numerical modelling studies designed to simulate the behaviour of the particles with a high semi-volatile content (Nikolova et al., 2016).

Recent highlights of the study will be shown including the characterisation of composition and the behaviour of particles as measured in the urban atmosphere.

Conclusions

This work adds substantially to knowledge of the chemical composition, properties and atmospheric behaviour of diesel exhaust nanoparticles. Models have been developed to simulate this behaviour both in street canyons and on an urban neighbourhood scale.

Acknowledgement

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HIGH O_3 & UFP EPISODES IN SPAIN: BOTTOM-UP OR UP-DOWN DOMINATED ATMOSPHERIC PROCESSES

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Summary

We present here results of 4 intensive international measurement campaigns for O_3 and ultrafine particles (UFP) that used tethered balloons and miniaturised instruments, as well as measurements performed at supersites around and in two main cities in Spain. We evidenced the importance of surface fumigation of high altitude O_3-rich layers due to the growth of the mixing layer, although local/regional generation of O_3 might also contribute to enhance surface concentrations in specific episodes. In a number of cases UFP episodes coincide with the O_3 ones but we evidenced that most probably sources of both pollutants are not directly linked.

Introduction

Photochemical pollution yields to intensive episodes of both O_3 and UFP in high insolation climates (Brines et al., 2016). We compile here data from intensive measurement campaigns around major cities of Spain to evaluate the summer atmospheric processes yielding to high O_3 concentrations and to intensive UFP nucleation episodes.

Methodology and Results

We carried out intensive O_3 and size resolved UFP (SMPS) measurement campaigns in May 2014 (into Barcelona), and July 2015 (70 km N Barcelona), 2016 (W Madrid) and 2017 (45 km N Barcelona). Aerosol variables and gaseous pollutants were measured at different supersites. In addition, high time resolved vertical measurements up to 1.2 km a.g.l were performed with airborne instrumentation, using tethered balloons. . To this end a PO3M U-V O3 analyser (B-Technologies) as well as non-commercial miniaturised CPC and SMPS systems (developed by the Hanyang University, S. Korea), Lee et al 2014 and 2015) were deployed.

Conclusions

We evidenced the importance of surface fumigation of high altitude O_3-rich layers due to the growth of the mixing layer, although local/regional generation of O_3 might also contribute to enhance surface concentrations in specific episodes for which we describe the phenomenology. Furthermore, photochemical nucleation episodes simultaneously recorded across large areas. We evidenced also relatively independent spatial patterns for O_3 and UFP. Thus, vertical variation of UFP levels was strongly depending of being inside or outside of the boundary layer until mid-morning, when the boundary layer depth exceeded the maximum height reached with the tethered balloons. Levels of O_3 were very little affected by the boundary layer growth. These were upwards increasing (up to the highest altitude reached) in the early morning profiles, homogenous at midday and again upwards increasing in the afternoon. In this case the comparison of O_3 and UFP evidenced top down and a bottom up processes, respectively. Into the city we found that nucleation is enhanced at mid altitudes of the PBL as source emissions are diluted. Finally in other cases we found plumes of nucleation at high altitude without relation with the local surface sources of precursors.

Acknowledgement

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EVALUATION AND COMPARISON OF CONTINUOUS BC AND NO_X MEASUREMENTS IN THREE SWEDISH CITIES (STOCKHOLM, GÖTEBORG AND MALMÖ) IN RELATION TO SOURCES AND TEMPORAL VARIABILITY

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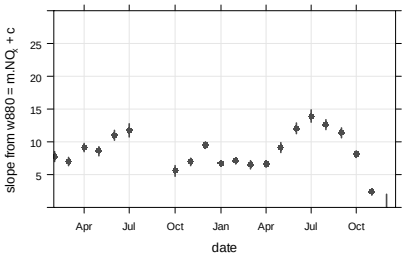
Summary
Black Carbon (BC) and Nitrogen Oxides (NO_X) possess environmental and human health risks. Concentrations of these air pollutants are highly influenced by road traffic emissions. The study aims to evaluate and compare temporal trends and sources of these pollutants at the kerbside in three Swedish cities-Stockholm, Göteborg and Malmö based on measurements in 2015 and 2016. The highest NO_X (about 150 µgm^{-3}) and BC (about 2000 ngm^{-3}) concentrations, in the diurnal variation, were observed less in 2015 at the Stockholm kerbsides compared to observations in 2013 (NO_X 270 µgm^{-3}; BC 4000 ngm^{-3}). The winter to summer NO_X emission ratios were 2.1 and 1.36 in Göteborg and Malmö, respectively. The ratios were 1.18 and 1.23 in 2005 and 1.15 and 1.16 in 2000 in the western Europe and central Europe, respectively. However, the BC_{370} and BC_{880} emissions ratios were reported to be 0.97 and 0.89 in Stockholm, 1.56 and 1.44 in Göteborg, and 1.35 and 1.26 in Malmö in 2015. The ratios were mostly lower than the BC ratios recorded at 1.34 and 1.76 in 2005 and 1.59 and 1.92 in 2000 in the western Europe and central Europe, respectively. The relative pollutants emission ratio observed were further lower in 2016 than in 2015.

Introduction
Black Carbon (BC) and Nitrogen Oxides (NO_X) are considered two major air pollutants that present risk to environmental and human health (USEPA, 2012). Road traffic emissions are the dominant source of both BC and NO_X concentrations in the urban environment (Morawska et al., 2008). The report presents an overview comparison of continuous BC and NO_X measurements in three Swedish cities (Stockholm, Göteborg and Malmö) in the year 2015. The evaluation of the air quality in three Swedish cities-Stockholm, Göteborg and Malmö was based on the daily, seasonal and yearly concentration variation of BC and NO_X, based on road traffic emissions in the environment in 2015. Finally, a comparison of the relative emission ratio changes between BC and NO_X was also assessed based on measurements from both 2015 and 2016.

Methodologies and Results

The light absorption seven wavelengths method was used to measure BC at 370 nm and 880 nm and the Chemiluminescent method was used for NO_X. The BC and NO_X measurements were recorded for every hour from January to December in 2015 and 2016. At the Stockholm Kerbside, the NO_X and BC concentrations were measured 150 µgm^{-3} and 2000 ngm^{-3} in the diurnal variation in 2015; which were 270 µgm^{-3} and 4000 ngm^{-3} in 2013.The highest winter to summer mean concentration ratio for NO_X was observed in Göteborg (2.00) followed by Malmö (1.4) and Stockholm (1.1) in 2015 (Fig. 1). The winter to summer ratio shows similar pattern for both BC_{370} and BC_{880}, where the maximum ratio was recorded in Göteborg followed by Malmö and Stockholm. The lowest ratios were in Stockholm (BC_{370} 0.97; BC_{880} 0.89). The ratios between the highest and lowest anthropogenic NO_X emissions were reported at 1.15, 1.18 and 1.23 on the global scale, western European scale and central European scale respectively in 2005 (Granier et al., 2011). The ratios were 1.17, 1.15 and 1.16 in 2000 respectively. On the other hand, the ratios between the highest and lowest anthropogenic BC emissions were found-1.28, 1.34 and 1.76 on global level, western European level and central European level in 2005; in 2000 these figures were 1.13, 1.59 and 1.92. The relative pollutants emission ratio observed was further lower in 2016 compared to 2015. However, the ratio of BC (BC_{370} and BC_{880}) to NO_X increased during summer (May to July) in Göteborg in 2016 (Fig. 2). A higher BC_{880} to NO_X ratio was also observed during summer in Malmö.

Conclusion
Introduction of Euro standard vehicles, strict emission regulations such as a traffic congestion charge and ban of studded tyres together with continuous dieselisation of the automobile fleet is gradually improving air quality at the investigated kerbsides.



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SPATIAL DISTRIBUTION OF BLACK CARBON IN ROME: CASE STUDY FOR HIGHLY QUALITY-ASSURED MOBILE MEASUREMENTS

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Summary
This study proposed a standard methodology to achieve highly quality-assured data from mobile measurements. First, including a fixed station in an urban background area along the route allowed for constant quality check of the mobile instruments against the reference instruments. Second, performing parallel mobile measurements not only provided a constant quality check of the instruments along the entire route but also increased the number of data points leading to representativeness of the spatial average. Third, optical instruments with limited particle number size distributions have been corrected to include the whole particle size spectrum (particularly the entire fine mode) to derive mass concentrations of PM. The proposed methodology addressed some of the main issues regarding quality of mobile measurements especially when considered for health impact studies, validation of modelled spatial distribution, and development of air pollution mitigation strategies.

Introduction
The mobile approach of measuring air pollutants have gained popularity over the last decade due to its wide range of applicability. However, capturing the real world scenario of spatial distribution of pollutants in a high quality level remains a challenge (Van den Bossche et al., 2015). Hence, this study proposes a standard methodology for mobile measurements and data processing that would produce reliable and quality-assured data of spatially resolved eBC and PM mass concentrations.

Methodology and Results
Mobile measurements for eBC (microAeth Model AE51) and particle number size distribution (PNSD; TSI Optical particle size spectrometer-OPSS Model 3330) were acquired using two identical platforms (backpacks). Parallel runs doubled the number of data points along the route, increasing the representativeness of the averaged data. This also lead to constant unit-to-unit inter-comparison of the instruments (+/- 5%). The performance of the instruments compared against the reference instruments in the fixed station was consistently checked during the 30-minute inter-comparison for each run and were well within 10 - 20% of the reference instruments. PM mass concentrations were derived from the OPSS number size distribution after correcting for refractive index effects according to the Mie scattering theory. The volume fraction of the fine mode (300nm – 1000nm) of the OPSS was corrected according to the volume fraction measured by the MPSS (10 nm – 10000 nm) in the fixed station. This method showed that the ratio of the fine mode particle volume concentration measured by the MPSS and OPSS was 6.5. The resulting spatial distribution showed the dependence of eBC and PM_{10} (Fig. 1) on traffic emissions, human activities, and meteorology. The result also showed that the spatial distribution of eBC and PM are not correlated. Hence, when considering personal exposure to surface level air pollution, the smaller and more toxic eBC should also be given more importance.

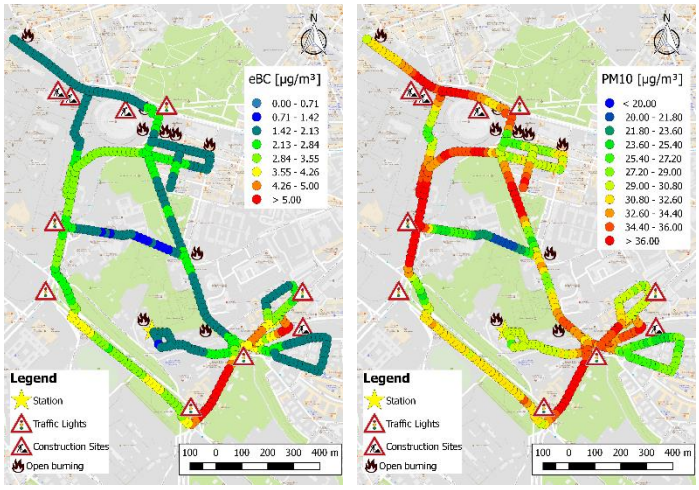

Fig. 1 Spatial distribution of eBC (left) and PM_{10} (right) along the route around the fixed reference station

Conclusions
As mobile measurements continue to gain popularity in the field of research, it has become even more important to have standard methodology to ensure high-quality and reliable data. Therefore, when performing mobile measurements, the proposed methodology significantly increased the quality and reliability of the data gathered which can then be used for health-impact studies, validation of models, and ultimately, as basis for air pollution mitigation strategies.

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The authors would like to thank the team that worked on the CARE 2017 project in Rome, Italy, especially the scientists and students who volunteered to perform the mobile measurements.

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ATMOSPHERIC DEPOSITION OF TRACE ELEMENTS IN THE VICINITY OF KARDZHALI LEAD-ZINC PLANT IN BULGARIA BASED ON MOSS BIOMONITORING

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Summary
For the first time the moss biomonitoring technique was used to assess the environmental situation in the area affected by one of the most hazardous industrial enterprises in Bulgaria – the Kardzhali lead-zinc smelter. It was known to be the main source of lead, cadmium, zinc, and sulphur oxide contamination in the country. The results were anticipated to be an extension to the available data on a small number of elements investigated by the State regulatory bodies. Three analytical techniques were used: neutron activation analysis, atomic absorption spectrometry, and inductively coupled plasma-atomic emission spectrometry. A total of 47 elements were determined (Ag, Al, As, Au, Ba, Br, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Fe, Hf, Hg, I, In, K, La, Li, Mg, Mn, Mo, Na, Nd, Ni, P, Pb, Rb, Sb, Sc, Se, Sm, Sr, Ta, Tb, Th, Ti, Tm, U, V, W, Yb, and Zn). To illustrate the deposition patterns of element pollutants, GIS technology was used to produce distribution maps.

Introduction
The lead-zinc smelter was founded in 1955, in the industrial part of Kardzhali town. It was famous for the production of nonferrous metals (zinc, lead, bismuth, cadmium and their alloys), sulfuric acid, and processing of exhausted batteries. The objective of this study was to determine atmospheric deposition of trace elements and hazardous ones, in particular, based on analysis of moss biomonitors growing in an environmental hot spot and the surrounding area. A temporary shutting down of the production processes took place during moss sampling, as a penalty for failure to observe the environmental policy. Thus, it could be assumed that biomonitoring took place around the time when the deposition rates from emissions were the highest.

Methodology and Results
The sampling strategy of the UNECE ICP Vegetation Programme on atmospheric deposition studies in Europe (United Nations Economic Commission for Europe, International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops) was applied, with the exception of the recommended sampling network density, altered due to the relatively small study area. In total 77 *Hypnum cupressiforme* moss samples were collected in the Kardzhali municipality (Fig. 1).
Neutron activation analysis, atomic absorption spectrometry, and inductively coupled plasma-atomic emission spectrometry were used to determine the content of 47 elements. A total of 47 elements were determined. The contents were compared with data from moss surveys conducted in Bulgaria and other European countries participating in the ICP Vegetation programme. Multivariate statistical analysis was applied to characterize the sources of elements determined in the samples. Four groups of elements were differentiated. *Factor 1* represents crustal material and vegetation (Al, Ba, Cs, Fe, Hf, K, Mg, Mo, Na, Rb, Sc, Sr, Ta, Th, Ti, U, V). *Factor 2* characterizes the smelter activities (Ag, As, Au, Cd, Cu, Hg, In, Pb, Sb, Se, Zn), and the highest factor score is observed on the sampling site closest to the smelter chimneys. *Factor 3* is associated with metallurgical industries (Co, Cr, Ni, and V). The studied area is rich in ore deposits and is characterized by former extensive mining activities. The highest factor loadings are found in sites located near an open quarry. *Factor 4* contains the elements Br, Cl and I, usually interpreted as "marine". The north-south direction of the wind rose and the seasonal climatic impact by the Aegean Sea agree with the marine interpretation.

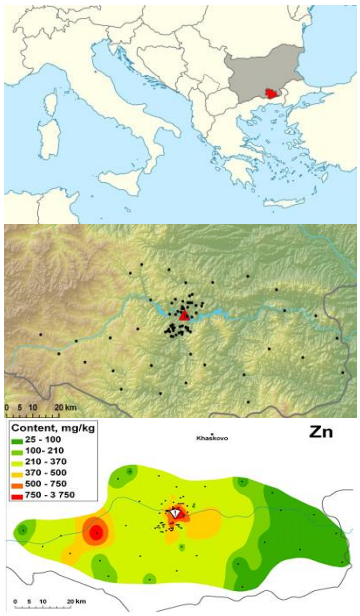

Fig. 1. Location of Kardzhali municipality. Sampling sites and a distribution map for Zn (exclamation sign marks the smelter)

Conclusions
Besides the well-known hazardous contaminants Pb, Zn, and Cd (first group of toxicity), elements posing a risk to the human health like Se, Ti, Cr, Cu, Ni, Al, As, Hg, and Mo (first, second and third groups of toxicity) were determined. The data obtained, used in conjunction with state monitoring programs, could provide for a better estimation of health and environmental risks, and aid risk-management decisions. Moss biomonitoring surveys could be of great use as they provide a cost-effective and efficient means for a time-integrated evaluation. As the smelter in Kardzhali is going to re-open after major renovation, the data could be used to assess the new pollution-control equipment efficacy. The anthropogenic association of the elements Ag, As, Au, Cd, Cu, Hg, In, Pb, Sb, Se, and Zn is typical for Pb-Zn concentrates processed in smelter plants, as well as in smelter products and by-products. Therefore, similar distribution patterns of element-pollutants may be expected for any lead-zinc plant, without consideration of the landscape peculiarities and productive capacity.

NORTH HEMISPHERE AIR QUALITY TRANSECTS TO ASSESS LEGACY AND EMERGING SEMIVOLATILE ORGANIC CONTAMINANTS

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Summary
The objective of this series of studies is to combine comprehensive overviews of "legacy" and "emerging" atmospheric pollutants, in order to assess their incidence and behaviour. Four different passive air sampling campaigns were done in a latitudinal transect covering background areas from Svalbard in the Arctic and the island of São Tomé in the Equator. Two of them (winter and summer) were dedicated to legacy persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs) and polybrominated diphenyl ethers (PBDEs) and the other two to polycyclic aromatic hydrocarbons (PAHs) and a class of contaminants of emerging concern: volatile methyl siloxanes (VMSs). PAHs and VMSs showed much higher levels in the atmosphere than POPs, which shift the seasonal trends with the latitude. Both long-range atmospheric transport (LRAT) and nearby sources contribute for the burden of SVOCs along the transect.

Introduction
Environmental pollution is affected by phenomena of "globalisation", as we are frequently dealing with global pollutants such as semi-volatile organic compounds (SVOCs) which are highly resistant to degradation by biological, photolytic or chemical processes. These properties make them a concern not only near the sources, but also up to the most remote locations of Earth. The migration processes of SVOCs are complex and worldwide, with predominant deposition in the higher latitude and lower temperature areas (Gioia et al., 2006).

Methodology and Results
Passive samplers were used: simple polyurethane foam (PUF) disks for legacy POPs and PAHs and sorbent-impregnated PUFs (SIPs) for VMSs. The levels of total siloxanes were in general, three to four orders of magnitude higher than those of total POP, reaching 1153 ng/m3 in Cape Verde. Cyclic siloxanes were clearly predominant over linear ones as were OCPs over PCBs and PBDEs. Of all the families of compounds, only OCPs showed a significant (positive) latitudinal trend, although PCB fractionation is also seen with the exception of the tri-CBs. The sampling sites located on small islands show some singular characteristics and their location can be crucial in the transport of chemicals. Of all the families of compounds, only OCPs showed a significant (positive) latitudinal trend, although PCB congener fractionation is also perceived.

Conclusions
There is an on-going need to continue these types of studies in order to assess not only a continental framework, but also these particular characteristics, namely in the case of VMSs, due to the magnitude of their presence in the background atmosphere, allied to the more recent acknowledgment of their potential hazardous effects.

Fig.1 Map of the sampling sites in the North Hemisphere latitudinal air sampling transect

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THREE DIMENSIONAL OBSERVATIONS (3DO) OF AIR QUALITY IN STUTTGART UNDER THE GERMAN FEDERAL MINISTRY FOR EDUCATION AND RESEARCH (BMBF) PROJECT

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Summary
This study aims to investigate air quality of Stuttgart and its aspects using three dimensional observations that were performed in Stuttgart among others by the Department of Air Quality Control (RdL) – Institute of Combustion and Power Plant Technology, University of Stuttgart under the project funded by Federal Ministry for Education and Research (BMBF). The project "Urban Climate Under Change", aims to develop an innovative urban climate model in order to monitor and improve the air quality of different cities in Germany. In this paper results of different measurements of meteorological parameters and air pollutants are presented.

Introduction
Ambient air quality has always been a highlighting problem for big cities with dense population and high traffic volume. The most common and traditional way for air quality monitoring are stationary air quality measurements. However, the main disadvantages of stationary monitoring stations are the lack of mobility and limited spatial resolution. It limits the possibilities of mapping of spatial distribution of air pollutants and understanding of behaviour related to local topography and climate. In order to provide high spatial and temporal resolution for air quality, three dimensional measurements are necessary.

Methodology and Results
In Stuttgart, it is targeted to investigate local flow systems, among others cold air flows and their effect on the air quality of the city. This was accomplished by a bunch of different kind of measurements like balloon measurements, bicycle and other mobile measurements, passive sampler measurements and stationary measurements. The tethered balloon measurements provides a vertical gradient of meteorological variables (air temperature, relative humidity, air pressure, wind speed and direction), as well as air pollutants (NO_2, NO, O_3, Particulate Matter and Black Carbon) from ground up to a height of several hundred meters above ground. These measurements were performed during the summer Intensive Observation Period (IOP) in the mid of August 2017 continuously for around two complete days. One sounding (ascent and descent) took about 30 minutes and after six hours, a break was taken to calibrate the instruments and to change the accumulators. The bicycle measurements were performed during the winter IOP in February 2017 and also during the summer IOP in July 2017. The measurement route covered the high traffic roads as well as the side roads and parameters such as air temperature, relative humidity, air pressure, wind speed, wind direction, solar radiation, NO_2, NO, O_3, Particulate Matter and Black Carbon as well as the geographical position of the measurements along the route by GPS were measured. For the results of vertical profile measurements using the balloon measurements showed the formation and dissolution of the inversion layer and hence the effect of that layer on other components and pollutants. The results from bicycle measurements show that the main source of pollutants generated in the area of investigation (Stuttgart) is because of traffic. Therefore, high concentrations of pollutants are observed close to the main roads and in the rush hour time. The relationship between the pollutants NO, NO_2 and O_3 (photochemical equation) is also verified from the results of the measurements. The bicycle measurements are for a short period of time and hence the concentrations for a longer period of time cannot be measured. In order to validate the data obtained from the bicycle measurements, the NO and NO_X concentrations were measured at different locations on the route of the bicycle measurements for a longer period of time using passive samplers.

Conclusions
The high pressure conditions lead to the formation of inversion layers and trap the pollutants hindering their dispersion. The problem with the high concentrations of the pollutants especially NO_2 in the city of Stuttgart is directly related to the local source i.e. traffic.

Acknowledgement
This work was supported by German Federal Ministry for Education and Research (BMBF) within the project "Urban Climate Under Change UC^2".

VERTICAL DISTRIBUTION OF REGIONAL NEW PARTICLE FORMATION EVENTS IN MADRID

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Summary
We describe the vertical distribution of new particle formation (NPF) events by comparing the aerosol size distribution measured aloft and at surface level in a suburban environment in Western Madrid. A comparison between data from nearby urban and suburban surface stations is also made. The events were detected simultaneously at all stations, with larger growth rates and smaller formation rates at suburban stations. At the urban stations, rare nocturnal nucleation mode particles were detected, which we associate with airport emissions. The vertical distribution of the events shows the existence of a residual layer in which stored aged particles grow slower than those inside the mixing layer.

Introduction
NPF events are known to be a principal source of atmospheric ultrafine particles (UFP) (Kulmala et al. 2016). The newly formed particles can affect human health by their inhalation as well as the climate by acting as cloud condensing nuclei after they grow to certain sizes. While many studies research this topic, few works have focused on the vertical distribution of the events. In view of this, we compared the aerosol size distribution aloft with surface levels and studied its temporal evolution.

Methodology and Results
The data used in this study was obtained during a summer campaign in and around Madrid, Spain, in July 2016. Three air quality supersites were used (urban and suburban), in addition to a setting in a suburban environment with two tethered balloons that allowed studying the vertical distribution of aerosol and air pollutants. All stations were within a range of 17 km. Amongst the instrumentation used, Scanning Mobility Particle Spectrometers (SMPS) were used to measure the aerosol size distribution at surface and the soundings. Intensive regional nucleation episodes were simultaneously recorded at all stations, followed by particle growth. Some days a marked decline in particle size (shrinkage) was observed in the afternoon, associated with a change in air masses. Additionally, a few nocturnal nucleation mode bursts were observed in the urban stations, which could be related with aircraft emissions transported from the airport of Madrid, according to wind speed and direction. Considering all simultaneous diurnal NPF events registered, growth rates were significantly higher at suburban stations, ranging 2.9-10.0 8 nm h^{-1} with a median value of 5.8 nm h^{-1}, compared to the urban stations (2.0-3.9 nm h^{-1} with a median of 2.7 nm h^{-1}) Median hourly maximum formation rates of 9.1-25 nm particles (including both primary and secondary UFP) are 2.0 cm^{-3} s^{-1} at the urban stations and 1.1 cm^{-3} s^{-1} at the suburban station. The condensation and coagulation sinks presented minimum values shortly before sunrise, increasing after dawn reaching the maximum value at 15:00 UTC. The vertical soundings demonstrated that UFP fluxes are transported from surface levels to higher levels. The morning soundings showed the presence of a residual layer in the upper levels in which aged particles (nucleated and grown on previous days) prevail. Particles in this layer also have a growing stage, with growth rates smaller than inside the mixing layer. Once the convection is strong enough, the soundings measured homogeneous distributions at all altitudes, which followed the same evolution in the other stations considered in this study.

Conclusions
Intensive regional NPF episodes were detected simultaneously at urban and suburban stations 17 km apart in Madrid. The urban stations had larger formation rates and smaller growth rates as compared to the suburban stations. In the early morning the vertical distribution of newly formed particles is differentiated in two layers, one in which convection is effective and another in which particles formed or transported the previous days are stored. However, around midday the soundings measure a homogeneous distribution at all measured levels, demonstrating that the newly formed particles are well-mixed and detected at all levels once the convection is effective.

Acknowledgement
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VERTICAL PROFILES OF LUNG DEPOSITED SURFACE AREA CONCENTRATION OF PARTICULATE MATTER MEASURED WITH A DRONE IN AN URBAN STREET CANYON

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Summary
Vertical profiles of lung deposited surface area (LDSA) concentration of particulate matter were measured with a drone in an urban street canyon environment in Helsinki, Finland. The use of a drone as a moving measurement platform was proved relevant also in this sort of an urban environment. The results showed the dilution profiles of LDSA concentration with a high resolution from the ground level up to an altitude of 50 meters clearly above the rooftop level.

Introduction
Street canyons are important environments in urban areas with respect to the dispersion of traffic emissions and human exposure. Pedestrians, cyclists, and people inside vehicles are exposed to relatively high concentrations of particles and gaseous pollutants on the ground level of street canyons because of the reduced natural ventilation. The vertical dispersion of pollutants affects the human exposure above the ground level in buildings and contributes to regional background concentrations. Previously, the emissions have been measured in street canyons at a few different heights, mainly restricted to the ground level and the rooftop. More detailed information on the vertical dispersion is needed, for instance, for the use of urban planning and the design of ventilation systems in buildings. Lung deposited surface area (LDSA) concentration is a relevant metric for particulate matter with respect to negative health effects especially in urban areas (Kuuluvainen et al., 2016) and it can be measured with different electrical particle sensors.

Methodology
The drone measurements were carried out in a busy street canyon in Helsinki next to an urban supersite measurement station (Mäkelänkatu 50) during two days in November 2016. In addition to them, simultaneous ground level measurements, long-term measurements, and stationary measurements at two different heights were conducted. An unmanned aerial vehicle (UAV) used as a moving measurement platform in the experiments was a quadrotor drone, and the particle sensor installed into the drone was a Partector (Naneos GmbH), which measures the LDSA concentration. In the measurements, the drone was flown from the ground level to an altitude of 50 m. The drone was able to operate 3–5 subsequent up-and-down flights before the battery has to be changed or recharged. Altogether, 48 up-and-down flights were conducted during the two days. In addition to the sensor installed into the drone, reference data was measured at different locations with another Partector and other devices such as a DiSCmini (Testo Ltd.), an electrical low pressure impactor (ELPI+, Dekati Ltd.), and an AQ Urban (Pegasor Ltd.).

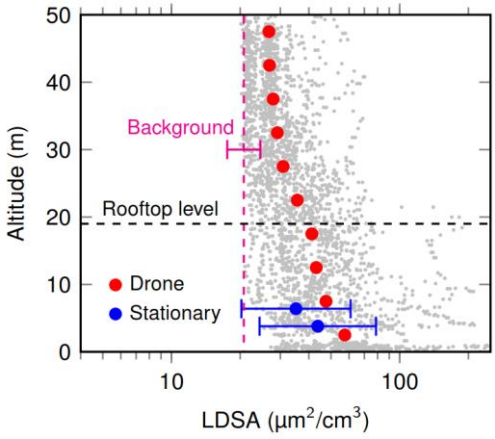

Fig.1 A vertical profile of lung deposited surface area (LDSA) concentration measured during one day with a drone in a street canyon with respect to background and stationary measurements.

Results
Figure 1 shows an example of the vertical profiles of LDSA concentration measured during the first drone measurement day. Two different dilution profiles can clearly be seen, one inside the street canyon and another above the rooftop level. The vertical profiles obtained from the drone measurements were also comparable to the stationary measurements carried out on the roof of the measurement station. The relevance of the vertical profiles could be estimated with respect to the simultaneous and long-term ground level measurements at different locations and with respect to the meteorological data.

Acknowledgement
This work was conducted in the INKA-ILMA/EAKR project funded by Tekes, European Union, Helsinki Region Environmental Services Authority (HSY), City of Tampere, City of Kuopio, Dekati Ltd., Genano Ltd., Nordic Envicon Ltd., Pegasor Ltd., Sandbox Ltd., Suomen Terveysilma, TreLab Ltd., and Vallox Ltd., as well as in the Cityzer project funded by Tekes, HSY, and Pegasor.

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BLACK CARBON AND ULTRAFINE PARTICLES IN THE PORT OF CIVITAVECCHIA (ITALY)

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Summary
This study aims at characterizing the loads and origins of black carbon and ultrafine particles in the port aerea of Civitavecchia (central Italy). To this goal, the CNR-ISAC van "AEROLAB" has been characterizing aerosols in the heart of the port (Molo 24 in figure 1) along the whole month of April 2016. This location allowed a good azimuthal separation with respect to the piers hosting different types of ships (e.g., Fig 1). Equivalent black carbon (eBC), and ultrafine particle (UFP) concentrations observed at Molo 24 have been studied as a function of their azimuthal origin. We find the Ro Ro passenger ferry piers to host the major sources in terms of eBC and UFPs. These are followed by small carrier's piers and by the cargo piers. Minor eBC and UFP origins were associated to the Cruise piers. No clear eBC and UFPs signals could be associated to the power plant during the field campaign period. Significant sources of eBC are linked to the vehicle and train operation areas nearby the Molo 24 measurement location. A smaller eBC signal was associated to the city light traffic.

Introduction
Civitavecchia is the major port serving the Rome area in central Italy. In addition to regular ferry links with Sardinia and Spain, the port hosts an important traffic of cruise ships, cargo ferries and carrier ships summing-up to some 3000 ship-movements per year, involving 4 million passengers and 1 million vehicles. The port touches the NW portion of the city of Civitavecchia (50,000 inhabitants), and extends NW for about 3 km, up the coal cargo pier serving the 2000 MW, coal-fired power station of Torrevaldaliga Nord (e.g., Figure 1). In spite of epidemiological studies showing increases in the mortality of residents living within 500m from the port, air quality level thresholds for PM10 and NOx are rarely exceeded in Civitavecchia. This study aims at evaluating the origins and loads of eBC and UFP in the port area, two pollutants with stronger health effects than PM10.

Methodology and Results
At Molo 24, eBC loads, UFP concentrations, wind speed and direction have been measured by means of a Magee AE33 Aethalometer, by a Tropos SMPS, and by a Lufft meteo station, respectively. Polar plots of average eBC and UFP concentrations as a function of wind speed (radial) and direction are presented in Figure 2a and 2b, respectively. The higher the wind speed the longer the distance of the emitters. Fig. 2a indicates the main sources of eBC were placed in the Ro Ro passenger's ferry area and in the nearby road and train junction. Secondary spots, coinciding with carrier's piers and car-cargoes loading areas. Conversely, UFP highest concentrations all originate from the Ro Ro passengers docking piers. Signals from the Cruise piers are low for both variables. Even lower the signals proceeding from the coal power plant (2km at NW). Some increase in eBC only is observed to originate from the town (SE), possibly associated to light traffic.

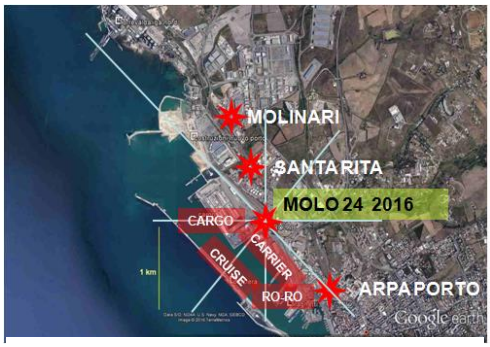

Fig.1 Location of monitoring sites and of docking areas in the port of Civitavecchia

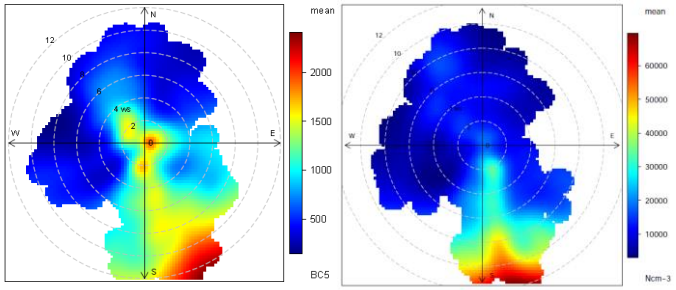

Fig.2 (a) Polar plot of eBC loads(ng/m3), and (b) polar plot of UFP number concentraion (cm-3).

Conclusions
The highest concentrations in eBC and UFP in the port of Civitavecchia during the month of April 2016 have been observed to originate mostly in the Ro Ro ferry piers area. Increases in eBC concentrations were also observed in the carrier's areas and in the vehicular traffic nearby Molo 24, and in the city area near the port. Since the Ro Ro ferry activity is the most regular one in Civitavecchia, actions should be taken to mitigate the impact of such sources on the city and on the port's environments.

Acknowledgement
This work was partly supported by the EU LIFE10 project DIAPASON, and by the CNR AirSeaLab project.

THE IMPACT OF VOLATILE ORGANIC COMPOUNDS ON NEAR SURFACE OZONE FORMATION IN RUSSIAN CITIES

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Summary
Ground-based concentrations of some important anthropogenic (aromatic) and biogenic VOCs (benzene, toluene, isoprene, monoterpenes) together with NO_x, CO and O_3 measured simultaneously along the Trans-Siberian railway (TSR) on a mobile laboratory in TROICA-12 campaign in summer 2008 have been analyzed to determine their contribution to surface ozone formation. The daytime ozone-forming potential (OFP) was calculated to assess relative importance of these species for ground-level ozone formation in cities with different population along the Trans-Siberian railway where concentration of pollutants reaches the highest values. It was shown that CO and biogenic VOCs (isoprene and monoterpenes) had the main contributions to ground-based ozone formation in all cities along the Trans-Siberian railway, regardless their population size. The impact of aromatic VOCs in all cities did not usually exceed 15%.

Introduction
Surface ozone is considered harmful both for the humans and for vegetation. Due to the global warming and urbanization significant positive trends for surface ozone have been found for different regions where main sources of carbon monoxide (CO), methane (CH_4) and volatile organic compounds (VOCs) are concentrated. The oxidation of these compounds, when interacting with hydroxyl and nitrogen oxides at rather high temperature and sunlight, leads to ozone formation. CO and CH_4 are slowly oxidized in the atmosphere and cause an increase in global and regional background ozone. However, the oxidation of some VOCs occurs during daylight hours and is accompanied by an increase in ozone concentration near VOCs sources, particularly in urban and industrial areas. The aim of this work was to assess the impact of biogenic and anthropogenic (aromatic) VOCs on tropospheric ozone formation and to compare it with influence of inorganic substances (like CO) in Russian cities where such data are limited.

Methodology and Results
The results of VOCs measurements (isoprene, benzene, toluene, monoterpenes) by proton mass spectrometry in different regions of Russia along the Trans-Siberian railway from Moscow to Vladivostok from TROICA-12 campaign on a mobile laboratory in summer 2008 are analyzed. Inorganic pollutants like O_3, NO_x, CO were measured in parallel. To evaluate the relative importance of VOCs and CO for ground-level ozone formation in the Russian regions along the Trans-Siberian railway, daytime ozone-forming potential (OFP) was calculated (Carter, 1994). CO and biogenic VOCs (isoprene and monoterpenes) had the main contributions to ground-based ozone formation in most of cities along the Trans-Siberian railway, regardless their population size (see Fig. 1). A very significant contribution to ozone production is made by monoterpenes (up to 30%), especially in the cities located in the areas with significant part of coniferous vegetation: Tumen, Ulan-Ude, Taishet. Isoprene contribution to ozone formation in the observed cities is also very significant, up to 42%, in the cities of the Far East region (Birobidjan, Khabarovsk) where a large part of deciduous forests is located. The impact of aromatic VOCs in the observed cities does not usually exceed 15%, but sometimes (for example, in Birobidjan) reaches 24%. The greatest impact of aromatic VOCs to ozone formation (up to 7.5 ppb of O_3) is obtained in the large cities along the Trans-Siberian Railway, with the highest concentrations of aromatic VOCs (1-1.7 ppb) and nitrogen oxides (> 20 ppb) being observed.

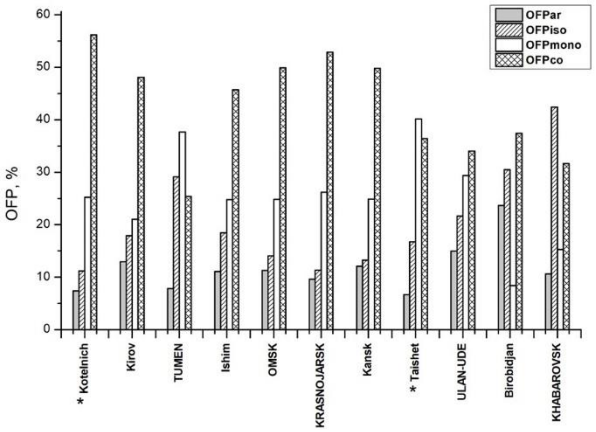

Fig. 1. OFPs of isoprene, aromatic hydrocarbons, monoterpenes and CO in cities along TSR (- towns with less than 50,000 inhabitants)*

Conclusions
It was shown that in all cities along the Trans-Siberian railway, regardless their population, CO and biogenic VOCs (isoprene and monoterpenes) had the main contribution to ground-based ozone formation. This contribution is within 25-56% and up to 30-40% for CO and biogenic VOCs, respectively. The impact of aromatic VOCs in all cities did not usually exceed 15%.

Acknowledgement
This work was supported by Russian Science Foundation (grant N 14-47-00049).

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CAN LOW-COST AIR QUALITY SENSORS HELP TO MONITOR AIR POLLUTION IN CITIES?

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Summary
We tested the performance in the laboratory and in the field of 24 commercial platforms (AQMesh). In carrying out this evaluation, we identified a main technical challenge associated with current commercial low-cost sensors, regarding the sensor robustness and measurement repeatability. Our results show that laboratory calibration is not able to correct for real world conditions and that it is necessary to perform a field calibration for each sensor individually. Despite that, we observed that currently some sensors are already capable of reproducing the NO_2 and PM_{10} variability. The data from the sensors was employed to generate detailed NO_2 and PM_{10} air quality maps using a data fusion technique. This way we were able to offer localized air quality information for the city of Oslo.

Introduction
Air pollution in cities has been shown to pose a risk for the health of city dwellers. For an effective protection of health, air quality information at high spatial and temporal resolution is often valuable as it may provide guidance regarding which pollution reduction or exposure reduction measures may be the most effective. Conventional approaches to air quality monitoring consist of well-maintained sparse and static monitoring stations. They offer high quality data but are too expensive to be deployed in sufficient numbers to capture the spatial heterogeneity of air pollution. Because of their lower price, sensor platforms can be deployed in significantly higher numbers throughout the urban environment.

Methodology and Results
We have conducted an evaluation of low-cost nodes to monitor NO_2 and PM_{10}, comparing the data collected with low-cost nodes against CEN (European Standardization Organization) reference analysers. 24 AQMesh nodes v3.5 were co-located in an air quality monitoring station in Oslo during 3 months from April to June 2015. The results show that even for identical sensors and platform, the performance can vary sensor to sensor. We performed a field calibration to reduce the bias and measurement errors, especially for those sensors that have higher offsets. In our case, after performing a linear regression, the average RMSE of the 24 pods was reduced from from 30 ppb to 9 ppb for NO_2 and from 19 ppb to 13 ppb for PM_{10} (Castell et al., 2017).

During January and March 2016, a network of 24 nodes was deployed in Oslo. During January, high NO_2 levels were observed for several days in a row coinciding with the formation of a thermal inversion. During March, we observed an episode with high PM_{10} levels due to road dust resuspension. Despite low-cost sensors being less accurate than regular air quality monitoring networks the nodes were able to reproduce the NO_2 and PM_{10} variability (Castell et al., 2018). To enhance the data from the sensors, we employed a data fusion technique that allows generating a detailed air quality map merging the data from the sensors and the data from an urban model, thus being able to offer air quality information to any location within Oslo (Schneider et al., 2017).

Conclusions
We have demonstrated that low-cost sensors have a big potential for air quality applications. Currently low-cost sensor nodes tend to suffer from high uncertainties, which makes them unsuitable for regulatory purposes. However, our results indicate that it is possible to extract useful information after post-processing the data. Low-cost sensor nodes and air quality maps at high spatial resolution can provide citizens with localized information at street level, increasing awareness and helping concerned citizens reduce their exposure to pollution.

Acknowledgement
This work has been possible thanks to funding from the projects Citi-Sense-MOB and CITI-SENSE. Citi-Sense-MOB is partly funded by EMMIA: The European Mobile and Mobility Industries Alliance under grant agreement no. SI2.647655. CITI-SENSE has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 308524.The AQMesh nodes for this investigation were provided by Environmental Instruments Ltd., UK (www.aqmesh.com, www.env-inst.com).

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FIRST STAGE OF THE POLLUSCOPE PROJECT:
SELECTION AND ASSESMENT OF PORTABLE AIR QUALITY SENSORS

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Summary
Today, air pollution is monitored using static stations and modelling, which provides valuable information to document air pollutant levels. Nevertheless, there is still a lack of knowledge about personal exposure, especially regarding indoor air quality. Therefore, the ANR-Polluscope project (2016-2020) aims to track air pollution all day long (indoor and outdoor) by equipping volunteers with small air quality sensors in order to monitor the air we actually breathe. Target pollutants are black carbon, particulate matter (PM), NO_x, ozone and VOCs. The first step of the project is to select and assess the sensors to be used, before to launch real measurements campaigns with volunteers. The results of these tests are presented here and include three testing stages. First, static measurements tests were performed to compare small sensors results with reference instruments. Then the sensors were tested into a controlled chamber in order to test their performance when environmental conditions (for instance humidity) vary suddenly. Finally, mobility tests were carried out, people wore the sensors all day long to measure the ability of the micro units to be efficient in real campaign conditions.

Introduction
Air quality is of vital importance, as shown by World Health Organization (WHO, 2016) which attributes 6.5 million deaths to air pollution in 2012. In the Île-de-France region (including Paris), 1.4 million people are for example exposed to NO_2 level above regulation limit in 2016 (Airparif, 2017). This is a serious health issue, and even with a dense static monitoring network and a sophisticated modelling, we still lack measurements of personal exposure, particularly about indoor air pollution. This is why the ANR-Polluscope would like to develop the concept of a participative observatory. The project aims at equipping volunteers with small air quality sensors in order to be able to quantify near real time personal exposure. During measurements campaigns, volunteers will carry the sensors all day long during some weeks in order to better monitor the air we breathe.

Methodology and Results
The selection of sensors is an important step for the project as these sensors need to fulfill several requirements (accuracy, small size, light weight, long battery-life, quick sampling rate, etc). Based on the literature, a preliminary selection of sensors was done and then the selected ones were tested following three different steps. First, the small sensors were compared with reference instruments at a fixed measurement site. Sensors were precisely qualified using the algorithm Sensor Evaluation Toolkit (SET) designed by Fishbain *et al.*, 2017. The main objective was to qualify the accuracy and the reproducibility of the micro units. Then the sensors were placed in a controlled chamber to test their sensitivity to humidity and their response time following quick variations in pollutants concentration. At last, the sensors were tested within mobility conditions, to estimate their ability to be run in real campaign conditions (sensibility to vibrations, quick changes in ambient conditions, etc.). Finally, the three chosen sensors measure respectively black carbon, PM and NO2.

Fia.1 Sensors installation

Conclusions
We developed a tests protocol (based on static and mobile measurements as well as chamber characterization) to assess small sensors to be used in measurements campaigns involving volunteers equipped with the sensors. The outcome of these tests is the selection of three sensors measuring respectively black carbon, particulate matter and NO2 which will be used in the following "real-world" Polluscope campaign in spring 2018.

Acknowledgement
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CO_2 MONITORING WITH LOW-COST SENSORS: PERFORMANCE, CALIBRATION AND CARBOSENSE NETWORK INTEGRATION

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Summary
Low-cost sensor networks are proposed as new concept for complementing existing AQ observations in cities and countries, but the operation poses various challenges. Here, we present findings obtained from extensive CO_2 sensor characterization tests and the operation of the Carbosense network. This includes the precision and accuracy of the LP8 and HPP CO_2 sensors, variability in performance between sensors, long-term sensor behaviour, power consumption and reliability of the data transmission. Furthermore, we present first measurements obtained from the nationwide sensor network and discuss operational aspects such as the assessment and assurance of the long-term data quality.

Introduction
A unique dense CO_2 low power sensor network is being deployed and operated within the Swiss project Carbosense. The network consists of 300 sensor nodes across Switzerland, including 40 nodes in the city of Zurich. The operation of the Carbosense platform requires the development of advanced measurement concepts that optimally balances precision, accuracy and reliability of the measurements and available resources. Measurements of the Carbosense network are being combined with atmospheric transport models. This should improve the quantification of anthopogenic CO_2 emissions and CO_2 fluxes of the biosphere as both categories are highly variable in space and time. A better understanding of CO_2 fluxes also enhances the ability to assess CO_2 reduction measures. Similar concepts could also be applied to other air pollutants.

Methodology
The Carbosense network is formed by (i) 300 nodes of battery-powered CO_2 low-cost diffusive NDIR sensors (SenseAir LP8), (ii) 30 temperature stabilized, mains powered NDIR low-cost instruments with active sampling and reference gas connection (SenseAir HPP (Hummelgard, 2015)), and (iii) high-precision laser spectrometers (Picarro G1301/G2302/G2401, CRDS) as reference instruments. Network deployment started in July 2017. The sensors are mounted at Swisscom radio transmitter locations, at MeteoSwiss meteorological stations, and at lamp or electricity poles within urban areas. Data of the LP8 and HPP sensors is transmitted as 10 minute averages and 1 minute values, respectively, over Swisscom's new Low Power Network (LPN) to a database hosted by Decentlab.
Over 300 LP8 CO_2 sensors have been integrated with a relative humidity and temperature sensor and with LoRaWAN communication (www.lora-alliance.org). All sensors were characterized in climate and pressure chambers with respect to carbon dioxide (350 – 1000 ppm), temperature (-5 to 50 °C) and pressure (770 – 1010 hPa). A calibration model was developed based on Beer-Lambert law, and relating the raw signal of the IR detector to the true CO_2 mixing ratio, determined by CRDS, and referenced to the WMO scale.
The impact of temperature and pressure variations on the IR detector signal is modelled by including polynomial correction terms in the Beer-Lambert equation. Largest IR signal changes are related to temperature variations. Pressure effects are slightly higher than expected for an ideal gas due to factors such as spectral line broadening and sensor design (Gaynullin, 2017). Relative humidity becomes a critical issue above ca. 95%, likely because of local condensation within the non-heated sensor unit.

LP8 sensors at a rack at the air quality monitoring station in Duebendorf (top) and a single LP8 sensor deployed in the city of Zurich (bottom).

Before network deployment and in addition to the chamber measurements, all 300 sensors were placed at an air quality monitoring station next to a Picarro reference instrument for several weeks to several months. Data from these periods were employed for extended calibration, the analysis of data quality in ambient conditions as well as the development of strategies to maintain and improve data quality on the long term.
Two of the more expensive and precise HPP instruments were also characterized with respect to pressure (770 to 1010 hPa) and CO_2 (0 to 1000 ppm) and operated in the field next to a reference instrument for several months. Pressure correction was based on measurements of integrated sensors, and zero drift was measured in the field by supplying to the instrument CO_2 free air for 36 minutes every 37 hours and reference gas of (383.5 ppm CO_2) for 15 minutes every four days. More extensive tests with an additional 20 units are planned during the next month.

Acknowledgement
Carbosense is supported by the Swiss National Science Foundation through Nanotera and the Swiss Data Science Center. Further support is provided by the Eurostars project CO_2.global. We acknowledge collaboration with Swisscom and SenseAir, and support during deployment by MeteoSwiss and the Zürich Environment and Health protection department.

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LASER BASED ALL-IN-ONE ENVIRONMENTAL GAS SENSOR

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Summary

We present an all-in-one environmental gas sensor based on dual-wavelength quantum cascade lasers (QCLs). These specially designed laser devices cover the target frequencies of the most important pollutants and greenhouse gases, and thus allow realizing multi-compound measurement capabilities in compact and cost-effective instruments.

Introduction

Infrared laser absorption spectroscopy is a highly selective and precise method for trace gas monitoring of pollutants and greenhouse gases. In combination with novel dual-wavelength continuous wave (cw) DFB-QCLs this technique offers a unique solution for compact multi-species laser absorption spectrometers for environmental monitoring, industrial applications, and medical breath analysis [1, 2].

Methodology and Results

In this work, three dual-wavelength DFB-QCLs are combined to measure up to nine pollutants and greenhouse gases in the same instrument. An absorption cell of 76 m pathlength is used to achieve high sensitivity and precision. The time division multiplexed laser driving and data acquisition schemes will be discussed in detail. Shortly, the lasers are driven time-multiplexed in intermittent cw mode [3] sharing a single detector and the spectra of each QCL are recorded by an FPGA based data acquisition and pre-processing system with a sampling rate of 125 MS/s and 14-bit resolution. The same FPGA system is used to provide the full control of the spectrometer. The spectra are averaged in real-time by the FPGA and then transferred to a PC for spectral analysis.

First results of measuring the greenhouse gases CO_2, N_2O and CH_4 and the pollutants CO, NO, NO_2, O_3, SO_2 and NH_3 are presented. The instrument performance and comparisons to standard air-quality monitoring instrumentation are discussed.

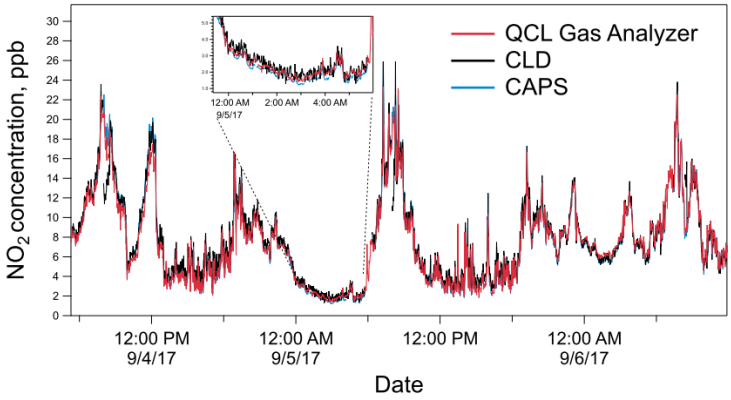

Figure 3: Sample data from QCL gas analyser compared to data from a CLD and a CAPS instrument.

Conclusions

Spectroscopic instruments using dual-wavelength QCLs have great potential to reduce the size and the cost of environmental monitoring stations by replacing several instruments, while delivering direct, selective, and precise measurements of all target molecules.

Acknowledgement

This work was financially supported by Nano-Tera.ch.

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PERFORMANCE TEST RESULTS FOR A COMPACT AIR QUALITY SENSOR

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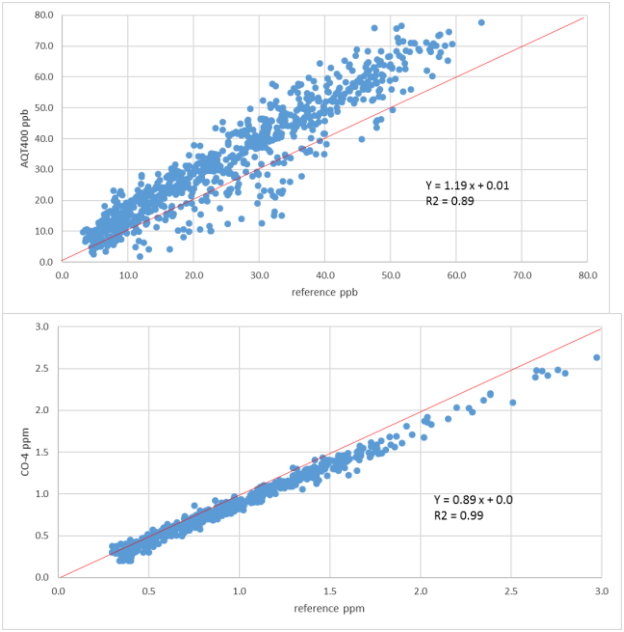
Summary
Performance of industrially manufactured compact air quality sensor is studied in different geographical and climatic regions. Testing results of principal pollution gases (NO_2, SO_2, CO, O_3) and $PM_{2.5}$ and PM_{10} particulates are presented against the reference instruments. Based on measurement results the possibilities and limitations of the compact instrument are discussed.

Introduction
Technologies for compact instruments for monitoring gaseous and particulate air pollution are developing rapidly and gaining increasing attention worldwide. These instruments are finding use in supplementary urban air quality networks, in pollution hot spot monitoring, environmental impact assessment and various research projects where easy deployment of compact instruments opens new possibilities. Also modern high resolution air quality modelling tools take advantage of supplementary air quality measurements.

Methodology and results
We are presenting performance test results for a compact industrially manufactured air quality sensor that measures four principal gaseous pollutants (NO_2, SO_2, CO, O_3) and $PM_{2.5}$ and PM_{10} particulates in a single weather protected enclosure.

Field test results from co-location studies with reference instruments are presented from different geographical and climatic regions. Time series and correlation data are presented and interpreted in relation to environmental conditions and the nature of local pollution environment. Preliminary studies on complementing the PM data from an optical particle counter with information derived from gas concentrations and nature of the test site are reported. Based on the measurement results the possibilities and limitations of the compact instrument are discussed.



NO_2 concentration (ppb) and CO concentration (ppm) correlations against reference analyzer in continental Asia during 5 weeks.

Conclusions
A state-of-the art performance has been demonstrated for an industrially manufactured compact air quality sensor. Based on the co-location studies with reference instruments the correlation coefficient R^2 for gaseous pollutants was found to vary between 0.5 and 0.9 R^2, and between 0.5 and 0.8 for $PM_{2.5}$ and PM_{10} particulates, with ambient conditions and particle size distribution playing an important role in the results obtained.

Acknowledgements
Valuable support and discussions with Jarkko Niemi and Anssi Julkunen from Helsinki Region Environmental Services Authority are gratefully acknowledged.

BIOMASS BURNING IMPACT ON AIR QUALITY IN DIFFERENT SPANISH LOCATIONS USING ACSM

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Introduction and objectives

The presence of ambient aerosols in the atmosphere implies adverse effects on human health and influence on climate. PM_1 concentration and chemical composition may vary widely with location, mainly comprised of secondary inorganic compounds and carbonaceous aerosols, the latter reaching up to 90% of the mass. One of the known sources of carbonaceous aerosols is biomass burning. Aerosol mass spectrometers have been widely used to identify and quantify the contribution of biomass burning to the ambient organic aerosol (OA) concentration: BBOA. The BBOA fingerprint is a mass spectral profile with enhanced signals at *m/z*60 and *m/z*73 from the ions $C_2H_4O_2^+$ and $C_3H_5O_2^+$ (Alfarra et al, 2007), arising from species resulting from the pyrolysis of cellulose, such as levoglucosan, mannosan, or galactosan. The present work identifies and quantifies the contribution of BBOA to ambient OA and characterizes the BBOA fingerprint at different urban and non-urban locations in Spain by using an Aerosol Chemical Speciation Monitory (ACSM, Aerodyne Research Inc.).

Methodology

Five sampling campaigns were carried out using an ACSM at different sites: two non-urban locations, Montseny regional background site (Minguillón et al, 2015) and Montsec continental background site (Ripoll et al, 2015), both located in northeast Spain; two urban locations in big cities, Barcelona in northeast Spain, and Granada in south Spain; and one small city in northeast Spain, Manlleu, highly influenced by biomass burning. The organic mass spectral data matrix from the ACSM was used to carry out the source apportionment of OA applying Positive Matrix Factorization (PMF) using the Multilinear Engine (ME-2) with the toolkit SoFi (Canonaco et al, 2013).

Results and Discussion

All five BBOA mass spectral profiles shared the aforementioned tracers at *m/z* 60 and *m/z* 73, whereas the degree of oxidation, traced by the intensity of the *m/z* 44 peak (from the CO_2), was different among sites. See example of the BBOA mass spectral profiles found at Granada, Montseny and Montsec (Fig. 1) and the relative source contribution to ambient OA during winter periods. While Montseny BBOA profile correspond to an intense wild fire episode, and was separated from the oxidized ambient OA present during that episode, the Granada BBOA includes a non-negligible portion of oxidized material, as shown by the relatively high intensity of *m/z* 44 signal, and the Montsec profile shows an intermediate oxidation degree. Relative contribution of BBOA to total OA during winter periods was between 14% (in Barcelona) and as high as 40% (in Manlleu).

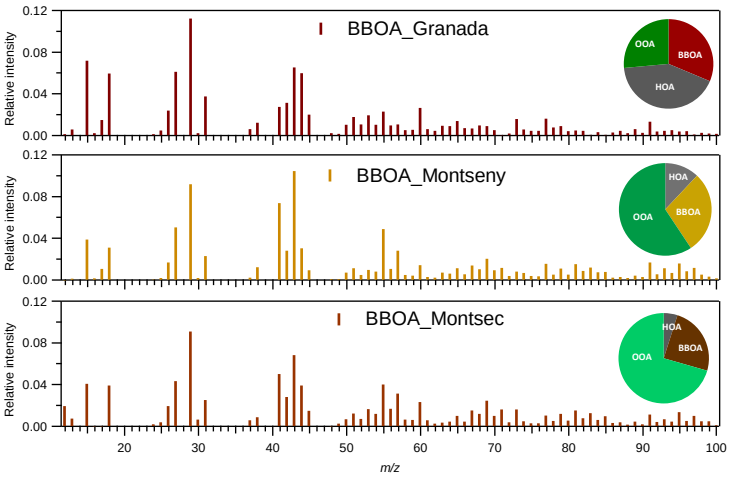

Fig.1 BBOA mass spectral profiles and relative contribution of HOA, BBOA and OOA to total OA in winter periods at Granada, Montseny and Montsec.

Acknowledgement

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POLLUTION SOURCES AND ATMOSPHERIC PROCESSES IN IN BACKGROUND MILAN BY 1-HOUR TIME RESOLUTION DATA OF PM2.5 COMPOSITION AND GASEOUS PRECURSORS

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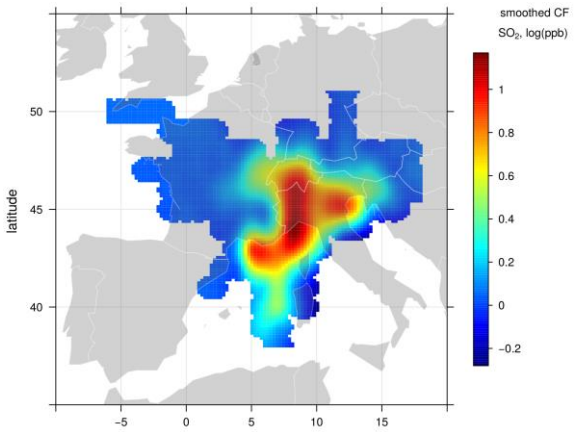
Summary
During summer 2012, composition of $PM_{2.5}$ and of its gaseous precursors has been sampled at 1-hour resolution in central background Milan, to investigate the processes leading to atmospheric pollutants formation and ageing. Results show the dominance of HONO formation at nighttime, the role of main two main pathways for nitrate formation occurring at nighttime and daytime, and the contribution of long distance sources to local sulphate and sulphur dioxide. A distinctive pattern for HCl was observed, although no source was possible to explain this Finally Equivalent Black Carbon, Elemental Carbon and Organic Carbon have been compared and a mass absorption coefficient has been estimated.

Introduction
Time resolved composition of both gas and particle phase atmospheric compounds are needed to understand and prevent atmospheric pollutants formation and ageing in densely populated areas with large emission load (i.e. hotspots). Po valley is one of the most important hotspot regions in Europe, with Milan metropolitan area exhibiting one of the poorest air qualities within the valley. This study aims to investigate the processes leading to atmospheric pollutants formation and ageing in Milan, by 1-hour time resolution characterization of atmospheric pollutants in both gas and particle phase.

Methodology and Results
Hourly data of main $PM_{2.5}$ inorganic ions and gases have been collected by the means of an Ambient Ion Monitor (AIM) URG-9000D (URG Corp, USA), including Cl^-, NO_2^-, NO_3^-, $SO4^{2-}$, K^+, Mg^{2+}, Ca^{2+}, Na^+, NH_4^+, and HCl, HNO_2, HNO_3, NH_3, NO, NO_2, O_3, SO_2 for ions and gases respectively. Further 1-hour time resolution data include: OC, EC and BC along with air quality reference measurements and meteorological parameters. The data proceed from an intensive sampling campaign in urban background Milan in summer 2012 (Bigi et al., 2017). The dataset was analysed by investigating mean diurnal pattern on weekdays and Sundays, pollution roses, bivariate polar plots and statistical models using backtrajectories. Nitrous acid (HONO) was shown to form heterogeneously at nighttime, with a formation rate dependent on NO2: formation rate and absolute concentration of HONO are consistent with previous observations of HONO in Milan (summer 1998) and with the drop in NO2 in Milan since 1998. Nitrate showed two main formation mechanisms: one occurring at nighttime involving N_2O_5 and leading to nitrate formation onto existing particles; another pathway consisting in the homogeneous reaction of ammonia gas with nitric acid gas occurred both daytime and nighttime. Moreover nitration formation was influenced by the ammonia content and the timing of air masses arriving in Milan. Low SO_2 concentration occurred throughout the campaign, with few occasional peaks associated to point source emissions in the Po valley or to shipping and power plant emissions SW of Milan, beyond the Apennines. A distinctive pattern for HCl was observed, featured by a morning minimum and an afternoon peak, and best correlated to atmospheric temperature, although it was not possible to identify any specific source for this species. The ratio of primary-dominated organic carbon and elemental carbon on hourly $PM_{2.5}$ resulted 1.7. Black carbon was highly correlated to elemental carbon and the average mass absorption coefficient resulted MAC= 13.8 ± 0.2 m^2 g^{-1}.



Conclusions
Combined and time-resolved measurement of $PM_{2.5}$ and of its gaseous precursors and allows to identify pollution sources and processes, providing a major insight on air quality to scientists and policymakers. It is noteworthy how air quality for a large metropolitan area, in a confined valley and under enduring atmospheric stability, is nonetheless influenced by sources within and outside the valley.

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ESTIMATE OF NITROUS ACID EMISSIONS FROM TRAFFIC IN A UK ROAD TUNNEL

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Summary
Measurements of nitrous acid (HONO) and nitrogen oxides (NOx) were performed over the summer 2016 in a city centre road tunnel in Birmingham, UK. HONO and NOx concentrations were strongly correlated with traffic density, with peak levels observed during evening rush hour as a result of traffic congestion in the tunnel. Data during this rush hour period were analysed to determine the emission ratio of HONO/NOx from vehicle exhausts. The analysis showed that even with a high percentage of diesel vehicles within the fleet (~60%) for this study, the emission ratio was at the lower end of the range reported by other studies. This result suggests that in order to accurately represent the OH radical budget, fleet-weighted HONO/NOx ratios may better quantify HONO vehicle emissions in models.

Introduction
Vehicular exhaust emissions are an important source of HONO in urban areas where traffic density is high. This is important because HONO can photolyse rapidly to form OH radicals, which oxidise VOCs, resulting in ozone production in the presence of NOx. The HONO/NOx emission ratio is often used to infer the HONO contribution from vehicles. Various studies have determined this ratio either directly via dynamometer tests on individual vehicles or from ambient roadside/tunnel measurements. These studies show the HONO/NOx ratio is highly variable, ranging between 0.03 and 2.1 %, with a ratio of 0.8% (Kurtenbach et al. 2001) widely adopted in modelling studies. Recently, Trinh et al. (2017) recorded higher HONO/NOx ratios from diesel vehicles compared to petrol, under most driving conditions. In our study we used measurements taken inside a road tunnel to estimate the HONO/NOx ratio for the contemporary UK fleet where the percentage of diesel vehicles is ~60%.

Methodology and Results

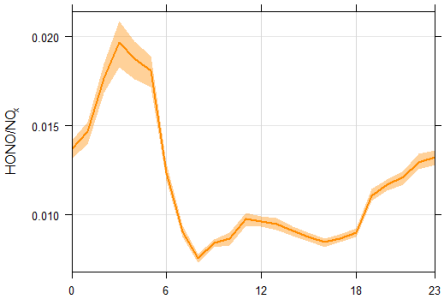

Fig 1. Diurnal variability of HONO/NO_x measured in a roadway tunnel

During July/August 2016, a broadband cavity enhanced absorption spectroscopy system (BBCEAS) was deployed in the southbound bore of the A38(M) Queensway Tunnel, Birmingham to perform high temporal resolution measurements (20s) of HONO and NO_2.Commercial monitors also measured NO, NO_y, and CO_2. Traffic information was obtained from roadside cameras at the entrance to the tunnel. Approximately 32,000 vehicles travel through the southbound tunnel each day.

Measured ratios of HONO/NOx demonstrated a strong diurnal cycle (Fig.1) with the highest ratios occurring during the night and a minimum in the mid-morning. The high night-time HONO/NOx ratios were likely to be the result of heterogeneous conversion of NO_2 to HONO on the tunnel walls in addition to a small amount of background ambient HONO and vehicle emissions. To estimate direct exhaust emission ratios, we focused on rush hour periods when traffic density was at its highest. Peak HONO and NOx levels measured in the tunnel coincided with evening rush hour (4-7pm) when traffic was moving slowly through the tunnel. Traffic information indicates that the fleet was dominated by cars, over half of which had diesel engines. The average HONO/NOx emission ratio during the evening rush hour period was calculated to be 0.61%.

Conclusions
This study investigated HONO emissions using measurements obtained in a roadway tunnel in Birmingham, UK. HONO levels correlated well with vehicle density, indicating that vehicle exhausts were the major source of HONO in the tunnel. Diesel vehicles comprised the majority of vehicles using the Queensway Tunnel, yet the calculated HONO/NOx ratio during rush hour was lower than the emission ratio of 0.8% (based on a fleet comprising 75% gasoline cars), widely used in models. The observed lower ratio may be the result of new technologies aimed at reducing emissions, particularly for diesel vehicles.

Acknowledgements
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CHARACTERIZING AIR QUALITY IN DIFFERENT URBAN SITES: TUNNEL AND SCHOOL

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Summary
A survey of measurements has being performed to characterize air pollutants in different urban scenarios: a tunnel crossing a highway with dense traffic flow and a school at 500 m far from it, both in the city, for more than two years. The aim of the study has been the assessment of the variability of air pollutants as a function of the season, daily time-frame and working periods in the two sites, being these patterns closely related to human habits, e.g., vehicle and heating systems use. In this work we present the huge deployment of conventional means utilized and also two systems developed at CEAM that integrate small low-cost sensors. Its use as a monitoring tool in air quality characterization is given. Nitrogen oxides (NOx), ozone (O_3), ammonia (NH_3), sulphuric dioxide (SO_2) and a number of volatile organic compounds (VOCs) have been measured in this study, from which a discussion on the variability observed and implications on the air quality is given.

Introduction
The World Health Organization (WHO, 2016) has identified air pollution as the greatest environmental risk to human health. Despite efforts to reduce it, it is still a challenge, especially in urban areas, where most of the population live and where it presents a high spatial and temporal variability. Hence, the availability of trend profiles and data on air quality related pollutants in cities is mandatory for elaborating legislation aimed at improving air quality and therefore human health.
With this aim and within this context, small sensor technology has suffered a huge development recently, becoming a suitable candidate for air quality measurements. Certainly, their small size and price allow them to be used as a network of sensors capable of providing high temporal and spatial frequency measurements. Therefore, they are suitable to characterize an area or city and they have, under certain considerations, an increasing potential as a complement of conventional methods. The work presented here, comprising long-term measurements and intensive campaigns represent an interesting set of data showing differences in the characterization of the air quality in the two scenarios selected.

Methodology and Results
Different methods have been combined in both sites: a) monitors, b) cartridges with active sampling, both used during five two-week active campaigns; c) passive dosimetry, used in the extensive measurements and d) small sensors used during the last year of measurements and coinciding with the last intensive campaigns.
Results have allowed to characterize air quality as a function of summer and wintertime, observing variability in the daily profiles and in the working days and weekends. Trend series obtained with passive dosimeters show NO_2 values in the tunnel that double those in the school, with maximum concentrations of 122.8 µg/m3. Regarding working days and weekend patterns, monitoring data and small-sensors show negligible differences between summer and wintertime and average values of 60.3 µg/m3 in working days and 37.8 ug/m3 during weekends. Trend profiles obtained with monitors have been also followed by the sensors, with good correlations (R2=0.82). In the school, the lower traffic effect and the use of heating systems result in higher NO_2 average concentrations in the winter than in the summer, varying between 55.0 and 20.5 µg/m3. Besides, VOC differences have been also found between both sites. For instance, daily average of formaldehyde, known to be one of the main secondary products of many VOC reactions, was found to be 11.4 µg/m3 and 6.5 µg/m3 in the tunnel and in the city in the winter, respectively.
An interesting outcome of this study was the coincidence of the measurement period with the maintenance works to reopen an oil station, which clearly affected the air quality for two months. Anomalous concentrations of different pollutants were found, e.g. propylbenzene: 524.2 µg/m3; 135-trimethylbenzene: 134.1 µg/m3; formaldehyde: 92.2 µg/m3.

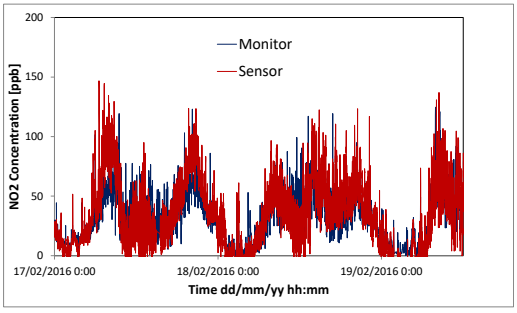

Fig.1 NO_2 measured with monitor and sensors

Conclusions
A discussion on the trend patterns and results obtained is given. Clearly, pollutant concentrations in the tunnel have been found to be dominated by heavy traffic, while the urban site is affected by both traffic and by the use of heating systems. The huge number of pollutants studied by combining long-term measurements and intensive campaigns, has allowed to draw conclusions on their variability. Together with the deployment of conventional measurement methods, small sensors have been run and results show that they are good candidates to be utilized in air quality characterization aimed at decision-making related to decontamination (traffic regulation, etc.), at awareness or for citizens information purposes.

Acknowledgement
This work was supported by PHOTOCITYTEX - LIFE13 ENV/ES/000603 and by the Horizon 2020 programme through the EUROCHAMP-2020 Infrast. Activ., No 730997. We acknowledge M. Salazar and J. Carreño for their help during sampling.

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SPATIAL AND TEMPORAL VARIABILITY OF ULTRA-FINE PARTICLES TRANSVERSE TO A MAIN ROAD IN BERLIN, GERMANY

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Summary
This study analyses spatial and temporal variability of ultra-fine particles (UFP) transverse to a main road on two transects in the city of Berlin. Total particle number concentration (PNC) as well as the percentage of local sources were analysed in relation to the distance to the road, wind speed and wind direction. Results show a rapid decrease of PNC with increasing distance from the road. Traffic density has a substantial impact on concentration levels as well as temporal variations. A large percentage of the PNC at the roadside can be attributed to traffic.

Introduction
The impact of particulate matter on human morbidity and mortality has been well documented (e.g. Atkinson et al. 2015), especially the impact of traffic-induced particles (Khreis et al. 2016). Due to their small size, UFP can be especially harmful because of high lung deposition efficiency and the ability to enter the blood stream directly (Hertel et al. 2010). Unfortunately, UFP is also highly spatially and temporally variable. While studies show the spatial distribution of UFP near highways (He and Dhaniyala 2012), at intersections (Goel and Kumar 2016) or in street canyons (Kumar et al. 2008; Weber et al. 2013), little is known about the distribution transverse to main roads into less frequented side streets in cities.

Methodology and Results
During a six-week campaign, PNC of UFP, wind speed and wind direction were measured to analyse the spatial variability of air quality with increasing distance to the road. The campaign was carried out on two transects perpendicular to a six-lane road with east-west orientation in the centre of Berlin. Observations took place at nine locations along the transect to the North and six locations along the transect to the South on 18 days with 76 runs per transect. Traffic counts at the main road, single vehicles on the transects as well as traffic light phases were recorded. Reference instruments on the central strip and on the second floor of a near-by building allowed in-depth analysis of temporal variations of PNC.
Percentage of near-traffic concentrations of UFP was calculated by dividing the measured PNC by the difference between the measured and the lowest PNC per run. PN at the measurement points was normalized by subtracting the median of the PNC per run at the roadside from the PNC at the measurement point to compare concentration patterns in the transects.
Our study shows that total PNC of UFP as well as its spread along the side streets rapidly decrease with growing distance to the main road. Weekend days in contrast to working days are characterized by lower differences in PNC between main road and within the side streets. Traffic volume has a substantial impact on concentration levels as well as temporal variations. Local sources contribute up to three quarters of the measured UFP at the roadside. High PNC along the transects are only found with wind coming from the direction of the main road.

Conclusions
This study shows spatial and temporal variability of UFP transverse to a main road in the city centre. The impact of traffic volume as a source and wind for dispersion was shown and will allow for the calculation of different scenarios regarding traffic management and measures that affect ventilation of built-up areas. The results of this study can contribute to developing a statistical dispersion model.

Acknowledgement
This work is funded by the Federal Ministry of Germany (BMBF) under its project Urban Climate under Change (UC^2) within sub-project URBMOBI-GIS, grant No. 01LP1602B. We thank all the project partners within (UC^2) for their support.

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Health Integrated Assessment for Air Quality Policy Support

HIGH RESOLUTION MODELLING AND INTEGRATED HEALTH IMPACT ASSESSMENT OF AIR POLLUTION – THE NORDICWELFAIR PROJECT

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Summary
Air pollution has serious impacts on human health, wellbeing and welfare (e.g. Landrigan et al. 2017). Understanding how air pollution can be regulated optimally is necessary on global, regional and local scales. Linking detailed information of the spatio-temporal distribution of air pollution and the chemical composition of the atmospheric particles with register data for mortality and morbidity in the Nordic countries, the goal of NordicWelfAir is to gain new understanding of the health impacts from different kinds of air pollution, from different sources. This will provide the basic understanding needed for strategies to reduce air pollution and to assess impacts on health and the distribution of related societal costs and welfare.

Introduction
The overall aim of NordicWelfAir is: 1) to further understand the link between air pollution levels, the chemical composition of the pollution and the associated health effects, and 2) to investigate and assess the effects of air pollution on the distribution of associated health impacts, socio-economics and welfare in the Nordic countries. The research collaboration is running for a period of five years (2015-2020) and has 16 partners from five Nordic countries.

Methodology and Results
Main methods include: 1) High spatial resolution emissions, where a detailed common Nordic emission inventory down to 1 km x 1 km resolution is constructed. 2) Integrated modelling, where a state-of-the-art advanced and integrated air pollution model system from hemispheric scale, European scale, and national scale is used for calculation of high resolution (down to 1 km x 1 km resolution) air pollution levels and human exposure over a long period (1990-2016). 3) Health effects of air pollution, where the potential causal impacts of individual chemical air pollutants as well as mixtures of air pollutants on health outcomes are investigated. 4) An assessment and quantification of the overall negative health outcomes of air pollution in terms of premature deaths, hospital admissions, days of reduced activity, respiratory diseases, mental disorders, etc. on high resolution down to 1 km x 1 km in the Nordic countries for the different population groups, using the integrated model system EVA (Brandt et al., 2013). 5) Distribution of welfare and challenges for the Nordic welfare systems, where an assessment and quantification of socio-economic impacts from air pollution and effects on distribution of welfare in the Nordic countries is carried out.

Conclusions
First results from the NordicWelfAir project including the emission inventories and first multi decade air pollution model runs for the period 1990-2016 and assessment of health impacts are presented. Even though the population exposure are mostly below the WHO guideline for the annual $PM_{2.5}$ level, the health impacts from air pollution in the Nordic countries are considerably.

Acknowledgement
NordForsk under the Nordic Programme on Health and Welfare Project #75007: Understanding the link between air pollution and distribution of related health impacts and welfare in the Nordic countries (NordicWelfAir). http://NordicWelfAir.au.dk

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ENVIRONMENTAL AND HEALTH IMPACTS FROM SHIPPING EMISSIONS: QUANTIFYING BENEFITS FROM A POTENTIAL EMISSION CONTROL AREA (ECA) IN THE MARMARA SEA (TURKEY)

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Summary

Ship emissions degrade air quality and affect human health (Corbett et al., 2007; EEA, 2013). This study aims to quantify the environmental and health benefits which would be obtained from mitigating shipping emissions. To this end, a case study in the Eastern Mediterranean basin (the Marmara Sea and the Istanbul Strait, in Turkey) was selected. Dispersion modelling was combined with health impact assessment to quantify the environmental and health benefits which would derive from the implementation of a sulphur emission control area (ECA) in the Marmara Sea. Results evidence a 10% reduction in mortality due to exposure to SO_2, and reductions in hospital admissions for respiratory diseases of 2% and 14% due to exposure to $PM_{2.5}$ and SO_2, respectively. We conclude that the implementation of an ECA in this region would be a positive, technically viable and real-world measure to reduce air pollution from ships in Turkey.

Introduction

Because maritime traffic is increasing due to the globalisation of manufacturing processes, the best strategies to reduce impacts from shipping emissions are technological. These include the use of low sulphur-content fuels (e.g., EU Directive 2005/33/EC), the introduction of shore side electricity (e.g., in Sweden, The Netherlands or Germany), or the designation of emission control areas (ECAs). Sulphur ECAs, specific coastal regions where only low-sulphur fuels may be consumed by ocean-going ships, have proven to be useful tools to reduce ship-sourced air pollution along the North American, Canadian and European North and Baltic Sea coastlines. The present work assesses the environmental and health benefits which would derive from designating an ECA in the Marmara Sea and the Turkish Straits (50,000 ships/year; 23 million inhabitants).

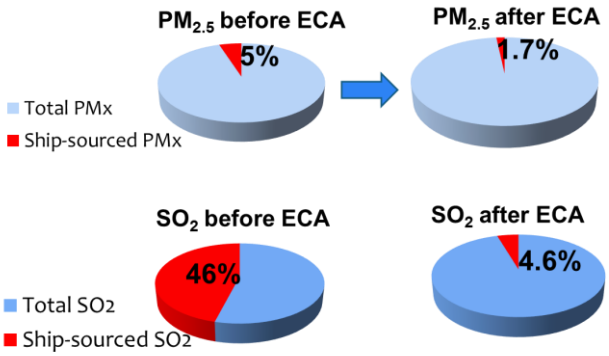

Fig.1 Ship-sourced vs. total $PM_{2.5}$ and SO_2 concentrations before and after the potential ECA implementation.

Methodology and Results

The methodology used followed a linked approach where: (1) dispersion modelling was performed with CALPUFF to quantify the shipping contributions to air pollution; (2) modelled concentrations were incorporated into a health impact analysis to quantify the health burden due to shipping emissions. Human health impacts were quantified by the environmental Benefits Mapping and Analysis Program (BenMAP-CE) developed by the US-EPA (www.epa.gov/air/benmap/). BenMAP is a free and open source software tool that uses a Geographic Information System (GIS) to estimate the health impacts and economic benefits occurring when populations experience changes in air quality. The majority of the population (14 million inhabitants) is concentrated in Istanbul city. Results showed that, in Istanbul, shipping emissions contributed with 2.5 $\mu g/m^3$ to PM_{10} (primary + secondary, 4% of annual PM_{10} mass), 1.9 $\mu g/m^3$ of $PM_{2.5}$ (primary + secondary, 5% of annual $PM_{2.5}$ mass) and 3.2 $\mu g/m^3$ of SO_2 (46% of annual SO_2; Figure 1). Our analysis evidenced that implementing an ECA would be technically viable and that it would reduce the ship-sourced component of PM_{10} and $PM_{2.5}$ in Istanbul (as ambient concentrations) by 67%, and SO_2 by 90%. The subsequent reduction of the air pollution burden on health was quantified as 210 hospital admissions from exposure to PM_{10}, 290 hospital admissions from exposure to SO_2, and up to 30 premature deaths annually due to ECA emission controls.

Conclusions

The designation of an ECA in the Marmara Sea and the Turkish Straits is evaluated as a positive and real-world measure to reduce air pollution from ships in Turkey. We conclude that this kind of assessment would be necessary for other regions around the globe to minimise the burden on health and the environment of maritime transport emissions.

Acknowledgement

This work was supported by Twinning Project Nr. TR/10/IB/TR/01 “Control of Ship Emissions in Turkey” and the Spanish MAGRAMA (UCA2009020083).

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DAMAGE COST MODEL FOR AIR POLLUTION IN FINLAND

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Summary

This study reports an estimate for external health damage costs per unit of air pollution emission reduction from key sources in Finland. The predicted damage costs are highly dependent on the assumed values of statistical life years or lives, as the cost of premature mortality tends to dominate the total costs. Particulate emissions from urban sources were generally found to be an order of magnitude more costly than those from non-urban sources. Total health costs caused by the studied Finnish air pollution emissions in 2015 were over 600M€ annually, of which two-thirds were from urban machinery, traffic and residential wood combustion.

Introduction

The health impacts of air pollution are highly dependent on the location of the emission sources. Finland is an atypical European country in the sense that it has a very low population density (16/km^2). In this study, we give an estimated range of health damage costs per unit change of pollutants from different emission sources in Finland. Knowledge of these external costs is essential in designing the most cost-efficient air quality policies.

Methodology and Results

To estimate the air quality impact of a change in current emissions, a spatially distributed emission inventory was created for 2015, using Finnish Regional Emission Scenarios (FRES) model (Karvosenoja 2008). The dispersion of primary particles was calculated using source-receptor matrices at a resolution of 250m x 250m, based on the Gaussian multiple source model UDM-FMI (e.g., Karvosenoja et al. 2011). The formation and dispersion of secondary particles was assessed using the chemical transport model SILAM. The resulting changes in PM2.5 concentrations were then combined with spatial population data to estimate the health effects. We only included costs related to human health, since they usually dominate the total costs. Table 1 shows a mid-range estimate for damage costs per source, using a value of statistical life (VOLY) of 57 700€. In general, the predicted damage costs are largely determined by the assumed VOLY's. By selecting a widely used value in Europe, we can compare the results with previous studies. As expected, the emissions of primary particles from low altitude sources in urban areas had the highest costs per emission ton. Construction machinery and traffic in cities had the highest unit cost values. Big reductions of secondary PM precursors don't have a linear effect on concentrations, but most of the costs come from primary particle emissions. In total, annual air pollution emissions from the studied sources in Finland caused external costs of approx. 620M€. Majority of the costs, over 400M€, were caused by emissions from urban sources.

Table 1 Health damage costs for selected emission source categories of PM2.5 in Finland in 2015, €/ton of emission. Separation between urban and non-urban emissions was made for PPM2.5 only.

	Urban	Non-urban
Road transport, primary PM2.5	120 000	11 000
Machinery, primary PM2.5	150 000	4 200
Residential wood combustion, primary PM2.5	58 000	7 300
Wood combustion in recreational houses, primary PM	-	4 600
Road transport, NOx to secondary PM2.5	710	
Agriculture, NH3 to secondary PM2.5	1000	
Power plants and industry, primary PM2.5	7300	
Power plants and industry, NOx to secondary PM2.5	340	
Power plants and industry, SO2 to secondary PM2.5	1000	

Conclusions

Construction machinery, vehicular traffic and residential wood combustion in urban areas are the most harmful sources of air pollution in Finland, as measured in euros per unit mass of emission. A conclusion of this study is therefore that it would be especially effective to mitigate the emissions from these sources. Measures that control numerous small sources tend to be relatively costly, but the price may be justified, given the high external costs that the emissions cause to the society.

Acknowledgement

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HEALTH BENEFITS OF IMPLEMENTING EXHAUST-FREE TRANSPORTS IN MALMÖ MUNICIPALITY, SOUTHERN SWEDEN

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Summary: Air pollution, responsible for 1 in 8 premature deaths worldwide, is the major environmental threat to human health. Quantitative health impact assessments of hypothetic changes in air pollution can be a support for governments when they design policies to reduce health effects of air pollution. This study estimates health impacts attributable to a hypothetical decrease in $PM_{2.5}$ and NO_2 exposure in Malmö Municipality in Southern Sweden, for the year 2016, corresponding to transports free of exhausts in the municipality.

Methodology: Health Impact Assessments were calculated with the following formula:

$$\Delta Y = Y_0 \cdot (1 - e^{-\beta \cdot x})$$

Where **ΔY** is the change in the number of health outcomes, Yo is the baseline number of outcomes, **(ß)** are the risk estimates from the epidemiology literature, and **(*x*)** is the hypothetical air quality change. We used air pollution data and hypothetical air quality change modelled by a Gaussian dispersion model (AERMOD) combined with an emission database with more than 40 000 sources.

Results: The average reduction was 5.1µg/m^3 NO_2, which would prevent 93 premature deaths annually, 21 new cases of incident asthma in children between 5 and 14 years, 95 less children with bronchitis every year and 30 hospital admissions for respiratory disease. Our calculations show that the reduction in NO_2 would also prevent 87 dementia cases, and 11 cases of preeclampsia every year, even though these calculations are more uncertain. The cost attributed to 93 premature deaths is 236 million euro per year.

Conclusions: The assessment is sensitive to uncertainties in the relative risk estimates and to exposure misclassification errors. For example, the alternative calculation of mortality based on another dose-response estimate resulted in 64 prevented deaths annually. The reduction in mortality due to the air quality improvements accounts for about 2.6- 3.8% (depending on what dose-response estimate was used) of total natural cause mortality in the Malmö municipality, which is 16 times larger than the annual traffic fatalities in Malmö.

Funders: This study is funded by Swedish Environmental Protection Agency and Swedish Research Council, FORMAS. It is part of the project ARIEL Air Pollution Research in Local Environmental Planning.

Health Impacts from Air Pollution Exposure

SIXTEEN POLYCYCLIC AROMATIC HYDROCARBONS. DO THEY REPRESENT PAH AIR TOXICITY?

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Summary
In the present study 88 polycyclic aromatic hydrocarbons (PAHs) in both gas and particle phases were analyzed for 13 different projects. PAHs were collected from different sources (biomass burning, mining operation, urban emissions including vehicle exhausts) and quantitatively analyzed using gas chromatography mass spectrometry (GS-MS). PAH concentrations were converted to benzo(a)pyrene-equivalent (BaPeq) toxicity using the toxic equivalency factor (TEF) approach. TEFs of PAH compounds for which such data is not available were estimated using TEFs of the close isomers. Estimation of carcinogenic potency based on analysis of 16 PAHs prioritized by U.S. Environmental Protection Agency (EPA) has been the most popular approach within an air quality community. Our results showed that analysis of only 16 PAHs significantly underrepresents the carcinogenic potency of collected air samples.

Introduction
PAHs are of major concern in all environmental compartments due to their mutagenic and carcinogenic properties. The most common carcinogenic effect of PAHs on human cells is DNA damage through the formation of adducts in a number of organs, including liver, kidney, lungs (Farmer, 2003; Poirier, 2016). For this reason, the role of atmospheric PAHs in carcinogenic potency of atmospheric emissions has to be carefully estimated. PAHs are mainly formed during natural and anthropogenic combustion processes of fuels like wood, coal, peat, oil, fossil fuels, waste, crop/agricultural waste, animal dung, etc. (IARC, 2010). In the present study, concentrations of 88 gas- and particle phase PAHs measured during various ambient (mostly urban locations) and source studies (including vehicular, biomass burning, etc. emissions) were used to estimate relative carcinogenic risks of gaseous and particulate PAHs based on their toxicity equivalency factors.

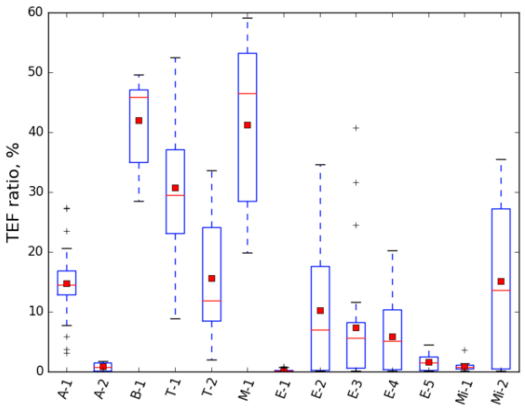

Fig. 4.BaPeq ratios of 16 EPA particle phase PAHs to 88 PAHs for both gas and particle phases

Methodology and Results
Gas and particle phase PAHs were measured during 13 projects focused on analysis of: urban ambient air (A-1, A-2), biomass burning (B-1), meat cooking (M-1), engine exhaust (E1-E5), traffic emissions in a road tunnel (T-1, T-2), and mining operations (Mi-1, Mi-2). Total, 325 filter and XAD samples (650 individual samples) were collected, extracted, and analyzed. Detailed descriptions of sampling and GC-MS analysis can be found in previously published paper (Samburova et al., 2016). The concentration of each individual PAH compound was multiplied by the determined TEF value (Nisbet and LaGoy, 1992) and BaPeq toxicity values were calculated.
BaPeq values for all 88 PAHs were compared with those calculated for 16 EPA priority particle phase PAHs and we found that 16 particle-bond EPA PAHs responsible only 14.4% on average for all projects ranging between 0.2 – 41.9% (Fig. 1) and health risk of analyzed samples is most likely significantly underestimated.

Conclusions
Our results showed that PAH compounds, which are not included in the list of 16 EPA PAHs, are very abundant in analyzed samples. Analysis of BaPeq values for 88 gas and particle phase individual PAHs showed that contribution of non-EPA PAHs such as 1- and 2-methylnaphthlalenes, benzo(e)pyrene, dibenzo(a,i)pyre dibenzo(a,h)pyrene, is substantial to carcinogenic potency of analyzed air samples.
The results of this research stress the need for data on TEF values for additional PAHs and incorporation of these compounds into the health risk assessment. Measurements of gas phase PAHs are also recommended because of the strong contribution of the gas phase to the total BaPeq toxicity of atmospheric PAHs.

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OZONE AND VEHICLE EXHAUST PM EXPOSURE AND ITS ASSOCIATION WITH ADVERSE PREGNANCY OUTCOMES

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Summary

We have made dispersion model calculations of mean exposure to vehicle exhaust particulate matter (PM) and O_3 of 147 089 pregnant women giving birth in the metropolitan area of greater Stockholm between 2003 and 2013 in order to analyse the impact of the exposure on preterm delivery (PD) and small for gestational age (SGA). The first, second and third trimester mean exposure was calculated separately for each woman. High O_3 exposure was associated with lower SGA and higher risk of PD, but neither was significant when fully adjusted for confounders. Preliminary, we have found that exhaust-PM exposure is negatively associated with risk of PD (also in a fully adjusted model), but increased the risk of SGA, however not significantly in a fully adjusted model. These results need to be verified.

Introduction

Higher levels of traffic air pollution and ozone during pregnancy have been linked with both preterm delivery (PD) and intrauterine growth restriction (estimated by low birth weight and small for gestational age, SGA). Exposure data are often based on stationary air pollution monitors, which may not provide optimal resolution when attributed to individual exposures. Some previous studies have based their traffic air pollution exposure assessment on monitoring stations located within 2 or 4 miles of the study objects, or have used satellite images to estimate air pollution levels with rather coarse resolution (10x10 km squares). Here we have modelled both PM and O_3 exposure of 147 089 pregnant women (247 579 births) at 100 by 100 meter resolution. We also present a new methodology to obtain spatially resolved hourly ozone concentrations without using a detailed photochemical model.

Methodology and Results

A detailed emission database was used to calculate hourly concentrations of PM-exhaust and NO_x in greater Stockholm with a methodology described previously by Segersson et al. (2017). Register data from the Swedish Medical Birth Register on all children born in the Greater Stockholm area, conceived between August 2003 and February 2013, was included in the study population. Trimester mean exposure was then obtained based on their home addresses. Spatial variations of trimester mean ozone concentrations were calculated by converting the calculated NO_x concentrations (NO_x) to ozone (O_3) using the measured NO_x at a central urban background site (NO_x(UB)) in Stockholm and the difference between ozone at the urban background site (O_3(UB) and at a rural background site, O_3(RB) according to the following relation:

$$O3 = O3(UB) - [NOx - NOx(UB)] \left[\frac{O3(RB) - O3(UB)}{NOx(UB)}\right]$$

Log-binomial regression using the general additive model-function in mgcv package in R was used to estimate potential associations between the exposure variables and SGA and PD. Potential confounders included were maternal and paternal level of education, family income, family situation, parity, maternal smoking habits and body mass index (BMI) at first antenatal visit, maternal region of origin, maternal age at delivery and conception date.

First trimester O_3 was negatively associated with SGA in an unadjusted model, but the association was effectively null after adjusting for first trimester exhaust particles. There was no association between second trimester O_3 and SGA. Higher exhaust particle exposure during first, second trimester as well as full pregnancy were associated with an increased risk of SGA in the unadjusted model, but the associations were not statistically significant in the fully adjusted model.

Higher levels of O_3 during the first trimester was linearly associated with a higher risk of PD: the Prevalence Rate Ratio (PRR) per inter quartile range, IQR (29.4 µg/m3 for first trimester) increase was 1.08 (95% CI: 1.04 – 1.12) in the unadjusted model. The association was however not statistically significant in the fully adjusted model (1.03, 95% CI: 0.98, 1.08). First and second trimester exhaust particles showed a non-linear negative association in the unadjusted model, and was negatively associated with PD in the fully adjusted model. The PRR per IQR (0.93 µg m^{-3}), 95 % CI: (0.89, 0.97) during the first trimester.

Conclusions

A new methodology to obtain 100 meter by 100 meter spatially resolved hourly mean O3 concentrations without the need for advanced photochemical modelling has been validated successfully. High O_3 exposure was associated with lower SGA and higher risk of PD, but neither was significant when adjusted for confounders. Preliminary we have found that exhaust-PM exposure was negatively associated with preterm delivery, but did not significantly affect SGA.

Acknowledgement

This study was part of the Swedish Clean Air and Climate research programme funded by the Swedish Environmental Protection Agency.

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BRONCHIAL AND VASCULAR EFFECTS INDUCED BY DIFFERENT DIESEL PARTICLES EMISSION SOURCES

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Summary
This study aims to compare the biological effects induced by three different diesel combustion particles (DEPs), focusing on their health hazard at both respiratory and vascular levels. In particular, DEP coming from a EuroIV engine, run under STOP&GO driving condition, resulted to be the more enriched in PAHs and more effective at all biological endpoints. Cell viability, oxidative stress, cell morphology, release of inflammatory mediators and genotoxic potential were investigated in the bronchial cell line BEAS-2B. The conditioned media, derived from these cells, were then used to treat human microvascular endothelial cells (HPMEC), in order to evaluate DEP-induced endothelial activation. DEPs with high content of PAHs, derived from an emission source of a high traffic area (DEP EuroIV) were responsible for both lung and vascular biological outcomes.

Introduction
The link between increased particles emissions and cardiovascular diseases has been well documented (e.g. Lee et al., 2014), but the mechanisms leading to these effects are still unknown, even if the activation of the respiratory endothelium seems to be involved. The release of mediators from the exposed epithelium has been suggested to be involved in this process and here investigated.

Methodology and Results
Two *in vitro* models were used to compare the effects induced by the different DEPs: a conditioned media system and a co-culture *in vitro* model on Transwell inserts, mimicking the interplay between lung epithelium and pulmonary capillaries. Bronchial BEAS-2B cells were exposed to two standard reference DEP (1650b, 2975) and a DEP sampled from a EuroIV vehicle run over a chassis dyno. After DEPs exposure (5μg/cm^2 for 20h), the expression of ROS species and the HO-1 oxidative stress marker were investigated by cytofluorimetric and Western Blot analyses, respectively. The release of cellular mediators (IL6, IL6R and VEGF) in BEAS-2B supernatants was assessed with ELISA. The genotoxic potential of DEPs was evaluated with the analysis of yH2AX expression, a biomarker of DNA double-strand breaks. Moreover, HPMEC lung microvascular endothelial cells were exposed for 24h to BEAS-2B conditioned media. The expression of endothelial adhesion molecules (ICAM-1 and VCAM-) was analyzed. Finally, a 3D *in vitro* air-blood barrier (ABB) was used: epithelial cells were treated with DEPs and after 24h the release of inflammatory mediators and endothelial activation were investigated. Among the different particles, only DEP EuroIV was able to induce oxidative stress, IL6 and IL6R release in BEAS cells and a consequent endothelial activation, as evidenced by the increased expression of ICAM-1 and VCAM-1 in HPMEC. These results are confirmed by the experiments on the co-culture model.

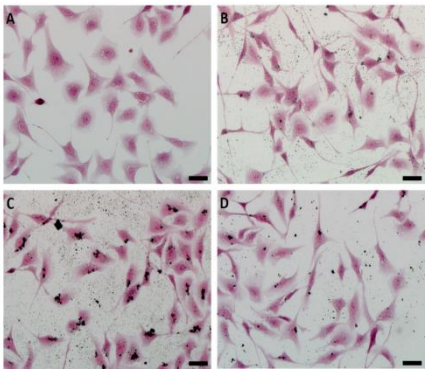

Fig.1 Morphology of cells exposed to three different DEPs: A) control cells, B) 1650b, C) 2975 and D) EuroIV.

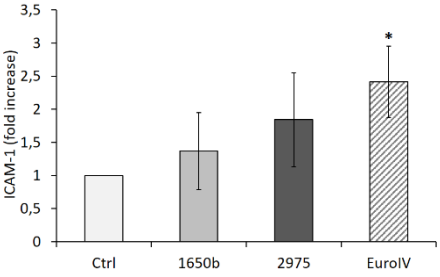

Fig.2 ICAM-1 expression in endothelial cells exposed to different conditioned media.

Conclusions
As traffic continues to increase in Europe, the emission of diesel combustion-derived particles will continue to contribute significantly to the atmospheric particles. Furthermore, these emissions include several substances with high toxicity to humans and the environment (e.g. metals and PAHs). DEP-induced cardiovascular effects may derive from the inflammatory response of lung epithelial cells and they are modulated by PAHs-enriched particles, whose physicochemical properties are more reactive and effective on the respiratory epithelium and endothelium.

Acknowledgement
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PARTICULATE MATTER AND MARKERS OF GLYCEMIC CONTROL AND INSULIN RESISTANCE IN TYPE 2 DIABETIC PATIENTS: RESULT FROM WELLCOME TRUST GENETIC STUDY

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Summary
This study investigated whether long-term exposure to PM_{10} pollution is associated with biomarkers of glycaemic control. we estimated the ambient concentration of PM10 at the home address of diabetic patients. Glycaemic biomarkers were obtained from WellGen study. We used multiple linear regression analysis to investigate the possible associations between these two data sets. Long-term exposures were linked to adverse effects on the markers of glycaemic control in diabetic and smoking and WHR were modifiers of this association. Better assessment of exposure may lead to progress for preventive and control strategies in air pollution health effect.

Introduction
There is growing evidence that air pollution is associated with increased risk of type 2 diabetes (T2DM). However, information related to whether particulate matter (PM) contributes to worsened metabolic control in T2DM patients is inconsistent.
We examined the association of PM10 exposure with glucose-function parameters in young- onset T2DM patients.

Methodology and Results
We investigated the association between a year ambient concentration of PM10 at residential places, using AERMOD dispersion model, with fasting plasma glucose (FPG), hemoglobin A1c (HbA1c), 2hrs post meal plasma glucose (2hPG), homeostasis model assessment of insulin resistance (HOMA-IR), β-cell function (HOMA-β) and disposition index (DI) in 1213 diabetic patients from the Wellcome Trust Genetic study at the Diabetes Unit, KEM Hospital Research Center, Pune, India. We used linear regression models and adjusted for a variety of individual and environmental confounding variables. Possible effect modification by age, gender, waist to hip ratio (WHR) and smoking status were investigated. Sensitivity analysis assessed the impact of relative humidity (RH) and temperature a day before examination and anti-diabetic and HHR medication (Hydralazine, Hydrochlorothiazide and Reserpine).
We found that 1 SD increment in background concentration of PM10 at residential places (43.83 µg/m3) was significantly associated with 2.25 mmol/mol and 0.38 mmol/l increase in arithmetic means of HbA1c and 2hPG, respectively (Fig. 1). A similar increase in PM10 was also associated with 4.89% increase in geometric mean of HOMA-IR (Fig. 2) The associations remained significant after adjustment to RH and temperature, and WHR and smoking enhanced the size of the effect.

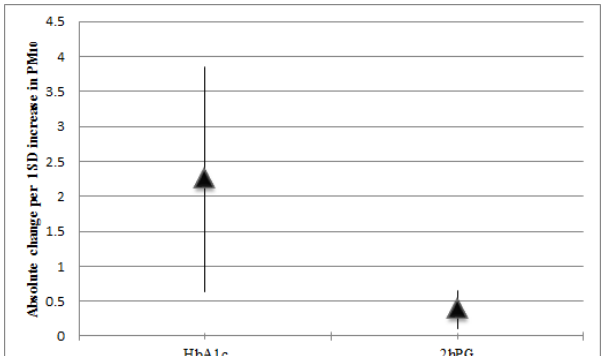

Figure 5: Association between exposure to PM10 and biomarkers of glycemic control

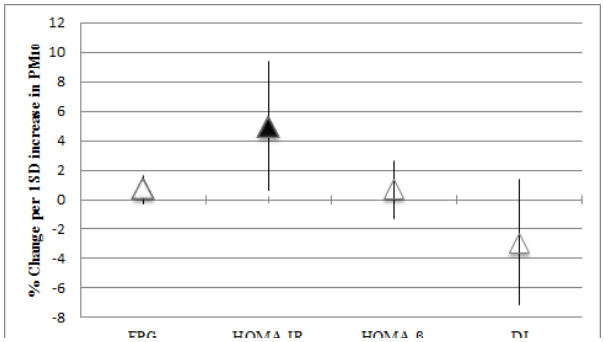

Figure 6: Association between exposure to PM10 and HOMA-IR, HOMA-β and DI

Conclusions
Our study suggests that long-term exposure to PM10 is associated with higher glycaemia and insulin resistance. In context of our previous demonstration of association of SO2 and NOx and plasma C-reactive protein, we suggest that air pollution could influence progression of diabetes complications. Prospective studies and interventions are required to define mechanism and confirm causality

Acknowledgement
This work was supported by: The Wellcome Trust, London, U.K. We acknowledge the contribution made by WellGen study group and Ms Smita Kulkarni, Diabetes Unit, in data collection and data management, and Mr Dattatray Bhat, Diabetes Unit, for laboratory measurements. Air pollutants and meteorological data were taken from Maharashtra Pollution Control Board and Meteorological Department, Pune Office respectively

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THE EFFECTS OF PHOTOCHEMICAL AIR POLLUTION ON RESPIRATORY HEALTH IN ABUJA NIGERIA

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Summary
This study aims to critically evaluate the effect of photochemical smog on COPD patients in Nigeria. A cohort of COPD patients was recruited from two large hospitals in Abuja Nigeria. Symptom questionnaires, daily diaries, dyspnoea scale and measurement of lung function were used to obtain health data. Real-time air pollution data was obtained from a monitoring site at Abuja airport. Measured air pollution concentrations, for the precursors of photochemical smog, are far higher than those recorded in the developed world where a link between air pollution and respiratory health has been observed. The lung function values recorded for the cohort would indicate that respiratory health in the cohort is reduced with a mean age suggesting that COPD is developing at a far earlier age in Nigeria. The correlation between measured air pollution and an exacerbation of symptoms will be investigated as part of this project.

Introduction
Many studies have investigated the effects of air pollution on health in the developed world however information from the developing world, including Africa is sparse (Mustapha et al., 2011). However, research has shown that the concentrations of air pollution in Nigeria are considerably higher than those reported in the developed world (Olajire, Azeez & Oluyemi, 2011).

Method and Result
A cohort of patients was recruited 45 from the University of Abuja Teaching hospital, and 28 from the National Hospital both in Abuja, Nigeria. All members of the cohort were attending respiratory clinics at the hospitals and had been diagnosed with COPD. Lung function was determined using spirometers supplied from the UK, at each clinic attendance. Information on symptoms was obtained using a modified version of the St Georges respiratory questionnaire with 30% of the cohort reporting worse wheeze in the morning, 10% cannot go shopping, 15% take long time to get washed, 25% walk slower, 15% if they hurry have to stop and 5% cannot take bath.

Mean +/-SD Age	Mean +/- SD FEV_1	Mean +/- SD % predicted FEV_1
57.8 +/- 6.1	2.35 +/-2.41	61.3 +/-37.6

Table 1 Mean +/- SD, Age, FEV1 and % predicted FEV1 for the cohort n= 73

The results show that the mean FEV_1 for the cohort was 2.35 with the mean predicted % being 61.0 indicating that the patients in the cohort have impaired lung function.

Patients were asked to keep daily diaries of their symptoms and this information will be correlated with air quality data. An ozone monitor has been supplied from the UK and has been sited at the Nigerian Meteorological agency (NIMET) monitoring site at Abuja airport. Other pollutants monitored at the site are NO_x and PM_{10}.

Concentrations of NO_x and PM_{10} are far in excess of those measured in the developed world and would indicate that there is the potential for air pollution to impact on respiratory health notably in the winter. The high temperatures found in Abuja are also likely to lead to the formation of a range of secondary air pollutants including ozone and secondary particles.

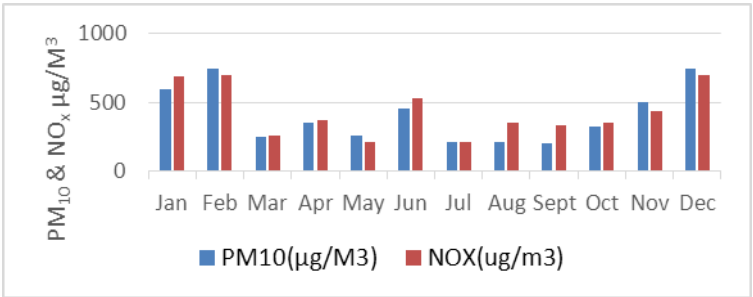

Figure 1: Concentrations of NOx and PM_{10} in Abuja Nigeria 2016

Conclusion
It is likely that the concentrations of air pollutants monitored in Abuja will lead to an exacerbation of the symptoms reported by the cohort of COPD patients. The study will investigate this using patient diaries and real-time air pollution measurements.

Acknowledgements: this work was supported by the Tertiary Education Trust Fund (TETFund) via the National Universities Commission (NUC), Nigeria.

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ASSOCIATION BETWEEN RESIDENTIAL WOOD BURNING AND DEMENTIA INCIDENCE IN A LONGITUDINAL STUDY IN NORTHERN SWEDEN

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Background and Aims. There is highly suggestive evidence for an effect of air pollution exposure on dementia-related outcomes, but evidence is not yet present to clearly pinpoint which pollutants are the probable causal agents. The aim of this study was to assess the association between exposure to source-specific fine ambient particulate matter ($PM_{2,5}$), especially from residential wood burning, with dementia.

Method. We used data from the Betula study, a prospective longitudinal study of dementia in Umeå, Northern Sweden. The study size was 1 806 and the participants were followed from study entry (1993-1995) to 2010. Modelled levels of source-specific fine particulate matter at residential address were combined with information on wood stoves or wood boilers, and with with data on dementia diagnosis and individual-level characteristics, from the Betula study. Cox proportional hazards models were used to estimate Hazard Ratios (HRs) and their 95% CIs for dementia incidence, adjusted for individual-level characteristics.

Results: The contribution to $PM_{2.5}$ from local residential wood burning was associated with dementia incidence with a hazard ratio of 1.55 for a 1 $\mu g/m^3$ increase in $PM_{2,5}$ (95% Confidence Interval (CI): 1.00-2.41, p-value 0.05). Study participants with an address in an area with the highest quartile of $PM_{2,5}$ from residential wood burning and who also had a wood stove were more likely to develop dementia than those in the lower three quartiles without a wood stove with hazard ratios of 1.74 (CI: 1.10-2.75, p-value 0.018). Particulate matter from traffic exhaust seemed to be associated with dementia incidence with hazard ratios of 1.66, (CI: 1.16-2.39), p-value 0.006, and 1.41 (CI: 0.97-2.23), p-value 0.07, in the third and fourth quartiles, respectively.

Conclusions: Ambient levels of particles from residential wood burning, and vehicle exhaust, seem independently linked with dementia risk during a 15-year follow-up period in a well examined cohort. Moreover, the use of a wood stove at home increased the risk. Particles stemming from wood-burning may cause more health effects than what has been shown before in epidemiological studies.

TRENDS IN AIR POLLUTANTS AND HEALTH IMPACTS IN THREE SWEDISH CITIES OVER THE PAST THREE DECADES

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Summary

This study estimates the health impacts associated with the time trends of NO_x, NO_2, O_3 and PM_{10} in the Swedish cities of Stockholm, Gothenburg and Malmoe from the 1990's until to 2015. The concentrations are based on measurements from central monitoring stations representing urban background levels, but corrections for population exposure have been performed in some cases. The trends are very different for the pollutants that have been studied; NO_x and NO_2 have been decreasing in all cities, O_3 exhibits an increasing trend in all cities, and for PM_{10}, there is a slowly decreasing trend in Stockholm, a slowly increasing trend in Gothenburg, and a non-significant trend in Malmoe. Impacts on the change in life expectancy at birth are calculated based on the trends and the relative risks associated with exposure to these pollutants. The calculations indicate that the life expectancy at birth has increased by 1.09, 0.49 and 0.57 years for the populations in Stockholm, Gothenburg and Malmoe, respectively, when using NO_2 as indicator of the reduced air pollution exposure during the period 1990 – 2015. The increased O_3 exposure, on the other hand, has caused a decrease in life expectancy by 0.17, 0.36 and 0.23 years for the populations in Stockholm, Gothenburg and Malmoe, respectively. Changes in PM_{10} exposure have had relatively small impacts on the change in life expectancy at birth.

Introduction

Worldwide, many cities, especially in high-income countries, show substantial decreasing trends in air pollution concentrations (e.g. Colette et al., 2011). This means that the population exposure, and the associated health effects, has been reduced for NO_x, NO_2 and PM_{10}, with the exception of O_3, which instead shows increasing trends. The general questions in this study are: i.) How does different trends in different air pollutants affect the health assessment, and which pollutant is most relevant to consider? ii.) Which dose-response relationships should be used? iii.) Which are the main uncertainties in such calculations?

Methodology and Results

Our trend analyses are based on simultaneous, continuous measurements of NO_x, NO_2, O_3, and PM_{10}, during the period 1990 to 2015 in Stockholm, Gothenburg and Malmoe. The trends (Fig. 1) have been developed by using the Openair package, where a median slope (red line), based on all data points (blue line) during the measured time interval, has been calculated. The green values in the top represent the median slope in µg m^{-3} $year^{-1}$, with a 95 % confidence interval in brackets. The stars that follow represent the significance level, where three stars means $p < 0.001$, and one star means $p < 0.05$. The WHO AirQ+ software tool for health-risk assessment of air pollution has been used to calculate the gain in life expectancy thanks to reduced air pollution exposure among the general

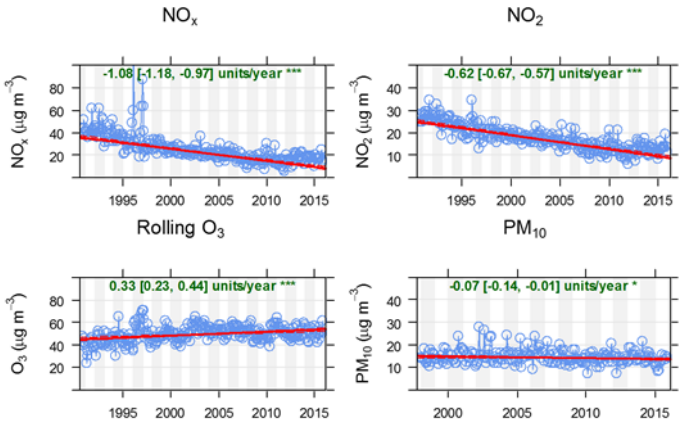

Fig.1 Trends in NO_x, NO_2, O_3 and PM_{10}, measured in Stockholm from 1990 – 2015

population. Based on the reduced exposure to NO_2, the life expectancy at birth during the period 1990 – 2015 has increased by 1.09 years (95 % CI; 0.48 – 1.71) in Stockholm, and in Gothenburg and Malmoe, 0.49 years (95 % CI; 0.22 – 0.75) and 0.57 years (95 % CI; 0.25 – 0.89), respectively.

Conclusions

In general, all cities exhibit decreasing trends for NO_x and NO_2, while O_3 in all cases exhibit increasing trends. Up to around 25 % of the overall population life-expectancy increase (3 – 4 years), may be due to decreased air pollution exposure. An overall conclusion is that the changing air pollution concentrations have a significant impact on the public health.

Acknowledgement

B. Forsberg is supported by NordicWelfAir and H. Orru by the Estonian Ministry of Education and Science (IUT34-17).

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THE "CARBONACEOUS AEROSOL IN ROME AND ENVIRONS (CARE)" EXPERIMENT

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Summary
This study aims to provide baseline levels of carbonaceous aerosols in Rome, and to address future research directions for toxicological studies related to carbonaceous aerosols. At this end, the "Carbonaceous Aerosol in Rome and Environs (CARE)" experiment was carried out in the downtown Rome in February 2017. First results indicate that BC mass concentration in Rome is larger than those measured in similar urban areas across Europe. The toxicological analysis carried out points to the importance of measuring particle size and composition, the effects of toxicity being higher with lower mass concentrations and smaller particle size.

Introduction
In February 2017 the "Carbonaceous Aerosol in Rome and Environs (CARE)" experiment was carried out in the downtown Rome to address the following specific questions: what is the color, size, composition, and toxicity of the carbonaceous aerosol in the Mediterranean urban background area of Rome? The motivation of this experiment is the lack of understanding of what aerosol types are responsible for the severe risks to the human health posed by particulate matter (PM) pollution, and how carbonaceous aerosols influence radiative balance. The first experimental results of the CARE experiment are presented by Costabile et al. (2017). The objective of this work is to provide baseline levels of carbonaceous aerosols for Rome, and to address future research directions.

Methodology and Results
Physicochemical properties of the carbonaceous aerosol and relevant toxicology were characterised by: (i) measurements (minutes to 1-2 hours) of black carbon (eBC), elemental carbon (EC), organic carbon (OC), particle number size distribution (0.008--10 μm), major non refractory PM_1 components, elemental composition, wavelength-dependent optical properties, and atmospheric turbulence; (ii) mobile measurements of eBC and size distribution, and (iii) assessment of toxicological variables.
Figure 1 show diurnal cycles during weekdays (red lines) and weekends (green lines), of equivalent black carbon, total particle number concentration, Total Kinetic Energy, and hydrocarbon-like organic aerosol. The urban background mass concentration of eBC in Rome in winter is on average 2.6±2.5 μg m^{-3}, mean eBC at the peak level hour being 5.2 (95\%CI=5.0-5.5) μg m^{-3}. Having compared these values to those in the literature, we found that eBC mass concentration in Rome is larger than values measured in similar urban areas across Europe. Also, the toxicological analysis showed that the effects of toxicity are higher with lower mass concentrations and smaller particle size.

Conclusions
Findings of the CARE experiment reinforce the need for an urgent update of existing air quality standards for PM_{10} and $PM_{2.5}$ with regard to particle composition and size distribution, and data averaging period. Our results reinforce existing concerns about the toxicity of carbonaceous aerosols, support the existing evidence indicating that particle size distribution and composition may play a role in the generation of this toxicity, and remark the need to consider a shorter averaging period (< 1 hour) in these new standards.

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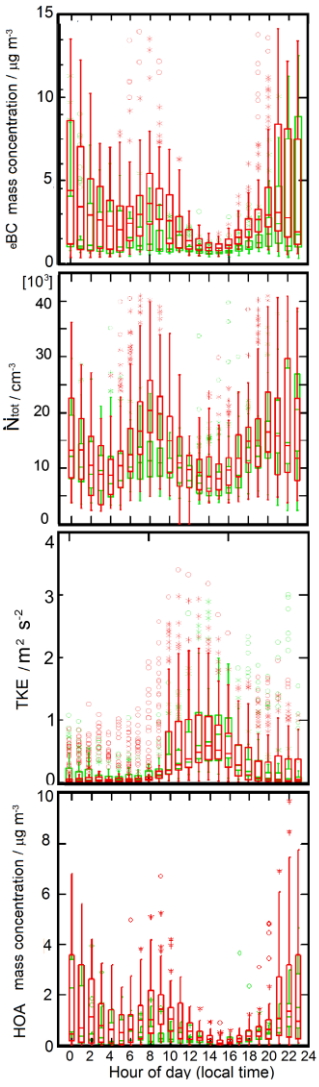

Fig.1 Aerosol and meteo variables in Rome

ESTIMATION OF POPULATION EXPOSURES TO MAIN AIR POLLUTANTS IN FINLAND: ADJUSTMENT OF CHEMICAL TRANSPORT MODEL RESULTS BASED ON MONITORING

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Summary

Population exposures to air pollution are commonly estimated using either monitoring network data or modelling results, but modern approach considers the combination of both. The representativeness of the air quality observations are often limited due to sparse networks. Air quality models do not have this problem but suffer from own uncertainties. For a realistic impact assessment, a combination of both sources renders the best results. The intelligent fusion of the high-resolution model results and observation data allows the better reproduction of both spatial distribution and time evolution of pollutant concentrations.

Introduction

Air pollution has been identified as the leading environmental health risk factor in developed countries (Hänninen et al., 2014). Exposure computation, being the main instrument in evaluation of this risk, is subject to challenges in spatiotemporal representativity among other factors (Hänninen et al., 2017). In this work, we construct exposure assessment environment using high-resolution SILAM model predictions and a set of in-situ observations of Finnish monitoring network. The main pollutant considered in the study is $PM_{2.5}$. The model is evaluated against the monitoring stations and a fusion procedure is constructed. Main results present the combined exposure estimates accounting for the model bias and underestimation of variance. The procedure will later be expanded also to other pollutants.

Material and methods

The air quality monitoring network in Finland in 2015 consisted of 37 monitoring stations for $PM_{2.5}$, including 13 background stations, 7 traffic stations and 5 industrially located stations. SILAM model simulations were set at 0.01° (about 1 km) spatial resolution covering the whole Finland. The run was nested in regional SILAM simulations (emission: CAMS). The Finnish national emission was compiled using FRES model (Karvosenoja 2008). Exposures were calculated as a population-weighted outdoor air concentration at 1 km resolution.

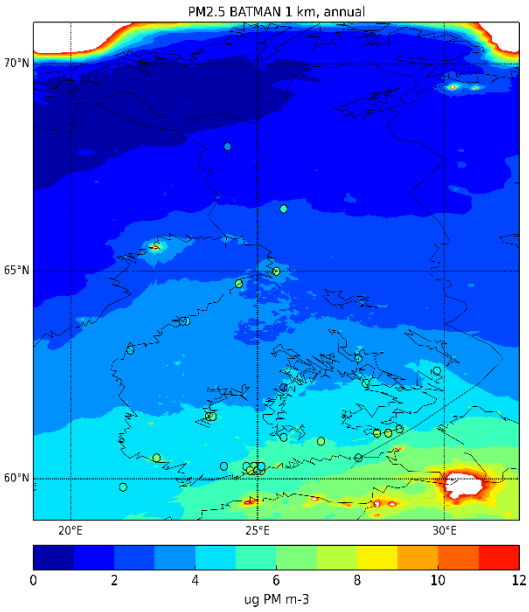

Fig.1 *Annual modelled (contours) and observed at the stations (circles) concentrations of $PM_{2.5}$ in 2015.*

Results

The modelled annual $PM_{2.5}$ concentrations were computed for 2015 (Fig.1) and the mean values showed pretty good agreement with the observed ones at the 37 available stations (FAC2=95%). A small low bias was observed, especially in the northern part of the country (R^2==17.6 %; MB=-1.1 µg m^{-3}; FB=-22%), also noticed in standard deviation (s_{obs}=1.4 µg m^{-3}, s_{pred}=0.93 µg m^{-3}) and variance (ratio var_{pred}/var_{obs} 0.41). The bias and dynamic range corrections were then the key steps in fusion procedure. SILAM includes data assimilation modules, which will be used in future work. The population exposure computed after fusion procedure was about 20% higher than from row model data, whereas the increasing of the standard deviation consist of about 30%.

Conclusions

The $PM_{2.5}$ concentrations were simulated for the whole Finland and showed to be in a good agreement with observed levels. The limited under-estimation of both mean values and dynamic range were corrected at the fusion step, before computing the population exposure.

Acknowledgement

This study was funded by the Academy of Finland project BATMAN and supported Nordforsk project NordicWelfAir. Additional STM/TEKAISU and EU LIFE+ INDEX Air contributed to the interpretation of the results.

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EXPOSURE OF CIVIL WORKERS TO AIRBORNE PARTICLES AND THEIR TRACE ELEMENTAL COMPOSITION

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Summary
This study aims to quantify the exposure of workers from civil construction sector to particles and their trace elemental composition. Measurements of particulate matter (PM_{10}) and particle number concentrations (PNC) were performed in a typical work environment of civil construction in Brazil. PM_{10} were collected in PTFE filters and EDX-fluorescence analysis were performed to identify the trace elements. The PM_{10} and $PNC_{0.3}$ varied between 1.9-6,050 μg m^{-3} and 5,615-502,069 particles L^{-1}, respectively. Ca, Si and Fe were those elements with highest concentrations, but toxic elements such as Ti, Mn and Zn were found in all samples and with concentration above 400 ng m^{-3}. This study suggest that this exposure may cause damage to health.

Introduction
The exposure to inhalable particulate matter (PM_{10}) are linked with several health damages and same specific work activities present high levels. The Civil construction is among sectors that generate large quantities of particles. However, are less explored the exposure of the workers and their potential health damage, and in Brazil is unavailable scientific studies analysing these exposure in real conditions. Considering this, we measured and analysed the workers exposure to PM_{10} and particle number concentrations (PNC) in a civil construction during workday's journeys.

Methodology and Results
Personal monitor and collector (pDR-1500™, Thermo Scientific) and monitor of number concentrations (Metone 804) with cut-off of 0.3 μm were employed in the civil construction environment. The collector operates at 3 L min^{-1} to collect PM_{10} in the PTFE filters. The PM_{10} and $PNC_{0.3}$ varied between 1.9-6,050 μg m^{-3} and 5,615-502,069 particles L^{-1}, respectively (Fig. 1). The energy dispersive X-ray fluorescence (ED-XRF) technique was used to analyze the PTFE filters and respiratory deposition dose (RDD) were calculated. The highest concentrations were from those elements derived from cement, such as Ca, Si and Fe (Fig. 2). Ti, Mn and Zn were also found in all samples, originated probably from steel. The S was attributed to fuel combustion of diesel from indoor and outdoor local activities. The average of total RDD of elements during a day-journey was around 350 μg. Although, workers use mask may occur damages on health associated with this exposure, since toxic elements such as Ti, Mn and Zn were found, and they, typically are in the fine fraction of particulate matter. Therefore, are under analysis the potential damage of this exposure based on results from analysis of several biomarkers in blood collected in those workers. Cavaralli et al. (2008), for example suggest cardiotoxicity of $PM_{2.5}$ metal exposures and specifically to manganese. Chen et al. (2012) found that the Long-term exposure to silica dust is associated with substantially increased mortality among Chinese workers.

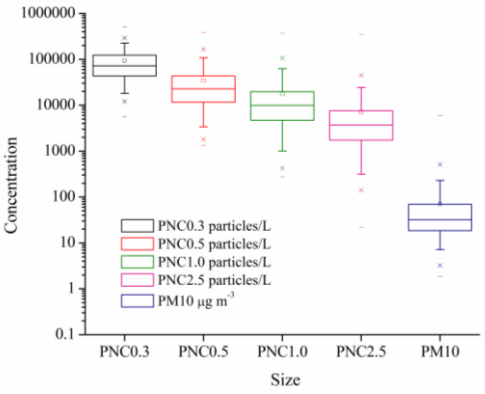

Fig.1 Particles concentrations in civil construction environment.

Conclusions
The construction sector is among those with highest air pollutants emissions, and several workers are daily exposure to these particles. PM_{10} trace elements from civil construction environment suggest they may cause damage to health, since were found toxic elements and in relatively high concentrations.

Acknowledgement
This work was supported by CNPq (process 404104/2013-4; 303491/2015-9). We acknowledge all workers, which freely participated of this survey.

Element	Average (μg m^{-3})	SD (μg m^{-3})	Median (μg m^{-3})	N	RDD (μg/kg-day)
Ca	47.464	49.165	29.488	10	2.4012
Si	21.986	25.844	12.906	10	1.1123
Fe	10.175	14.111	3.915	10	0.5147
K	4.710	6.073	1.945	10	0.2383
Al	4.316	4.431	2.990	10	0.2184
S	4.214	5.105	2.028	10	0.2132
Mg	2.634	2.545	2.034	10	0.1333
Ti	0.650	0.674	0.392	10	0.0329
Mn	0.626	1.192	0.070	10	0.0317
Zn	0.413	0.998	0.075	10	0.0209
Cu	0.290	0.419	0.067	7	0.0147
Cl	0.284	0.542	0.076	10	0.0144
P	0.087	0.037	0.085	8	0.0044
Pb	0.032	0.040	0.008	7	0.0016
Ni	0.028	0.016	0.028	2	0.0014
V	0.008	0.011	0.003	4	0.0004
Br	0.004	0.003	0.004	5	0.0002
Total	97.921	111.204	56.113	-	4.9538

Fig.2 Trace elements and respiratory deposition dose

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PARTICULATE EMISSIONS FROM THE COMBUSTION OF PELLET, CHARCOAL AND WOOD INDUCE DIFFERENT CYTOTOXIC RESPONSES IN A549 CELLS

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Summary
This study aims to investigate the biological effects of biomass combustion-derived particles (PM10) collected from the emission of heating systems operating with pellet, charcoal and wood. Monocultures of human A549 alveolar cells were used to study the PM-induced effects. Different biological endpoints were evaluated. Pellet-derived particles seems to have higher toxic properties in comparison with charcoal and wood ones, suggesting a correlation between their chemical properties and toxicological profile. These data demonstrate that biomass combustion-derived particles may activate different toxicological pathways, suggesting that the fuel type and its quality may have an important role in the strategies to prevent respiratory diseases.

Introduction
Biomass largely contribute to particulate air pollution and likely to the adverse health effects observable in the exposed populations, including increased lung cancer risk, exacerbation of respiratory diseases and cardiovascular function impairment. Several studies, focusing on the potential toxicological effects of biomass-derived particles, are reported in literature and the results have shown different responses on the biological endpoints investigated on *in vitro* and *in vivo* systems. Differences among results are related to the use of diverse particles types, whose difference in composition may depend on the specific fuel, the combustion conditions, and the combustion appliances used (Jalava et al., 2012; Sussan et al., 2014). In the present study, we investigate the possible different toxicological properties of particles collected during the combustion of different fuels under identical conditions in the same stove (commonly used).

Methodology and Results
PM10 particles were morphologically and chemically characterized. A549 cells were exposed for 24h to 5 μg/cm^2 PM. Cell viability, inflammatory response, antioxidant and xenobiotic metabolism activity, DNA damage and cell cycle alterations were investigated.
Pellet-derived particles decreased cell viability, inducing necrosis, while charcoal and wood mainly induced apoptosis. Oxidative stress-related responses and cytochrome P450 enzymes activation were observed after exposure to all the combustion particles tested. Furthermore, DNA lesions and cell cycle arrest were observed only after pellet exposure. Differences in particles toxicity properties could be explained by their chemical composition, since pellet has a higher amount of metals with respect to charcoal and wood, which have higher quantities of PAHs. Among metals, the highest concentration of zinc (Zn) was observed in pellet. Literature data report that high concentration of Zn in PM correspond to higher particles toxic properties.
For this a cell cycle analysis after cells exposure to particles pre-incubated with TPEN, a zinc chelator has been performed. The results obtained show that pellet, in the presence of TPEN, is unable to induce the cycle arrest.

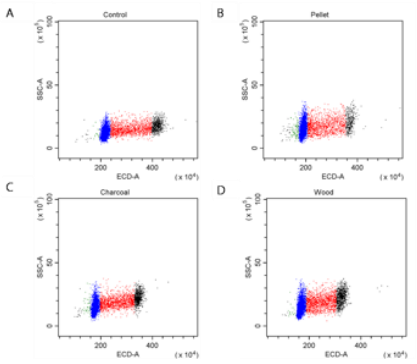

Fig.1 Dot plots representing A549 cell cycle.

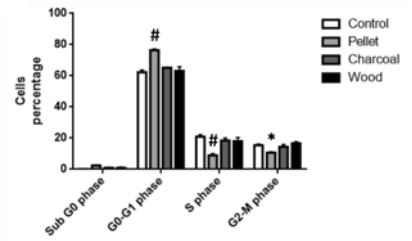

Fig.2 Histogram shows the cells percentage in each phase of the cell cycle.

Conclusions
These data suggest that differences in the responses induced by biomass particles may be related to the activation of different pathways in the lung. Further studies will elucidate the molecular mechanisms responsible for these toxic effects, and will improve our knowledge on PM-induced respiratory disease.

Acknowledgement
This work was supported by Cariplo Foundation (2013-1038) and MAECI project (ID PGR00786).

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PERSONAL AIR POLLUTION EXPOSURE IN RURAL AND URBAN BEIJING

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Introduction

According to the World's Health Organisation (WHO), approximately 7 million premature deaths per year are associated with poor air quality. China, as a rapidly industrialising country with a large and in many parts enormously dense population, suffers particularly from the effects of air pollution [1]. Residents in Chinese megacities, including Beijing, and surrounding areas are regularly exposed to annual PM concentrations that exceed WHO guideline values. In order to initiate more targeted interventions, we need to gain a better understanding of emission sources and exposure pathways.

Aim

This study is part of the AIRLESS[1] project which aims to investigate the links between personal exposure to individual air pollutants and health responses. The integration of novel portable monitors allows a highly spatiotemporally resolved acquisition of personal air quality data, resulting in a better distinction between individual exposures. Contrasting personal exposure of both urban and peri-urban participants, this paper aims to examine the relative contribution of regional air pollution, behavioural patterns and characteristics of built environments to the overall exposure of individuals.

Methodology

In total, 251 participants were recruited in urban Beijing (n=123) and a rural village (n=128) called Pinggu which is located about 70 km northeast to central Beijing. Each participant carried a novel portable air quality monitor for one week in both, winter and summer season. The participants were relatively mobile during the study period and contributed to a dense spatial distribution of data points around the ambient monitoring sites and a wide coverage of the surroundings. An automated algorithm was developed to classify the time-series exposure data into indoor and outdoor categories. An example of the measurements collected by one participant is presented in Fig 1.

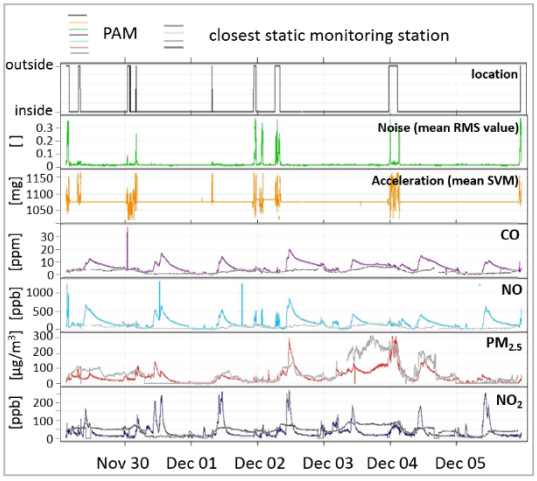

Fig 1 Time series of selected parameters measured by a portable monitor during field deployment. Pollutant concentration

Results

Confirming previous research on daily time-activity patterns, it was found that most of the participant's time was spent indoors, independent of the residential area and season. Hence, household air pollution was a significant contributor to the overall personal air pollution exposure, particularly in rural areas where biomass and coal are commonly used for cooking and heating. Outdoor sources had a much smaller impact due to the little time spent outside. The contribution of regional background air pollution constitutes only 37-47% of the overall personal exposure, meaning that sparsely distributed monitoring stations are likely to underestimate personal exposure. Fig 2 summarises the contributions from regional background pollution, indoor and outdoor emission sources to the mean overall CO exposure in Beijing and Pinggu. The variability of exposure between participants was larger than the variability between the two cohorts which stresses the importance of personal air quality monitoring over the reliance on aggregated estimations, based on the work/home location of the individual.

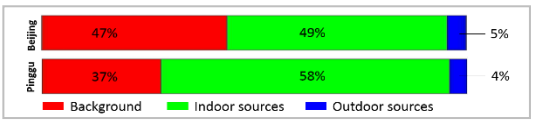

Fig 2 Contribution from background pollution and emission sources in indoor and outdoor environments to mean overall CO exposure of

Conclusion

The portable devices have the potential to improve personal air pollution exposure estimations substantially. Their high spatiotemporal resolution enables an in-depth analysis of the individual variability of air pollution exposure which may differ substantially between rural and urban areas as well as between residents of the same area. A more precise exposure estimation may contribute to a deeper understanding of the effects of environmental stressors on health responses and help develop evidence-based interventions to prevent health risks associated with air pollution.

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1 "Effects of air pollution on cardiopulmonary disease in urban and peri-urban residents in Beijing", part of "Air Pollution and Human Health in a Chinese Megacity" project

ASSESSING PERSONAL EXPOSURE TO AIR POLLUTANTS USING AGENT BASED MODELLING AND WEARABLE SENSORS

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Summary
An individual exposure model was developed using Agent Based Modelling (ABM) to simulate human movement and interaction behaviour, informed by wearable sensors data. This model can feed into a population-based exposure assessment without imposing prior bias, but rather basing its estimations onto emerging properties of the agent system behaviour. This method integrates Socioeconomic Status (SES) data and provides the capacity for aggregation at various levels of population size. It is a novel approach that permits the computationally efficient identification of refined time-activity diaries and exposure profiles throughout the day, for different sociodemographic groups of population.

Introduction
Innovations in sensors technology create possibilities to collect environmental and exposure-related data at unprecedented depth and breadth, 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 epidemiology studies and exposure simulation modelling. Measuring, though, personal exposure directly requires a large number of people and therefore is often not feasible due to time and financial constraints. Considering these substantial technical and ethical hurdles involved in collecting real individual space-time movement data for whole populations, a decision has been made to simulate movement and interaction behaviour using ABM, informed by sensor data, captured in local campaigns. ABM is a modelling technique that simulates the actions and interactions of autonomous software "agents", enabling a better understanding of the behaviour of individuals and populations in social and evolutionary settings.

Methodology and Results
A model was developed for the city of Thessaloniki, Greece, that simulates behaviours of all the agents the system (city) is composed of. City population and sociodemographic data, as well as road and buildings networks, were transformed into human, road and building agents respectively. Particular emphasis is being given in the case of in-model incorporation of SES data. Survey outputs with data on lifestyle/behavioural patterns were associated with human agent behavioural rules, aiming to model representative to real-world conditions. Moreover, observations on spatiotemporal behaviours, derived from a portable sensor campaign on 50 households were extrapolated to the larger population of the city and translated into human agent rules, considering sociodemographic variations. Human agents differentiated for age, gender or income follow different rules, express different behaviours leading to a human agent-specific exposure profile. At the end of a model run, activity patterns are determined for every individual based on the prevalence of specific preferences and decision-making. Coupling position information with spatially resolved pollution levels allows us to assign pollutant concentrations to an individual. PM levels and size distribution varied among different parts of the urban agglomeration and hours of the day. Personal exposure results were up to 20% more accurate than the equivalent estimates using ambient air concentrations of PM as exposure proxy.

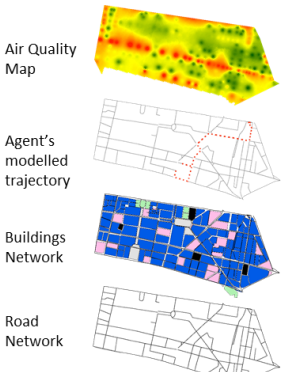

Fig.1 Exposure assessment using ABM

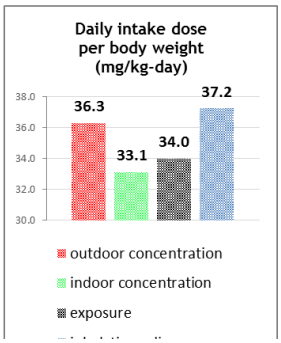

Fig.2 Daily intake dose per body weight for a randomly

Conclusions
Our method leads to a refined exposure assessment model addressing effectively vulnerable population sub-groups. The computational platform developed can be further used as a means for estimating and comparing the probable effects of different air pollution management strategies on public health prior to implementation, therefore reducing the time and expense required to identify effective policies and thus implementing the precision prevention paradigm.

Acknowledgements
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Indoor Air Quality

INVESTIGATION OF THE SUBMICRON PARTICLE BUDGET IN AN UNOCCUPIED BUILDING

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Summary
This study seeks to improve our understanding of the drivers controlling particle concentrations in unoccupied indoor environments, i.e. air exchange, infiltration of pollutants from outdoor, surface deposition, possible nucleation of new particles, and particle transformations. A mass balance analysis of indoor aerosols has been performed using time-resolved measurements of particle number concentrations and composition during two campaigns. The first measurement campaign has been carried out from summer 2016 to fall 2017 and consisted in characterizing some of the parameters mentioned above, using gas tracers and two optical counters (OPC; TSI 8220 AEROTRAK) over 6 particle size bins (from 0.3 to over 10.0 µm). A second intensive campaign has been conducted during the fall of 2017 and consisted in characterizing the size distribution and chemical composition of submicron aerosols and its precursors, using state-of-the-art instrumentation such as HR-ToF-AMS and PTR-ToFMS for continuous measurements of both indoor and outdoor concentrations. We will first discuss the main parameters driving the indoor aerosol budget and we will provide insights into potential indoor sources or transformations by comparing indoor to outdoor particles.

Introduction
People spend 80-90% of their time indoors, being exposed to air pollutants from both indoor and outdoor sources (Klepeis et al. 2001). According to World Health Organization, 4.3 million premature deaths worldwide were attributable to household air pollution in 2012, 99,000 of them being in Europe (2014). Associated health risks are higher indoors compared to outdoors as a result of the reduced volume and the multiplicity of indoor sources (i.e. volatile organic compounds - VOCs, particles, inorganic trace gases), usually leading to increased pollutant concentrations. Among them, PM_1 are present at higher number concentrations compared to larger ones and their large surface area can act as a medium for the adsorption of VOCs. These particles can deposit in the lower respiratory tract, access the circulatory system, and move to other organs easily (Lanzinger et al. 2016).

Methodology and Results
A budget evaluation of indoor aerosols has been performed in an unoccupied positive energy facility from IMT Lille Douai, an engineering school and research center located in northern France. The first measurement campaign consisted in characterizing the air exchange rate, the penetration factor, deposition rates of particles over 6 particle size bins and their ambient indoor and outdoor concentrations. These measurements were used to constrain a mass balance model (Eq.1) to evaluate the relative importance of each term:

$$V\frac{dC_{in}}{dt} = \alpha PVC_{out} + R + (\alpha + K)VC_{in} + S \qquad \text{(Eq. 1)}$$

where V is the volume of the room (m^3), C_{in} and C_{out} the indoor and outdoor particle mass concentrations (µg m^{-3}), respectively, α the air exchange rate (h^{-1}), P the penetration factor (dimensionless), R the resuspension term (µg h^{-1}), K the deposition rate (h^{-1}) and S the indoor source emission rate (µg h^{-1}). All necessary parameters to constrain the mass balance equation under unoccupied conditions (C_{in}, C_{out}, α, K; P) have been extensively characterized over various environmental conditions and the budget analysis indicated a missing source of PM_1 particles. For particles over 5 µm a positive imbalance is probably due to resuspension, while for small particles it could be attributed either to resuspension, nucleation, evaporation of larger particles, condensation or a combination of these processes (Fig. 1). From the observed temperature dependence of the missing terms, it is speculated that the missing source for the small particles is either formation of new particles and/or physicochemical transformations.

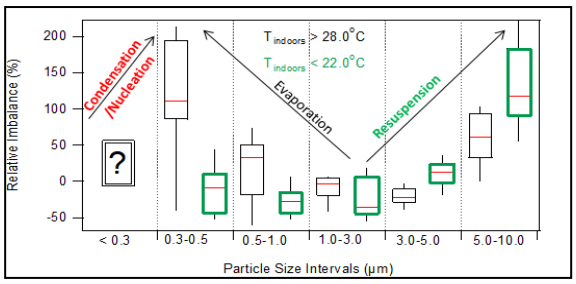

Fig.1 Relative Imbalance [$\alpha PVC_{out} - \alpha VC_{in} - KVC_{in}$]/ αPVC_{out}

Conclusions
The present study investigates the drivers controlling the particle concentrations indoors and focuses on the existence of possible PM_1 sources and/or transformations as well as the importance of each term in the mass balance equation. The second campaign will help to better understand PM_1 chemical composition and size distribution indoors in order to assess what the observed missing source is.

Acknowledgement
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SEASONAL CONTRASTS OF INDOOR EXPOSURE TO $PM_{2.5}$ IN URBAN & RURAL BEIJING

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Summary

This study aims to 1) understand the indoor exposure to $PM_{2.5}$ in rural and urban Beijing during winter and summer, 2) understand the causes of seasonal and spatial differences in indoor exposure levels. *RTI MicroPEM V3.2* nephelometer was deployed in houses of selected subjects to monitor indoor $PM_{2.5}$ for at least 48 hours. Preliminary results show significant seasonal differences between winter and summer exposure levels in both rural and urban subjects. Future investigations will be conducted to analyse the reasons for seasonal and spatial differences, using the fuel type, behaviour and air purifier data that were collected in this study. Through such analysis, we hope to provide evidence for the current intervention on fuel change for domestic heating in Beijing city and inform future policies.

Introduction

As the largest megacity of China, Beijing now faces high concentrations of ambient air pollution, and, in peri-urban regions household air pollution from biomass burning for heating and cooking. To tackle the problem, Beijing is introducing interventions on fuel for domestic heating in rural and urban Beijing as part of its strategy package. Starting from late 2016, low-quality coal was banned in many parts of rural Beijing for heating during winter. The Effects of AIR pollution on cardiopuLmonary disEaSe in urban & rural reSidents in Beijing (AIRLESS) study, is an international collaborative research project between UK and China to understand the health effects of air pollution in rural and urban Beijing. My project focuses on indoor exposure to $PM_{2.5}$ in AIRLESS rural and urban panels during winter 2016 and summer 2017.

Methods and Results

Indoor deployment sub-panels were recruited out of the AIRLESS panels in rural and urban Beijing. Urban sub-panel members were selected considering the floor of residence and the distance to main road; the selection criteria of the rural sub-panel was (i) home exposure to environmental tobacco smoke (ETS), (ii) fuel used for cooking and (iii) fuel used for heating. Instruments (*RTI MicroPEM V3.2)* were deployed indoor to monitor $PM_{2.5}$ continuously for at least 48 hours. As Fig. 1 shows, in both rural and urban sub-panels, there were significantly higher ($p < 0.01$) log-transformed indoor exposure levels in winter than summer. Currently the effects of fuel types and air purifier on indoor air quality in rural and urban Beijing are being investigated.

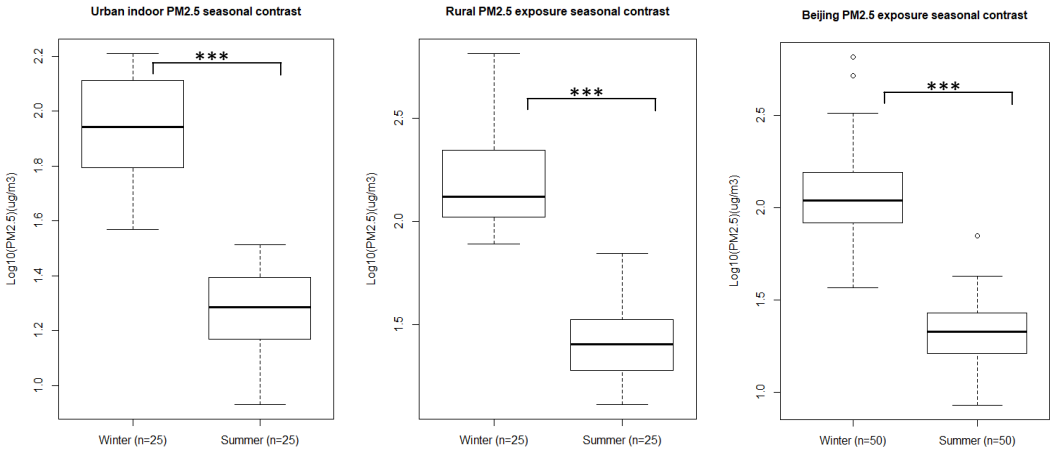

Figure 1: Boxplots of seasonal contrasts in urban, rural and both sites.

Conclusions

This project shows that there are significant seasonal differences in indoor exposure levels to $PM_{2.5}$ in AIRLESS rural and urban sub-panels. In future, we hope to inform fuel use interventions and behaviour changes in Beijing.

Acknowledgements

This research is funded by Medical Research Council (MRC), the Natural Environment Research Council (NERC grant number NE/N007018/1), National Natural Science Foundation of China (NSFC grant number 81571130100). We would also like to thank our PKU collaborator for their assistance in data collection. Thanks to all participants in the AIRLESS project. Thanks to AIRPOLL and AIRPRO study team for sharing their data.

PARTICULATE MATTER MEASUREMENTS IN AN UNDERGROUND RAILWAY STATION IN NORWAY

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Summary
We will present the results from a study that was designed to map PM-concentrations and indoor climate in different areas of an underground railway environment, focusing on public areas and working environments. $PM_{2.5}$ and PM_{10} were sampled at several sites at Norway's second most frequented railway station, including the platform in the basement and shops on the ground floor. During the same time, PM was monitored continuously at the platform. PM-levels above recommended standard values were observed especially at the platform and in shops which are not completely enclosed. Offices on the station's premises have satisfactory PM-levels. An important outcome from our study is that optical PM-monitors need to be specifically prepared for applications in the railway environment.

Introduction
The railway is one of the cleanest modes of transport in urban areas. Transporting a large amount of passengers on railway networks helps to reduce vehicle traffic and thus atmospheric emissions from motor vehicles. In indoor railway environments, however, the exposure to particle pollution is at a rather high level. This may affect employees at their work places who spend a significant part of the day in indoor environments of the railway station.

Methodology and Results
Particulate matter ($PM_{2.5}$ and PM_{10}) was sampled at six sites within the underground environment of Nationaltheatret railway station in Oslo (Norway). The measurement sites were two shops, two offices, a technical corridor and one of the main railway platforms. The shops had unobstructed air exchange with the arrival hall, while the offices were enclosed towards the surroundings and received filtered air through the ventilation system. Sampling was carried out using two particle samplers (reference method), one sampling $PM_{2.5}$ and one sampling PM_{10}, for one week at each site with 12 hours exposure time per sample. Indoor climate parameters CO_2, temperature and relative humidity were logged in parallel. Continuous monitoring of PM_{10} and $PM_{2.5}$ with higher time-resolution was carried out at the platform during the whole 6-week period (Fig. 1). The PM-monitor applied an optical measurement method. Maximum PM-levels were measured at the platform, 24-hour $PM_{2.5}$-averages varied between 134 and 179 µg/m^3. The Norwegian norm for indoor climate gives a limit of 15 µg/m^3 as a daily $PM_{2.5}$-average. This concentration was regularly exceeded in both shops and in the technical corridor. PM levels in the offices was satisfactory. The average PM-levels at the platform largely exceeded concentrations observed at a busy traffic site (Fig. 2). A large discrepancy between the PM-concentrations measured by the PM-monitor, compared to the reference method, was found. The composition of the particles with high metal content is assumed to be the reason.

Fig.1 PM-monitor on railway platform in the basement of the station

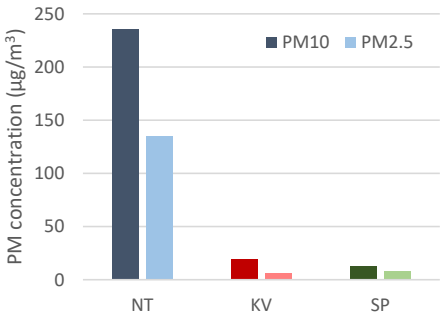

Fig.2 Comparison of PM-concentrations at the platform (NT) to ambient air monitoring stations (KV: traffic site, SP: urban background site).

Conclusions
Railway traffic leads to high particulate matter concentrations within the enclosed environment of the station. The PM-level measured at the platform is comparable to the concentrations found at metro and railway stations in other cities on an international basis (Abbasi et al., 2013). The study lead to a discussion on measures to reduce PM-levels at the station and to reduce exposure of employees.

Acknowledgement
This work was commissioned by the Norwegian National Rail Administration. We acknowledge the security guards at Nationaltheatret station for their help during sampling.

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PM CONCENTRATIONS IN RAILROAD TUNNELS IN STOCKHOLM AND IN DRIVER CABIN OF COMMUTER TRAINS

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Summary
This work includes measurements of particle concentrations (including PM10, PM2.5 etc) and size distribution in two 5-6 km long rail road tunnels in Stockholm County. The filtration system inside the drives cabins are working efficiently filtering roughly 80% of PM10, providing a good work environment even inside tunnel systems. Overall, the particle concentrations inside cabins were low, as long as that doors were closed. The enclosed platform in the Citybanan tunnel have likely lead to lowering the particle exposure for the commuters on the platform, although their exposure is still significant, comparable to that on the open platform in the Arlanda rail road tunnel outside Stockholm, which was approximately 150 µg/m^3 of PM10.

Introduction
There are several previous studies of particle exposure of train travelers but few of the train staff's expose. Health studies have shown that rail road particles, mainly consisting of iron but also a lot of carbon, are genotoxic and oxidative (Karlsson et al. 2005, 2006). Health risks have been assessed as likely larger for road traffic related particle exposure than rail road particles. (Järvholm et al, 2013). A new rail road tunnel opened in Stockholm in July 2017, Citybanan. Citybanan stretches between Södra station and Odenplan City station and consists of a 6 km long tunnel. The new tunnel includes two stops with enclosed platforms, e.g. the aim is to provide cleaner air on the platforms by trapping the particle rich tunnel air inside the tunnel and also to prevent suicide attempts. However, this have caused concern among the train staff. The main aims of this work is to evaluate 1) Particle concentration inside driver cabins 2) filtration efficiency of ventilation system in driver cabins and 3) Particle concentrations on platforms at stations inside rail road tunnels.

Methodology and Results
This study consists of two parts. During first part, which was a pre-study before the opening of Citybanan, the filtration efficiency in the driver cabin ventilation system was evaluated by comparing PM10, PM2.5 and PM1 concentrations inside driver cabins with those on the platform in an existing rail road tunnel. The tunnel is 5 km long and includes one stop, at Arlanda Central station. Measurements were performed using portable particle instruments Lighthouse 3016 IAQ inside trains and ELPI+ and Lighthouse 3016 IAQ on the Arlanda Central platform. Two staff members are located on the train, a driver that normally does not open the door and a train host located in cabin in the middle of the train, which regularly opens the door during stops. The measurements showed that the concentration of PM10 inside driver cabins was approximately 20 % of that on the platform, given that no door was opened during the stop at the station. The average PM10 concentration on platform was 155 µg/m^3 during the 5 days of measurement 28th Nov- 2nd Dec 2016.

During the second part of this study, particles concentration were monitored inside driver cabins traveling Citybanan during three days. Measurements were performed during three days at morning and evening rush hours including a P-trak, and two Lighthouse IAQ 3016 in both cabins with staff. For comparison simultaneous measurements were performed at one of the stations with enclosed platform, Odenplan City. The results showed increasing particle concentrations from morning to evening rush hour every day on the platform. The levels were lowest on Monday and highest on Wednesday, indicating that particle concentration build up during week due to heavy traffic compared to during weekends. The particle concentrations were similar to those in the Arlanda tunnel during the pre-study. The results from the on-board measurements shows that the driver, that works in an enclosed environment with filtration of incoming air are exposed to significantly lower particles levels than the other train staff, which opens the cabin door during stops at stations. The driver's exposure during the travel inside the tunnel have been compared with the train host exposure and the commuters spending time on the Odenplan platform the same amount of time. The analysis showed that the driver exposure is lowest, the train host have medium exposure with brief peaks and the commuters on platform experience the highest average concentrations. Moreover the platform measurements at Odenplan also showed that moving closer to the doors leading to the rail road tracks resulted in higher concentrations suggesting that the particle concentrations on the platform would be higher without the enclosure. More work is planned to be performed in the coming week in which includes simultaneous measurements on platforms at all stops within Citybanan tunnel and a station after the tunnel including ELPI+, Lighthouse and P-trak.

Conclusions
The filtration system inside the drives cabins are working efficiently providing a good work environment even inside tunnel systems. Overall PM10 and PM2.5 concentrations inside cabins are low, as long as that doors are closed. The enclosed platform in the Citybanan tunnel have probably lead to lowering the particle exposure for the commuters, although their exposure are significant, comparable to the Arlanda rail road tunnel outside Stockholm, in Stockholm county.

Acknowledgement
This work was commissioned by Stockholm public transport company SL. We acknowledge staff at KTH for their help during sampling and analysis.

Air Quality Forecasting

COMPOSITION AND ORIGIN OF FORECASTED SURFACE PM_{10} OVER EUROPEAN CAPITALS DURING A POLLUTED EVENT IN DECEMBER 2016

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Summary
By focusing on a specific episode, this study aims to test the reliability of our new forecasting and near-real time source allocation system for surface PM_{10} concentrations over all European capitals by comparing the predictions with observations and inter-comparing simulations from two different regional chemistry transport models. The concentrations are calculated over the 28 European capitals plus Bern, Oslo and Reykjavik. The system is able to predict in near-real time the local and external contributions of the PM_{10} concentrations over different capitals, investigated further here for a pollution event occurring between 01 and 09 December 2016. Inter-model discrepancies in the PM_{10} concentrations and simulated ratios between local and external contributions are discussed.

Introduction
Particulate matter with an aerodynamic diameter lower than 10 µm (PM_{10}) is a well known pollutant, which is related to mortality at high exposure. The World Health Organization (WHO) states a guideline value of 50 µg/m^3 daily mean that should not be exceeded in order to ensure healthy conditions. 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 31 European cities (EU28 + Iceland + Norway + Switzerland) on a daily basis within the CAMS71 Copernicus project. The LOTOS-EUROS chemistry transport model (Manders et al., 2017) has also been used in several air quality studies over Europe, especially for PM. Intercomparison studies shows a good correlation for the different PM components, but also a systematic underestimation in total PM mainly due to missing processes description for secondary organic aerosols.

Methodology and results
Each source receptor simulation is done with a horizontal resolution of 0.25°×0.125°, using the anthropogenic emissions from TNO-MACC version 3, forest fires from GFAS and chemical boundary conditions from ECMWF-IFS. The determination of the origin of PM_{10} for EMEP/MSC-W is based on the difference between a base run where all emissions are included in full, and perturbation runs where the anthropogenic emissions over the source area are reduced by 15%. In LOTOS-EUROS, the source apportionment is directly calculated in an integrated module.
The impact of the definition of the city area on the budget of PM_{10} (local and external contributions) has been studied here. It appears that in particular the local contribution is very sensitive to its definition.
A large influence of dust has been shown over Valetta, sea salt over Reykjavik, while PM_{10} over Berlin was largely influenced by sea salt and secondary inorganic aerosols. PM_{10} was dominated over Bucharest by primary organic matter. For the period under study it can be shown that the PM_{10} over Paris was largely influenced by external sources, representing up to 80% during a few days as shown in Fig. 1.

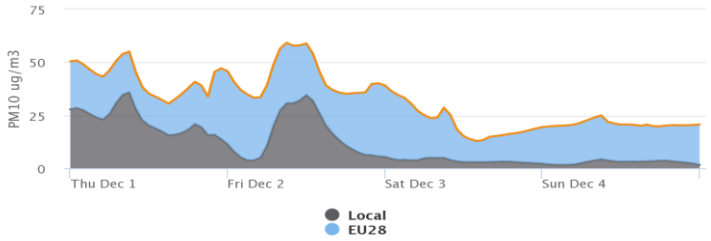

Fig. 1 Time-series of PM_{10} concentrations forecasted by EMEP/MSC-W over Paris from December 1st to December 4th 2016. The grey color represents the local contribution and the blue color represents the EU28 external contribution. The orange line highlights the total PM_{10}.

Conclusion
Comparisons to data are used to investigate further how reliably EMEP/MSC-W CTM simulates surface PM_{10} over European cities and whether the source receptor calculations contribute to the understanding in the origin of the surface pollution.

Acknowledgement
This work is partly funded by the EU Copernicus project CAMS 71 to provide policy support. The EMEP project itself is supported by the Convention on the Long Range Transmission of Air Pollutants, under UN-ECE.

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ATMOSPHERIC CHEMISTRY WITH THE ONLINE MULTISCALE NMMB-MONARCH V1.0 MODEL: GLOBAL-REGIONAL EVALUATIONS AND DATA ASSIMILATION

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Summary
The Multiscale Online Nonhydrostatic AtmospheRe CHemistry model (NMMB-MONARCH v1.0), formerly known as NMMB/BSC-CTM, is a fully online integrated system for meso- to global-scale applications developed at the Barcelona Supercomputing Center (BSC). The model provides operational regional mineral dust forecasts for the World Meteorological Organization (WMO; https://dust.aemet.es/), and participates to the WMO Sand and Dust Storm Warning Advisory and Assessment System for Northern Africa-Middle East-Europe (http://sds-was.aemet.es/). Additionally, the system contributes with global aerosol forecast to the multi model ensemble of the International Cooperative for Aerosol Prediction (ICAP; http://icap.atmos.und.edu/) initiative. The model will be the next generation chemical weather driver for the CALIOPE air quality forecasting system maintained by BSC (http://www.bsc.es/caliope/es), replacing the current version based on the WRF-CMAQ offline models.

In this talk, we will present an overview of the system with emphasis on recent developments and the new data assimilation capability. NMMB-MONARCH v1.0 has been enhanced with a new hybrid sectional-bulk multicomponent aerosol module. The aerosol module is designed to provide short and medium range forecast of the atmospheric aerosols for a wide range of scales, with the option to adjust the complexity of the chemistry scheme as desired. The module describes the lifetime of dust, sea-salt, black carbon, organic matter (both primary and secondary), sulfate and nitrate aerosols. While a sectional approach is used for dust and sea-salt, a bulk description of the other aerosol species is adopted. The CB05 chemical mechanism can be selected to solve the gas-phase chemistry or, alternatively, climatologies of most important oxidants are used for simplified aerosol runs. A simplified gas-aqueous-aerosol mechanism has been introduced in the module to account for the sulfur chemistry and a two-product scheme is used for the formation of secondary organic aerosols.

Both global and regional experiments will be presented. The model has been configured for a global aerosol evaluation experiment by applying emissions from the AEROCOM-HTAP v2 dataset together with online MEGAN biogenic emissions, and GFAS v1.2 biomass-burning analysis. Simulations of the global aerosol distribution have been performed over a 5-year period (2012-2016) at 1.4º x 1º horizontal resolution and 48 vertical layers. The total aerosol optical depth has been evaluated with AERONET and MODIS observations, while the intensive optical properties (single scattering albedo and asymmetry parameter) have been compared with available data from AERONET stations. Furthermore, results of a regional experiment over Europe at high-horizontal resolution (12 km x 12 km) with the full gas and aerosol chemistry activated will be described.

Finally, the aerosol data assimilation capability built for NMMB-MONARCH v1.0 will be presented. An ensemble-based data assimilation scheme (namely the local ensemble transform Kalman filter – LETKF) has been utilized to optimally combine model ensemble forecasts and observations, using a perturbed physics ensemble of NMMB-MONARCH v1.0 . Results assimilating mineral dust optical depth derived from satellite retrievals (MODIS AOD Dark Target and Deep Blue) show a significant improvement of the forecast of mineral dust.

This acquired new capability of assimilating observations and running ensemble forecasts, together with the above mentioned modelling enhancements, puts NMMB-MONARCH v1.0 at the forefront of current state-of-the-art research and operational chemical weather systems.

Acknowledgement
BSC researchers acknowledge the grants CGL2013-46736-R and CGL2016-75725-R of the Spanish Government.

EVALUATION OF THE COPERNICUS ATMOSPHERE MONITORING (CAMS) REANALYSIS WITH RESPECT TO OZONE AND CARBON MONOXIDE

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Summary
The Copernicus Atmospheric Monitoring Service CAMS provides continuous air-quality data, forecasts and processed information on atmospheric composition, supporting policy makers, business and citizens with enhanced environmental information. Recently CAMS has started producing a new reanalysis dataset, providing amongst others, global fields of carbon monoxide and ozone. The CAMS validation team is currently evaluating the first years of this reanalysis. First results indicate that surface carbon monoxide and ozone as well as tropospheric ozone could be reproduced with rel. biases mostly within ±10%, showing strong improvement compared to the former reanalysis run produced during the Monitoring of Composition and Climate (MACC) pre-operational phase of CAMS.

Introduction
Some of today's most important environmental concerns, such as air pollution or the concentration of greenhouse gases, relate to the composition of the atmosphere. For the operational provision of enhanced data and processed information on atmospheric constituents, the European Union has established the Copernicus Atmosphere Monitoring Service (CAMS) as part of the European Copernicus Program for monitoring the earth (http://atmosphere.copernicus.eu). CAMS provides, amongst others, daily forecasts of greenhouse gases, aerosols and reactive gases on a global scale and supplies the boundary conditions for an ensemble of more detailed regional air quality models. The CAMS service also analyses retrospective data records for recent years. The production of a new reanalysis data set for the period 2003-2017 has just started in CAMS. Within CAMS there is a dedicated validation activity in the frame of the CAMS validation subproject, which focuses on a posteriori validation of the CAMS regional and global products (e.g. Eskes et al., 2015).

Methodology and Results
For this presentation we will focus on the first evaluation results for the new CAMS reanalysis product. The reanalysis provides three hourly outputs of model fields for carbon monoxide and ozone, which were compared to surface observations from the Global Atmosphere Watch Program (GAW). Special attention was given to the heat wave period in August 2003. For the evaluation of tropospheric ozone profiles, ozone soundings from various networks were compared to the reanalysis output profiles. Validation scores (e.g. rel. Bias, Modified Normalized Mean Bias-MNMB, correlation coefficient R) were calculated for each station on a monthly and on a seasonal basis (Wagner et al. 2015). It is shown that the CAMS reanalysis can reproduce surface mixing ratios for ozone and carbon monoxide for Europe with mean MNMBs ranging between 2 and -12% for ozone and between -5 and -13% for carbon monoxide during the winter season of 2003. During the summer season, MNMBs range between 11 and -4% for ozone and between ± 2% for carbon monoxide. Mean correlation coefficients are greater than 0.6. The comparison with ozone soundings in the free troposphere of the Northern midlatitudes shows MNMBs between -9 and 5% for 2003, see Fig.1.

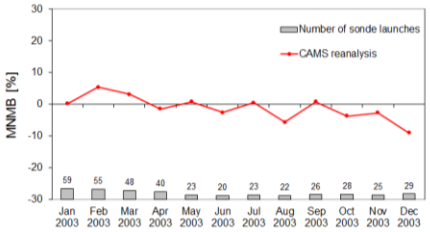

Fig.1 Modified Normalized Mean Bias of the reanalysis compared to ozone soundings over the Northern Midlatitudes

Conclusions
The CAMS production team is currently preparing a reanalysis data set of atmospheric constituents (e.g. ozone, carbon monoxide) for the period 2003-2017. We have validated the first year of data output for surface carbon monoxide and ozone as well as for tropospheric ozone profiles. Results show that the CAMS reanalysis shows a strong improvement compared to the former MACC reanalysis. Tropospheric and surface ozone and carbon monoxide have been reproduced accurately with MNMBs mostly smaller than ±10% and correlation coefficients greater 0.6.

Acknowledgement

We acknowledge the provision of data by the Global Atmosphere Watch (GAW) program and we wish to acknowledge the provision of ozone sonde data by the World Ozone and Ultraviolet Radiation Data Centre (http://woudc.org), by the Data Host Facility of the Network for the Detection of Atmospheric Composition Change established at NOAA (http://ndacc.org), by the Norwegian Institute for Air Research (http://nilo.no), and by the National Aeronautics and Space Administration (NASA). We acknowledge also with thanks the Copernicus funding provided by the European Union.

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A. Wagner; 2015. Evaluation of the MACC operational forecast system – potential and challenges of global near-real-time modelling with respect to reactive gases in the troposphere. Atmospheric Chemistry and Physics 15, 14005-14030.

AEROSOL PROFILE EVALUATION WITH IN THE COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS)

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Summary
Vertical profiles of aerosol backscatter coefficients (bsc), calculated from the Copernicus Atmosphere Monitoring Service (CAMS) global aerosol model are compared to bsc profiles measured by lidar-ceilometers within the network of the German Meteorological Agency (DWD, https://www.dwd.de/ceilomap). The model performance is evaluated as temporal correlation of bsc on selected model levels, monthly average profiles, and condensed in Taylor plots. Exemplary case studies are shown for Saharan dust events, long-range transported wildfire smoke and the aerosol loading in the planetary boundary layer (PBL). In general, a rather realistic aerosol distribution is provided by the model, particularly for long-range transport of Saharan dust and wildfire smoke. The sea-salt fraction is overestimated and the planetary boundary layer tends to be too clean and the transition to the free troposphere too smooth.

Introduction
The Copernicus Atmosphere Monitoring Service provides, amongst others, routine forecasts of trace gases and aerosols (https://atmosphere.copernicus.eu/) with the European Centre for Medium Range Weather Forecast (ECMWF) integrated forecast system (Benedetti et al, 2009). Verifications with bsc profiles, published in 3-monthly reports available at the CAMS website, serve as reference for users and developers at ECMWF.

Methodology and Results
The model fields, retrieved from the ECMWF archive, are converted from aerosol masses to backscatter coefficients by a forward operator which essentially consists of a look-up table of pre-calcuated aerosol-type/size and humidity dependent specific mass-backscatter coefficients. The impact of the assimilation is revealed by differences between the full model and a not constrained control run. Our focus is on the vertical variation. Both statistical analyses of means and correlations as well as process-oriented case studies are presented. The contributions from individual aerosol types are analysed to improve the representation of sources, sinks, transformations and transport of particles in the model.
Mineral (Saharan) dust is mostly captured accurately w.r.t timing, extension and measured bsc. Presence of smoke from wildfires is mostly reproduced but as for Saharan dust small vertical scales of few 100m are often not resolved. Yet there is no operational source for volcanic emissions.
The modelled vertical mean profiles agree reasonably to those from ceilometers (Fig. 1). The covariance with observed bsc on individual model levels reaches Pearson's r up to 0.37 and 0.34 for o-suite and control run, respectively. The aerosol load in the PBL is too small and the step at the top of the planetary boundary layer too lower values in the free troposphere is too smooth (Fig. 1).

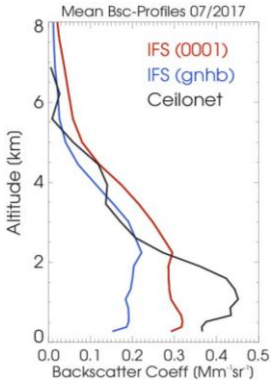

Fig.1: Mean bsc profiles from IFS model, control run and ceilometers in July 2017.

Conclusions
Source terms, transformation and transport of natural aerosols in the IFS model seem to be quite realistic, given the often good agreement to observed backscatter profiles. Dispersion and physical transformations of particles during transport (also long-range over several days) profit from accurate driving meteorology in the ECMWF model. The capping inversion at the top of the PBL is not yet resolved. Though it is no prognostic parameter, the Richardson diagnostic mixing layer height on average agrees reasonably to observations, although the latter have large uncertainties, too. The assimilation of column data scales up the whole profile rather than adding the appropriate larger portion to the PBL. It is expected that the introduction of nitrates in 2017/18 will improve but not solve this issue.

Acknowledgement
This work was funded by the European Union under Service Contract No 2015/CAMS_84/SC1 within the COPERNICUS European Earth Observation Programme (http://www.copernicus.eu/).

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BIAS CORRECTION OF MODERATE SCALE AIR QUALITY MODEL AS A PRAGMATIC TOOL FOR OPERATIONAL FORECAST AND HEALTH IMPACT ASSESSMENT

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Summary

We apply a simple statistical bias correction technique (empirical quantile mapping) to a long-term dataset of air quality forecasts over Europe and Italy. We used the WRF-CHIMERE modelling system, which provides operational experimental chemical weather forecast at CETEMPS (http://pumpkin.aquila.infn.it/forechem/), to simulate the years 2008-2012 at low resolution over Europe (0.5° x 0.5°) and moderate resolution over Italy (0.15° x 0.15°). We compared the simulated dataset with available observation from the European Environmental Agency database (AirBase) and characterized model skill and compliance with EU legislation using the Delta tool from FAIRMODE project (http://fairmode.jrc.ec.europa.eu/). We found that the model is generally positively biased for ozone (~50%), and negatively biased for PM10 (~50%). We show that a calibration period on 3 years of data is sufficient to greatly improve model skills and make it compliant with current European regulation. The corrected simulation is thus more reliable for operational air quality forecast and for health impact assessment.

Introduction

Deterministic air quality forecast is routinely carried out at many local Environmental Agencies in Europe and throughout the world by means of Eulerian chemistry-transport models. The skill of these models in predicting the ground-level concentrations of relevant pollutants (ozone, nitrogen dioxide, particulate matter, and others) a few days ahead has greatly improved in recent years, but it is not yet always compliant with the required quality level for decision making (e.g. the European Commission has set a maximum uncertainty of 50% on daily values of relevant pollutants). Post-processing of deterministic model output is thus still regarded as a useful tool to make the forecast more reliable.

Methodology and Results

The bias correction technique employed here is termed "empirical quantile mapping". Basically, it consists in calculating correction factors to the simulated cumulative distribution function (empirical quantiles), in order to make it equal to the observed distribution. The factors are estimated on a calibration period, and the applied to any other period of interest. Here we tested several configurations for the length of the calibration period and the frequency of update of the correction factors for PM10 and ozone. We evaluated improvement of model skills as a function of season, type of site, and forecast lead time.

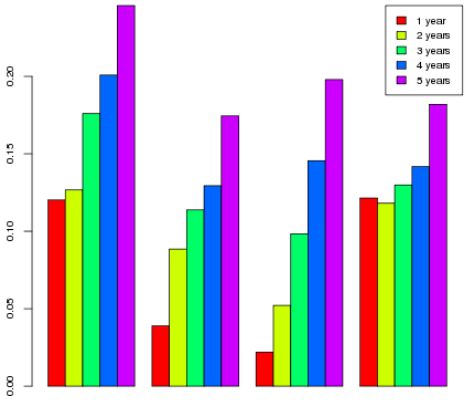

Fig.1 Coefficient of Efficiency of bias corrected PM10 simulated over Italy, at varying length of the calibration period.

Conclusions

We recommend the use of at least 3 years of data for the calibration of the bias correction. The method is effective for both PM10 and ozone, for all seasons and type of site (background, industrial, traffic). The benefit of the correction is generally maintained up to 2-3 days ahead of forecast. The moving window around a target day should be 3 weeks for spring-summer and 1 week for autumn-winter. Future developments include spatialization of the bias correction to grid cells without observations and test at forecast lead times beyond 3 days.

Acknowledgement

Computational resources were provided by Gran Sasso National Laboratory (LNGS) in the frame of the «Gran Sasso Computing Award 2015». This work was partly carried out in the frame of the "Smart Clean Air City L'Aquila" project, Italian Ministry of the Economic Development, codice programma n. M/0007/03/X23. R packages: openair, downscaleR

MOBILE APP FOR AIR QUALITY FORECASTING IN GUADALAJARA, MEXICO

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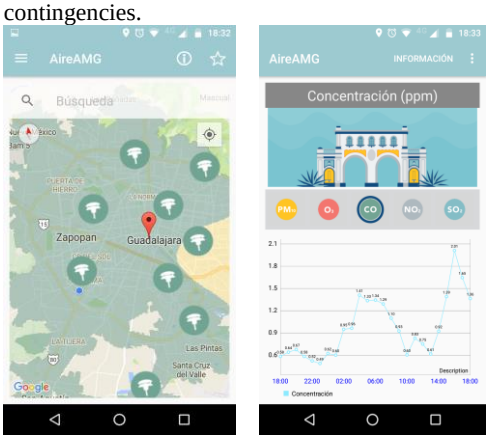
Summary
AireAMG is a mobile app for air quality forecasting in the Guadalajara Metropolitan Area in Mexico. This app uses real-time air quality measurements of five criteria pollutants, along with meteorological data, to forecast air pollution concentration. A novel scheme of Artificial Neural Networks (ARN) coupled to Kalman filters is used to generate air quality predictions for up to 24 hours for each of the monitoring stations locations. We used these predictions to generate ozone and particulate matter dispersion maps, by interpolating with the Inverse Distance Weighted (IDW) method. AireAMG updates these forecasts and dispersion maps every hour, and is available for Android and iOS systems.

Introduction
Air quality is a growing concern in megacities such as Guadalajara, Mexico. Local air quality contingency plans must take into account air quality forecasting, in order to better react and prevent poor air quality episodes. In addition, the general population needs to have accessible information regarding air quality, in order to prevent their exposure to high air pollutants levels. Systems such as Urban Air in China (http://urbanair.msra.cn/En) and USA's National Weather Service (http://airquality.weather.gov/), offer real-time air quality forecasting to the general population. SIMAJ, is the Atmospheric Monitoring System for the Guadalajara Metropolitan Area (http://siga.jalisco.gob.mx/), and offers real time air pollution measurements, but fails to provide specific forecasting of air quality. AireAMG is a mobile app system that offers air quality forecasts, based on SIMAJ's air quality measurements and is available for Android and iOS systems.

Methodology and Results
SIMAJ, the Atmospheric Monitoring System for the Guadalajara Metropolitan Area has ten air quality monitoring stations distributed throughout the city. AireAMG takes from SIMAJ real-time concentrations of five criteria pollutants: ozone, carbon dioxide, nitrogen dioxide, sulphur dioxide and particulate matter PM_{10}; along with four meteorological parameters: temperature, relative humidity and wind speed and direction. These parameters are used as inlets for a novel scheme of Artificial Neural Network (ARN), coupled with Kalman filters (González-Figueredo & Ramírez-Briseño, 2016), to forecast air quality levels in each of the ten locations of the monitoring stations. Then, we use the IDW method to interpolate air quality levels, and generate pollutant dispersion maps. IMECA colour code is used to represent the pollution magnitude (Norma NADF-009-AIRE-2006), as shown in figure 1a. The mobile app can show a dispersion map for ozone and PM_{10}, since these two parameters are those that usually reach values superior to the norm.
AireAMG allows the user to select any location in the city, and a pop-up screen shows the forecasting for the five criteria pollutants, as shown on figure 1b. The user can also save their favorite locations in order to follow the air quality easily.

Conclusions
AireAMG is the first mobile app in Mexico that offers air quality forecasts, not just real-time information. This app offers useful information for government agencies, and general population, and it can be used for decision-making regarding episodes of environmental contingencies.



a) *b)*

Fig. 1 AireAMG mobile app interface: a) pollutant dispersion map, b) air quality forecasting.

Acknowledgement
This work was funded by SICyT and COECyTJAL, through the 2015 grant for developing mobile apps with high social and environmental impact.

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Atmospheric - Climate Interactions and Impacts

SPECIAL SESSION

ENVIRO-HIRLAM DOWNSCALING IN RESEARCH AND OPERATIONAL APPLICATIONS FOR PEEX

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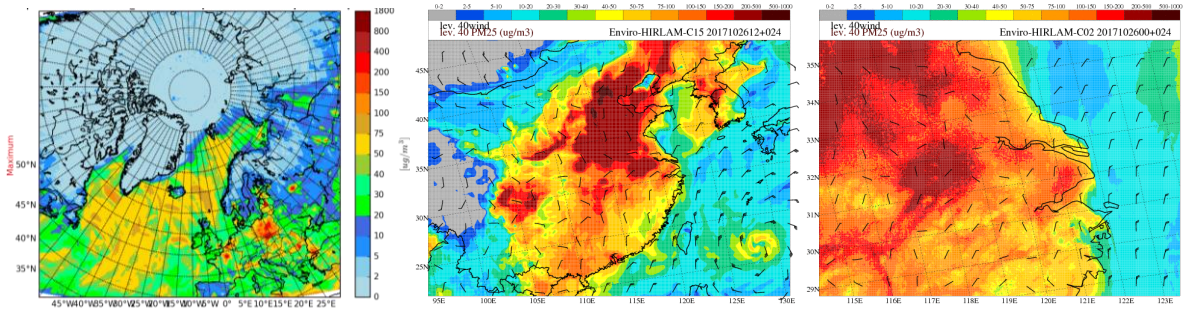
Summary
Applicability of the Enviro-HIRLAM modelling system in both research and operational modes for selected studies (based on research projects) in the PEEX domain is shown on examples with focus on regional-subregional-urban scales.

Introduction
The Pan-Eurasian EXperiment (PEEX; https://www.atm.helsinki.fi/peex) is a long-term interdisciplinary climate change, air quality, environment and research infrastructure programme. The main focus is on the Northern Eurasia, and in particular, for the territories of the Arctic-boreal regions and China. Since 2014, the PEEX-Modelling-Platform (PEEX-MP) has utilised a set of various models (30+ in total) run at different scales, resolutions, domains, etc. and used as research tools providing insights and valuable information/ output for different level assessments for environment and population. One of these models is seamless /online coupled integrated meteorology-chemistry-aerosols system, the so-called Enviro-HIRLAM. Seamless modelling of both meteorology and atmospheric composition provides additional value for PEEX studies.

Methodology and Results
Enviro-HIRLAM: Environment – HIgh Resolution Limited Area Model is developed as a fully online integrated numerical weather prediction and atmospheric chemical transport model for research and forecasting of joint meteorological, chemical and biological weather at multi-scales (Baklanov et al., 2017); and includes two-way feedbacks between air pollutants and meteorological processes. Different Enviro-parts were evaluated vs. ETEX-1 experiment, Chernobyl accident, regional-subregional-urban studies in EU FPs FUMAPEX, MEGAPOLI, TRANSPHORM, PEGASOS, MACC, MarcoPolo projects.
Research Mode: model was adapted, setup and run for areas (Fig 1a; which included selected Arctic-boreal regions) to study effects of aerosols (direct, indirect and combined) feedbacks on meteorology in North-West Russia (& St. Petersburg) and spatio-temporal variability of concentration and deposition patterns of sulphates from the Kola Peninsula pollution sources, for selected periods with unfavourable meteorological and air pollution episodes in months of summer and winter.
Operational Mode: model downscaling service was setup in FP7 EU MarcoPolo project (http://www.marcopolo-panda.eu/products/regional-air-quality-forecasts/enviro-hirlam) to perform forecasting (Fig 1bc) at resolutions of 15, 5, and 2.5 km (focus on Shanghai metropolitan area). The downscaling was used to study formation and development of meteorological and chemical (with focus on aerosols) fields on regional-subregional-urban scales for a larger part of the most populated territories of China.



(a) *(b)* *(c)*

Fig.1 Examples of Enviro-HILRAM model output for PM2.5 concentration: (a) research mode – Jan 2010 maximum value in EU and Artic domains & (b,c) operational mode – Oct 2017 (b) forecast over China & (c) Shanghai metropolitan area.

Concluding Remarks
The application of the seamless/ online integrated Enviro-HIRLAM model in downscaling research and operational forecasting modes is important for decision-makers and end-users by providing information on both meteorological conditions and atmospheric composition (or air quality) over regions of concern including metropolitan areas. These are crucial for better evaluation of potential impacts, risks, vulnerability and consequences for population and environment. Such output is also useful for completed, ongoing and planed measurement campaigns focused on observations for atmospheric composition and meteorology and for in-depth studying of relationships, feedbacks, interactions, etc. between chemistry-aerosols and meteorology in a changing climate. The model is planned to be further developed and applied for different research tasks according to the PEEX Science Plan (http://www.atm.helsinki.fi/peex/images/PEEX_SP__27052015.pdf).

Acknowledgement
The work was supported by EU funding: FP7 MarcoPolo project (Grant Agreement Number 606953; http://www.marcopolo-panda.eu), & NordForsk funding – CRAICC-PEEX (2014-2015), CarboNord (2014-2017), CRUCIAL (2016-2017) projects.

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COMBINING CLIMATE MODEL SIMULATIONS AND OBSERVATIONS TO UNDERSTAND AEROSOL EFFECTS ON ARCTIC CLIMATE

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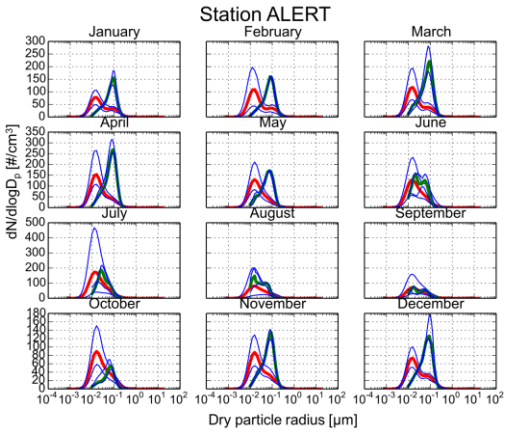
Summary
The objective of this work is to gain a process understanding of how mid-latitude aerosol emission changes influence Arctic climate. To this end, results from the general circulation model NorESM1 are combined with remote and in-situ observations of aerosol and cloud properties. Preliminary results show significant temperature responses in the Arctic despite weaker sea ice trends than observed. Modeld aerosol sizes are underestimated compared to in-situ observations implying that aerosol impacts on high-latitude low-level clouds might be underestimated in NorESM1.

Introduction
Previous studies using the general circulation model NorESM1 show that changing SO_2 emissions in various regions in the northern mid-latitudes cause significant surface temperature responses in the Arctic (Acosta-Navarro et al., 2016). The current work aims at gaining a process understanding of how these responses to mid-latitude SO_2 emission changes happen.

Methodology and Results
We compare modeled sea ice trends, aerosol and cloud properties to observations at high latitudes. Observations include in-situ aerosol size distribution observations (Freud et al., 2017), aerosol optical thickness (CALIPSO, Bourgeois et al., accepted), cloud cover fractions (CLARA-A2 Karlsson et al., 2016). Model data stem from the fully coupled ocean-atmosphere model NorESM1 (Kirkevåg et al., 2013 and references therein). Simulations follow the Climate Model Inter-comparison Project (CMIP 5) protocol. Aerosols are represented as internally and externally mixed particles that undergo physical and chemical processing and interact with radiation and cloud microphysics.



mean aerosol size distributions at station Alert. Blue lines indicate the range the data covers. Modeled (years 2005-2010, 3 unnudged runs) aerosol size distributions contain 15 data points for each month. Observational data cover the years 2011-2013 so each month contains up to three data points.

Preliminary results suggest that NorESM1 exerts rather weak sea-ice albedo feedback with decadal sea ice fraction trends two orders of magnitude smaller than observed. High-latitude (70-80°N) cloud cover fractions are consistently larger in NorESM1 compared to CLARA-A2. Moreover, convective transport of aerosol is overestimated in NorESM1 resulting in higher modeled free tropospheric aerosol optical thickness. Modeled aerosol populations are smaller than observations at five sites in the Arctic region show, especially during the winter months (Fig.1).

Conclusions
Given the above findings, Arctic aerosol activation and subsequent indirect aerosol effects might be underestimated in NorESM1. This has implications for the Arctic surface energy balance, which has been shown to be linearly proportional to the magnitude of arctic temperature amplification in various CMIP5 models (Nummelin et al., 2017).

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

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Summary
A dynamical modelling framework based on HadGEM3-ES2 and WRF-CMAQ has been used to study the role of regional meteorology and circulation patterns on extreme events over Asia for the present and future years. Simulations for four representative years (2000, 2020, 2030 and 2050) were conducted for this purpose. To characterise and quantify the changes in the circulation patterns, an Empirical Orthogonal Function (EOF) based analysis has been conducted. Wintertime minimum temperature is predicted to increase by 3-4^{0}C over Asia, whereas precipitation decreases by 20-30% during summer over South East Asia by 2050 compared to reference period of 2000. Furthermore, anti-cyclonic activity associated with low PV anomalies and high positive temperature anomalies influences the increase in frequency (3-4) and duration (~30 days) of heat waves and droughts over South Asia (SA), South East Asia (SEA), East Asia (EA) and North Asia (NA) regions of Asia. Overall, the results suggest that regional meteorology and circulation patterns influencing extremes over Asia and provides a deep insight for the policy implications involved in a warming environment.

Introduction
Synoptic weather and larger scale circulation patterns are closely coupled and have a major influence on regional weather and extreme events (e.g. Easterling et al. 2016). However, much of these studies are based on observational record and lacks in modelling effort. Considering this, an attempt has been made to examine the role of regional circulation on meteorology and extreme events in a changing climate over Asia.

Methodology and Results
In this study the initial and lateral boundary conditions from HadGEM2-ES global model have been used to drive the WRF-CMAQ. The model domain covers whole Asia (Fig.1) region with a horizontal resolution of 54 km and 36 vertical levels. Simulations were conducted for four HadGEM2-ES representative years (based on 10 years model runs) of 2000, 2020, 2030 and 2050. The model-simulated results are validated with the ERA-Interim reanalysis data. An Empirical Orthogonal Function (EOF) based analysis has been used to characterise and quantify the changes in the circulation patterns. Table 1 shows percentage variance of the first 5 EOFs for the geopotential height (Z) and basically reflects that how much of the aggregated yearly and seasonal atmospheric circulation can be explained by it in terms of its variance. More dominant effects are presented by the 1st EOF of Z followed by Tmax and Tmin that show an annual percentage of 80 to 82 % and a seasonal percentage ranging between 23 to 68 %. Further analysis shows that there is an overall increase in wintertime minimum temperature (by 3-4^{0}C) and decrease in precipitation (by 20-30%) over the Asian region. Furthermore, anti-cyclonic activity associated with low PV anomalies and high positive temperature anomalies influences the increase in frequency (3-4) and duration (~30 days) of heat waves and droughts over the regions of Asia.

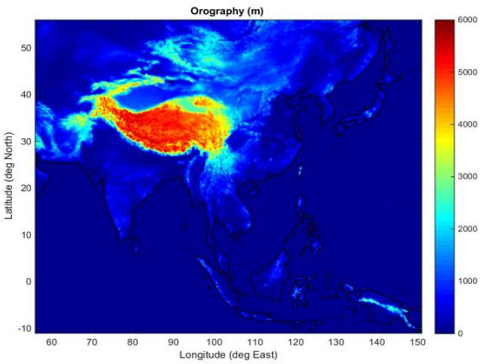

Fig.1 Model domain and topography (m)

Percentage (%) of variance explained by the first 10 seasonal and annual EOFs regarding Z300hPa

#EOFs	DJF	MAM	JJA	SON	Annual
1	66.2	62.1	40.4	67.2	82.5
2	9.7	14.7	20.7	13.9	5.9
3	4.5	5.1	9.6	4.3	2.8
4	3.8	4.1	5.3	3.6	2.1
5	3.1	2.6	4.5	2.4	1.4

Table.1 Percentage variance for the first five EOFs

Conclusions
This study shows an overall increase in wintertime minimum temperature and decrease in precipitation by 2050 over the region of interest. Results of this study have major implications for environment, health and socioeconomic state of the region.

Acknowledgement
This work is partly supported through TRANSPHORM (FP7) research project funded through the seventh framework programme of the European Commission. We acknowledge European Centre for Medium-Range Weather Forecasts (ECMWF) for making their ERA-Interim data available to this study.

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FINE PARTICLES IMPACTS ON HEALTH-CASES AND COSTS ON EUROPE UNDER CLIMATE CHANGE SCENARIOS

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Summary
Air pollution impacts human health, by the close relationship with climate change and because of the effects that pollution has on human health and welfare. This study tries to assess the impacts of present (1996-2015) and future (2071-2100) air pollution by fine particles on several pathologies and to estimate the difference in the costs associated to those health impacts on European population.

Introduction
Air pollution impacts health in a form that it also involves some associated external costs to society. This study is focused on particulate matter, especially fine particles (with a diameter of 2.5 μm or less, PM2.5). Exposure to PM2.5 is dangerous because they can reach lungs or even pulmonary alveoli, depending on particles size. PM2.5 impact on health is variable (from respiratory to until mortality) and all dwellers are under risk, especially children.

Methodology
In this work, air quality model data from the REPAIR project is used in order to check the possible changes in pathologies and diseases between present and future scenarios of climate change. The simulations used for assessing air quality in this work span the periods 1996-2015, as a present reference period, and 2071-2100 under RCP8.5 climate change scenario. The differences between these two runs will provide the changes in future air quality. The regional chemistry/climate model used has been WRF-Chem, assuming unchanged anthropogenic emissions but varying natural emission (which depend on climate conditions, and therefore vary in present and future simulations). Health effects studied in this work caused by fine PM2.5 are Respiratory and Cerebrovascular Hospital Admissions, Chronic Bronchitis, Congestive heart failure, Lung Cancer, Asthma, Diabetes and Premature Deaths.

Results and discussion
Nowadays, some south Europe areas are the most affected (northern Italy, southern Iberian Peninsula or southeast of Europe). For the future, these same areas are expected to increase their pollutants concentration levels. On the study area, some points exceed 90 μg/m³ of PM2.5 and they are expected to increase by almost 20 μg/m³. Chronic Bronchitis is closely related with particulate matter, though this pathology is widespread overall study area. Fig. 1 indicates that areas with higher pollution levels have a negative influence for the present on this pathology cases number. As for the aforementioned pathologies, for the future period (RCP8.5 scenario) an increase in cases for premature deaths is observed over southern Europe, leading to increases in the associated costs up to several billion euros.

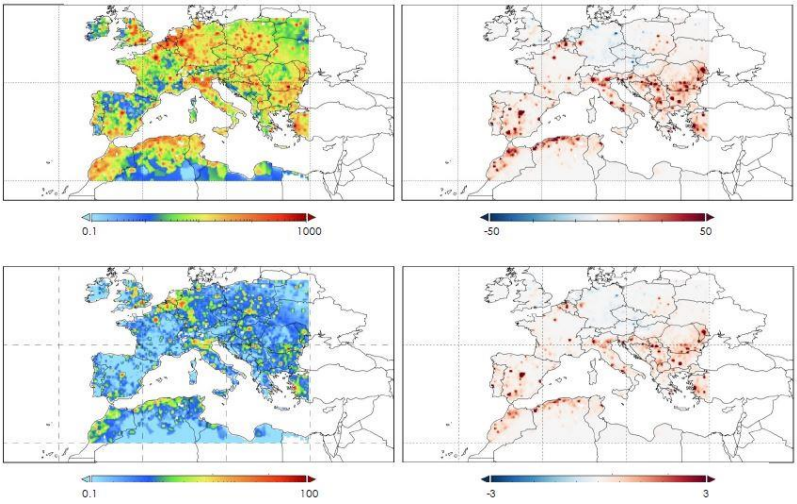

Fig.1 (Left column) (Top) Present cases by Chronic Bronquitis (CB) and (bottom) associated costs, in Meuro. (Right column) Changes projected in CB cases (top) and changes in costs (bottom) (Meuro) under the RCP8.5 scenario (2071-2100).

Conclusions
The most affected by fine PM2.5 pollution is southern Europe, especially the Mediterranean Basin. Premature deaths are the most important pathology in the study area in terms of costs and cases. All the pathologies included in this study will increase in the future period under climate change scenario if no mitigation policies for anthropogenic regulatory pollutants are implemented in Europe.

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DESCRIBING AIR QUALITY–CLIMATE INTERACTIONS WITHIN THE REPAIR PROJECT

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Summary

This work intends to characterize the role of aerosol effects on present climatologies under the umbrella of the REPAIR project and to evaluate modelling skills for reproducing aerosol-radiation and aerosol-cloud interactions. For that, two different simulations (with coupled chemistry, WRF-Chem, and not including atmospheric chemistry, WRF) have been evaluated against a number of different datasets. The results showed a general improvement in the temporal variability and correlation for several climatic variables (2-m temperature, precipitation) when the atmospheric chemistry was coupled with a regional climate model.

Introduction

The objective of the project *Air quality-climate interactions and impacts of renewable energies under climate change scenarios* (REPAIR) bases on the study of the impact of the air quality-climate interactions (AQCI) and potential future emission reductions due to the increased use of renewable energies (including wind and solar) on climate change in Europe through its mitigating role in radiative forcing and air quality. For that aim, a series of climate experiments have been conducted, covering present (1991-2010) and future (2031-2050) climatologies. Within the REPAIR project, this work aims to characterize the role of aerosol effects on the simulated present climatologies, which is one of the most important sources of uncertainty in the AQCI and to evaluate modelling skills for reproducing observed climatologies.

Methodology and Results

Simulations were run using the WRF-Chem model (Grell et al. 2005) version 3.6.1. The modelling domain corresponds to EURO-CORDEX at 0.44º and simulations cover a present period between 1991 and 2010. Two different scenarios have been evaluated: a base case, in which AQCI were not taken into account (WRF-alone); and a AQCI case, in which atmospheric chemistry was solved online and, thus, aerosol-radiation-clouds interactions were taken into account. The modelled climatologies for several climatic variables (mainly 2-m temperature, precipitation, radiation and wind) have been evaluated against observational data from the E- OBS database (Haylock et al., 2008). Particles mass [PM2.5 and PM10], sulfate [SO4], nitrate [NO3], ammonium [NH4], organic and elemental carbon [OC, EC] have been assessed versus observational data from AirBase and the European Monitoring and Evaluation Programme (EMEP). Moreover, aerosol optical depth at 550 nm (AOD555) have been compared with the Moderate Resolution Imaging Spectroradiometer (MODIS) retrievals from satellite. The evaluation of the simulations has been performed by using classical statistics. As an example, the results shown in Fig. 1 indicate that, although there is only a slight improvement in the bias of 2-m temperature when including the radiative feedbacks, the spatiotemporal variability and correlation coefficients are improved for the cases under study when atmospheric aerosol radiative effects were included. High AOD and particle matter levels were underestimated.

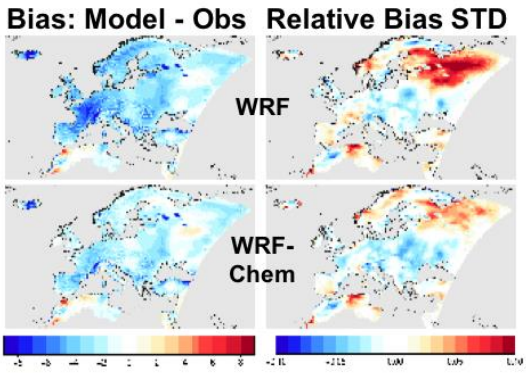

Fig. 1. Results for 2-m temperature. Right column: bias model against observation; Left: relative bias of standard deviation of model againts observation. Top: WRF-

Conclusions

In this study, a general improvement in the representation of modelled climatologies (e.g. temporal variability and correlation for 2-m temperature or precipitation) has been found, justifying not only the inclusion of radiative feedbacks in online coupled models, but also the increase in the computational time to include these effects. However, further studies are necessary to improve the model representation of aerosol optical properties. As far as we are concerned, this type of analysis has been carried out for certain episodes, so this study presented an added value because it covers climatically representative periods.

Acknowledgement

This work was supported by the REPAIR project (CGL2014-59677-R). Laura Palacios-Peña thanks to the scholarship FPU14/05505 from the Spanish Ministry of Education, Culture and Sports. As well as the people involved in E-OBS database, AirBase, EMEP and MODIS for providing this study with relevant data.

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INFLUENCE OF ATMOSPHERIC PRECIPITATION ON AIR COMPOSITION

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Summary
The influence of atmospheric precipitation on surface concentrations of main minor air gases (O_3, NO, NO_2, CO and SO_2) was studied by the data of measurements in Moscow. For this purpose dynamics of these gases from one minute to another was analyzed in time of each rain. All precipitation events during warm period of one year including even weak ones and, besides, all events of only strong showers during three years were taken into account. As a result of analysis only sulphur dioxide and ozone, unlike other gases, demonstrate on average statistically significant decrease in time of strong showers.

Introduction
Surface concentrations of minor air gases strongly depend on different meteorological parameters such as air temperature, wind speed, air humidity, etc. Among others, atmospheric precipitations may influence on them as well both directly (as a result of solution of gases on rain droplets, their wet deposition on the ground) and indirectly (due to strengthening both of wind speed and of vertical mixing during a rain). Special ecological station operated at the Meteorological observatory of Lomonosov Moscow State University (MSU) by common efforts of Obukhov Institute of Atmospheric Physics (IAP) and MSU continuously during the period from 2002 to 2014. Surface concentrations of all minor air gases were measured with 1 min temporal resolution. An accuracy of measurements was ±1 ppb for O_3, NO, NO_2, SO_2, and ±50 ppb for CO (Elansky et al., 2015). The influence of atmospheric precipitation on the air pollution levels was analyzed with the use of these data. Preliminary results were published in (Polezhayeva et al., 2011).

Methodology and Results
All records of station pluviograph at the MSU Meteorological observatory were precisely analyzed during three warm periods (from May to October) of three years (2002–2004) and, as a result, time of both beginning and end of each separate event of rains, including even weak ones, has been detected with an accuracy of ±1 min. The simultaneous each-minute measurements of surface concentrations of air pollutants at the ecologic station which operated at a distance of 50 m from pluviograph have been analyzed. Firstly a full sampling of all rains during one warm period of 2002, including weak rains (totally 59 cases) was used for the analysis. All data series of concentrations having a length of two hours (120 one-minute values) were normalized by the time of the rain beginning. Two partial samplings of 60 values before and after this moment were compared with each other. Besides, all rain events were divided into frontal and air-mass rains. In addition, frontal rains were divided into three groups: connected with cold fronts, warm fronts and occluded fronts. However it was found that neither full sampling of rains nor partial ones demonstrate on average clear influence on the air composition. Changes of all gases were quite different during separate rain events and an average tendency is not clear – probably, due to action of other factors. Then, separate sampling of only strong showers (having intensity not less than 0.1 mm per minute) which took place only after a long dry weather before them were taken into account (44 cases during three years). As is seen (Fig.1), strong showers clearly influence on ozone and sulphur dioxide. Average decrease of O_3 seems to be statistically significant with a 5% significance level. In addition, Student criterion was used for testing of this conclusion (both statistical distributions are close to the Normal law). As a result, it was found that differences between surface concentrations both of ozone, and of sulphur dioxide on average of 40 min (from 1 hour to 20 min before and from 20 min to 1 hour after the beginning of shower) are significant even with 0.999 confidence probability. Unlike them, CO doesn't demonstrate any clear changes – evidently, due to its extremely low solubility.

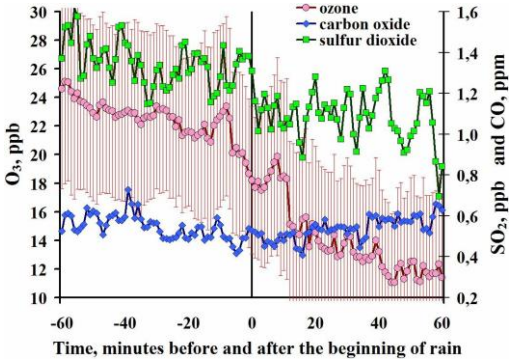

Fig.1 Average changes of the air pollution in time of strong showers in Moscow, 2004. The confidence intervals are calculated with 0.95 confidence

Conclusions
An influence of any rains on average of their full sampling including weak ones on dynamics of the main air pollutants is not clear. Only strong showers after long dry weather lead to statistically significant decrease of O_3 and SO_2. Unlike these gases, the CO surface concentration does not depend on precipitation.

Acknowledgement
This work was supported by the Russian Scientific Foundation (Project 16-17-10275).

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THE IMPACT OF CARBON MITIGATION MEASURES ON FUTURE AIR QUALITY

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Summary
Here we quantify the co-benefits to future air quality from implementing carbon mitigation measures to stabilise future climate. Two consistent future emissions scenarios are used within the composition-climate model HadGEM3-UKCA: one is a reference scenario of future economic growth and development (REF), whilst the other (RCP4.5) assumes the same development pathway but stabilises anthropogenic radiative forcing at 4.5 W m^{-2} in 2100. Implementing carbon mitigation measures in RCP4.5 reduces the impact of a changing climate on air pollutants and can additionally reduce their emissions by between 15-30% in 2050. The change in emissions and climate reduce annual mean surface concentrations of ozone and $PM_{2.5}$ by 10-20% over different world regions and the total number of days exceeding the World Health Organization's (WHO) daily mean air quality standards. In terms of climate forcing, the reduction in global mean effective radiative forcing (ERF) in 2050 relative to the present day due to enacting carbon mitigation measures is enhanced by decreases in tropospheric ozone but is partially offset by a positive aerosol ERF from reductions in aerosols. This study demonstrates that carbon mitigation policies to mitigate climate change have added co-benefits for global and regional air quality. However, the effectiveness of the carbon policies in reducing climate forcing is reduced due to the combined changes in ozone and aerosols

Introduction
Future policy measures to reduce air pollutants will improve air quality but policy measures aimed at reducing climate change could also inadvertently impact future air quality through changes to air pollutants co-emitted from carbon sources (West *et al*., 2013). Additionally, future changes in climate could also influence the concentration and spatial distribution of air pollutants – the climate penalty (Rasmussen *et al*., 2013). In this study, we quantify the impact on air pollutants from implementing measures to mitigate climate change, both in terms of their effect on air quality and climate forcing.

Methodology and Results
An emission scenario for the year 2000 is used as a baseline in this study and for model evaluation purposes. Two consistent future scenarios in 2050, developed by the same integrated assessment model, are used: one is a reference scenario (REF) of future economic development and population growth, whilst the other (RCP4.5) assumes the same development but applies mitigation measures to reduce carbon dioxide concentrations and stabilise anthropogenic radiative forcing at 4.5 W m^{-2} in 2100. The difference in emissions between RCP4.5 and REF are solely attributed to the effect of climate policies (e.g. Fig. 1 for SO_2). Here we have applied these two emission scenarios to a coupled composition-climate model (HadGEM3-UKCA) to ascertain the impact of such carbon mitigation measures on future air quality in 2050. Implementing carbon mitigation measures reduces future annual mean ozone and $PM_{2.5}$ surface concentrations by up to 20% in 2050. The total number of daily mean ozone and $PM_{2.5}$ exceedances of WHO daily mean air quality standards is also reduced in 2050. Carbon measures that reduce air pollutant emissions contribute more to the change in air pollutant concentrations than any changes induced by a modified future climate. Enacting carbon mitigation measures results in a positive aerosol ERF in 2050, relative to 2000, which partially offsets the benefits from the reductions in the global mean and ozone ERFs.

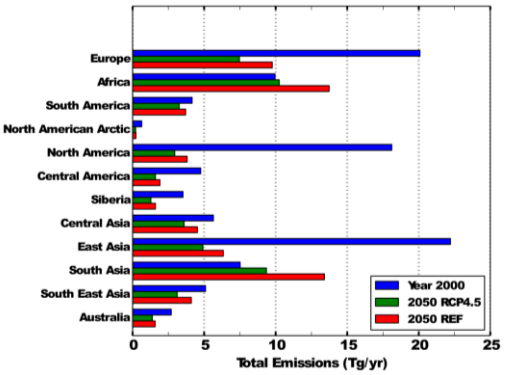

Fig.1 SO_2 emissions in 2000, REF and RCP4.5

Conclusions
Stabilising future climate by enacting climate mitigation measures has a co-benefit to air quality due to a reduction in the concentrations of air pollutants. However, the efficacy of carbon mitigation policies in reducing climate forcing is weakened from the opposite changes in ozone and aerosol ERFs.

Acknowledgement
Support for this work came from the BEIS Met Office Hadley Centre Climate Programme (GA01101) and the UK-China Research and Innovation Partnership Fund through the Met Office Climate Science for Service Partnership (CSSP) China as part of the Newton Fund.

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Meteorological Processes and Interactions

ON THE COMPARISON OF URBAN ENVIRONMENT EFFECTS PARAMETERIZATION

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Summary

The impact of cities and urban surfaces on weather, climate, and air-quality, is often assessed using modeling approach. In regional scale models, an urban parameterization in land-surface interactions can be included. This is especially important when going to higher resolution, which is common trend both in operational weather prediction and regional climate modelling as well as in coupled chemistry-transport modelling. However, model description of urban canopy related meteorological effects can significantly differ especially in the underlying surface models and the urban canopy parameterizations, which results in a certain uncertainty. To assess this uncertainty is important for adaptation and mitigation measures of the urban effects, which is often applied in the big cities, especially in connection to climate change perspective, but it is important in operational prediction as well. This is one of the main task of the project OP-PPR Proof of Concept UK as well as project Urbi Pragensi, where in addition to climate effects air-quality control aspects are studied. Effects of cities on urban and rural areas are evaluated, the impact of complexity of urban parameterization on the model results improvement is discussed with regard to demands on computational resources as well.

Introduction

The role of cities is increasing and will continue to increase in future, as the population within the urban areas is growing faster. Urban areas exert strong influence on human health through several different but partly cooperating ways. In term of direct effect of urban heat island, especially within episodes of heat waves the urban environment can cause the health risks as heart attack, especially to the specific groups of vulnerable people (elderly). Moreover, in longer term perspective it can be strengthen by the repeating abundance. In addition, the cities are significant sources of air-pollution emissions and following chemical reactions can be affected by the temperature and humidity, which are typically specific characteristics of UHI.

Methodology

In this study we assess the urban canopy meteorological forcing over central Europe on climate for the decade 2001-2010, using two regional climate models (RegCM4 and WRF) in 10 km resolution driven by ERA-Interim reanalyses. Three surface schemes (BATS and CLM4.5 for RegCM4 and Noah for WRF) and five urban canopy parameterizations are available: one bulk urban scheme, three single layer and a multilayer urban scheme. An example of the effect is shown in episode of weather prediction, where effects of resolution are shown. WRF options are tested for urbanized weather prediction in 3 km resolution as well.

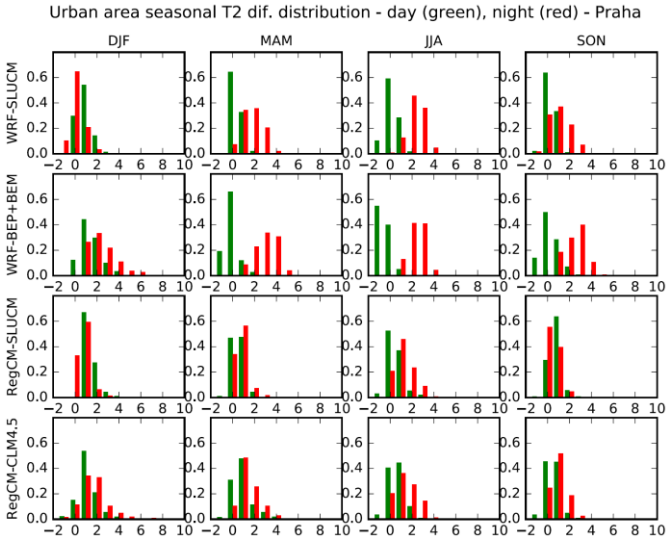

Fig.1 Urban heat island intensity for Prague

Results and Conclusions

Effects of cities on urban and remote areas are evaluated. There are some differences in sensitivity of individual canopy model implementations to the UHI effects, depending on season and size of the city as well. Effect of reducing diurnal temperature range in cities (around 2 °C in summer mean) is seen in all simulations, independent to urban parameterization type and model, due to well-known warmer summer city nights. On the other hand, very weak signal can be seen in bulk scheme for wind. Further, winter boundary layer increase by 100–200 m, together with wind reduction, is visible in all simulations. For the adaptation and mitigation purposes, rather than the average urban heat island intensity the distribution of it is more important providing the information on extreme UHI effects as shown in Fig. 1,, e.g. during heat waves, with strong effects on human health. We demonstrate that for big central European cities this effect can approach 10°C, even for not so big ones these extreme effects can go above 5°C.

Acknowledgement

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SENSITIVITY STUDY OF THE AIR QUALITY TO URBAN HEAT ISLAND MITIGATION STRATEGIES DURING A HEAT WAVE EVENT IN MILAN (ITALY) USING WRF-CHIMERE AT HIGH RESOLUTION

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Summary

Urban environments present health-related issues, some of which such as Urban Heat Island (UHI), Heat Wave, and air quality, are linked to each other. In this study, we investigate the impact of the 2015 heat wave on air quality in Milan (Northern Italy) and the effects that UHI mitigation strategies have on air quality, through numerical simulations at high resolution with the WRF-CHIMERE modelling tool. The negative effect of the Heat Wave is significant both for Ozone, a typical summer pollutant, and for PM10, a typical winter pollutant; the introduction of highly reflective materials for urban surfaces is effective in terms of lowering the ambient temperature, while deteriorates the air quality as it changes the surface radiative balance and reduces vertical mixing. Because of the size of the population living today in cities, similar issues are of great relevance and require the extension of the analysis to other mitigation measures.

Introduction

The emergence of a Heat Wave exasperates the phenomenon of the UHI, that is the heating of urban areas compared to the surrounding rural ones, already of its concern for the healthiness of urban environments (Li and Bou-Zeid, 2013). In this study, we aim to investigate the effect of the 2015 Heat Wave on the air quality in the city of Milan (Northern Italy) and explore the impact of the introduction of UHI mitigation strategies, e.g. highly reflective surfaces.

Methodology and Results

The modelling tool based on the WRF meteorological model and the CHIMERE chemistry-transport model has been used to simulate at high resolution (about 1 km) the urban atmosphere over Milan (Northern Italy) during the 10-day heat wave occurred in the July 2015 (label "2015" in Fig.1 and Fig.2). In order to investigate effects of such an event on the air quality we performed also a simulation of the same time perod in 2014 (label "2014" in Fig.1 and Fig.2); furthermore, we investigated secondary effects of UHI mitigation strategies on air quality through a simulation of the same target period in 2015 using for urban surfaces a value of albedo typical of highly reflective materials (label "2015 HA" in Fig.1 and Fig.2). The effect of the Heat Wave on both ozone and PM10 is significant; the increment of ozone concentrations especially during the central hours of the day is expected, given the known link with temperature. Results also show a positive effect of using high-albedo materials on the temperature and at the same time a negative effect on air quality with an increase in hourly concentrations of PM10 and ozone. Changing the radiative surface balance and reducing the Planetary Boundary Layer height is definitely crucial, and horizontal dynamics must also be investigated.

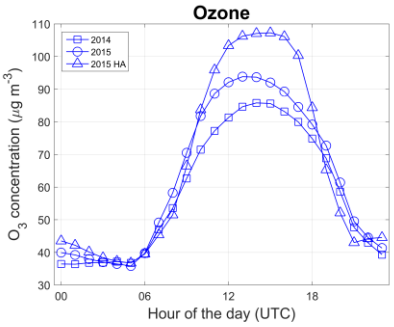

Fig.1 Average daily cycles of ozone

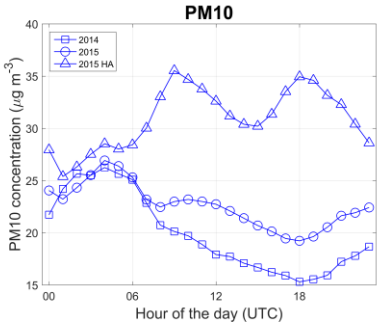

Fig.2 Average daily cycles of PM10

Conclusions

This study shows the negative impact that the 2015 heat wave had on air quality in Milan compared to the previous year and at the same time the non-positive effects on pollutant levels of using highly reflective materials. Considering the expected increase in frequency and duration of the heat wave due to climate change (IPCC, 2013), all this reveals the need to explore all possible ways to mitigate Heat Wave effects on ambient air quality.

Acknowledgement

Computational resources were provided by CINECA in the frame of Iscra-C ALTARIS7 project.

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STREET-LEVEL ASSESSMENT OF URBAN SCENARIOS ON THERMAL COMFORT AND AIR QUALITY BY THE MEANS OF NEWLY DEVELOPED URBAN SURFACE MODEL FOR LES MODEL PALM

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Summary
Urban mitigation scenarios for the development area in Prague, Czech Republic were calculated by the LES model PALM (Maronga et al, 2015) extended with the urban surface model for radiation processes (Resler et al., 2017). Scenarios included the effect of tree planting and surface albedo adjustment on the surface temperature and NO_X concentrations during a summer heat wave episode. It was shown that positive effect (cooling) in temperature can be accompanied by the increase of NO_X concentration. Thus the impact of urban mitigation scenarios has to be carefully assessed from all relevant points of view.

Introduction
Urban planning scenarios were evaluated for the block of buildings encompassing the crossroads of Dělnická Street and Komunardů Street in Prague, Czech Republic (50.1032431N, 14.4499719E, https://goo.gl/maps/7HvsN5SYwYn). This area was selected in coordination with the Prague Institute of Planning and Development as a case study area for urban heat island adaptation and mitigation strategies. This particular area represents a typical residential area in a topographically flat part of the city of Prague with a combination of old and new buildings and a variety of other urban components (such as yards or parking spaces). The area does not contain much green vegetation and the majority of the trees is located in the yards. The neighbourhood in the extent of approximately 1 km^2 has similar characteristics as the study area. For the sensitivity tests were chosen days 2–3 July 2015 which represents the time of a heat wave episode in Central European area.

To obtain surface (albedo, emissivity, roughness length, thermal conductivity, and capacity of the skin layer) and volume (thermal capacity and volumetric thermal conductivity) input material parameters needed for the proper setting of the PALM model, a supplemental on-site data collection campaign was carried out and a detailed database of geospatial data was created. This includes information on wall, ground and roof materials and colours which was used to estimate surface and material properties.

Calculations were done for: 1) reference (current) state, 2) widen Dělnická Street with trees along pavements on both sides, 3) widen Dělnická Street with trees in its centre. Also a sensitivity study evaluating the effect of position of tree alley was performed – the alley was gradually moved from one side of the street to the opposite side. Another type of sensitivity studies estimated the impact of changed surface colours. Evaluated parameters were temperature, NO_X concentrations, mean radiant temperature (MRT), and physiologically equivalent temperature (PET).

Results for the tree planting scenarios
Here, the results of two model runs are summarised: current state and scenario with widen Dělnická Street with a tree alley in the middle. The trees cool the street significantly. Nevertheless the decision, which scenario is the best one is not clear when also other criteria are taken into account: for the same scenario, increase of NO_X concentration could be noted.

Results for the albedo sensitivity tests
Results of the modelling with different surface colour (albedo) show that air temperature is influenced mainly by the colour of horizontal surfaces. One possible reason is that most of the radiation is adsorbed by the dark street surface that subsequently warms the adjacent air. It is also possible to see that the positive effect (cooling) in air temperature is accompanied by the increase of NO_X concentrations.

Acknowledgement
This work was done within the UrbanAdapt project (EHP-CZ02-OV-1-036-2015) supported by grant from Iceland, Liechtenstein and Norway. This work was also supported by the long-term strategic development financing of the Institute of Computer Science of the Czech Academy of Sciences (RVO:67985807).

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INFLUENCE OF SYNOPTIC CONDITIONS ON AIR POLLUTION IN MOSCOW

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Summary
This work is devoted to studying of synoptic conditions and their influence on surface concentrations of different air pollutants in big city (Moscow). The synoptic analysis of one full month (March of 2002) was made in two aspects: synoptic situation and a type of air mass. The average diurnal courses of both minor air gases (O_3, NO, NO_2, CO, SO_2) and submicron aerosol particles under different synoptic situations (types of baric field) and different air mass types are discussed.

Introduction
Air pollution strongly depends on synoptic conditions. Specific of synoptic analysis which was used here is high accuracy of the air mass type determination which was made accounting typical values of meteorological parameters for every type.

Methodology and Results
Detailed synoptic analysis of March, 2002, according to (Lokoshchenko, 1998), was carried out precisely in two ways. Firstly, one of five synoptic situations was determined: anticyclone centre, ridge axis, saddle or any weak-gradient field; cyclone centre or trough axis; forepart of cyclone or rear part of neighbouring anticyclone; cyclone rear or forepart of anticyclone; warm sector of cyclone. These types are divided from each other either by fronts or by lines of zero advection. Besides, a type of predominant air mass was determined as well using back trajectories of air particles, synoptic charts (surface, AT_{850}, AT_{700} and others), station data about main meteorological parameters (air temperature T, water vapour pressure, visibility range, etc.), sign and value of geostrophic advection $(\partial T/\partial t)_a$ and so on. All margins between different situations and air mass types were precisely determined with an accuracy of ±2 hours. Only periods of undoubted air mass types were taken into account for the analysis, without time of transitional or mixed types. Ecological station of IAP and MSU operated at the MSU Meteorological observatory. Each-minute measurements of minor air gases' surface concentrations were carried out with high accuracy: ±1 ppb for O_3, NO, NO_2, SO_2; ±50 ppb for CO (Elansky et al., 2015). Besides, submicron aerosol particles were measured here as well. As is seen (Fig.1), Arctic air mass (usually connected with cyclone rears) which was detected four times during this month is the cleanest among others (except only ozone) and the diurnal course of pollutants in it is smoothed. On the contrary, local (Continental Polar) air mass, which is observed as a rule at weak-gradient baric field, demonstrates both the highest levels of the air pollution, and the strongest diurnal courses. As is seen differs between Arctic and Continental Polar types as a rule are statistically significant. Maritime Polar air (which invaded into Moscow region six times during March, 2002) usually represents intermediate values. Regarding synoptic situations, the highest levels of the air pollution (except only O_3) are connected with weak-gradient baric field whereas the lowest ones were detected at cyclone rears; forepart and warm sector of cyclones demonstrate intermediate conditions. The levels of ozone in the afternoon are nearly the same at any type; at night their differences are clear and opposite to other minor gases.

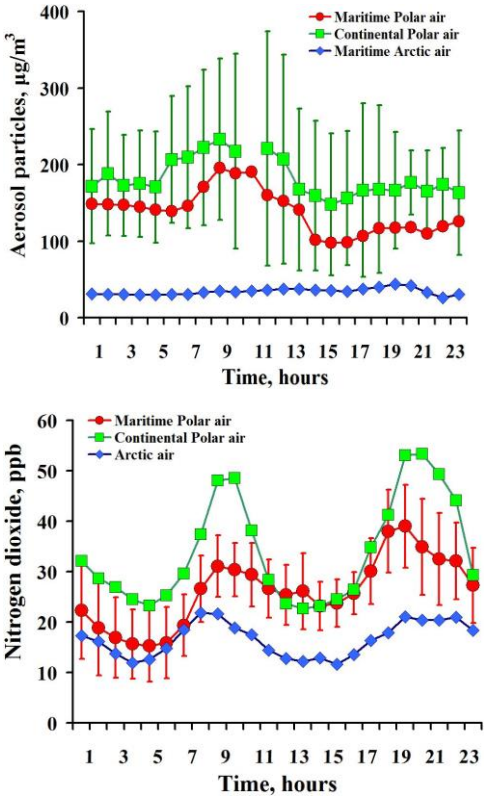

Fig.1 Average diurnal course of aerosol particles (top) and NO_2 (bottom) in conditions of different air masses. Moscow, March 2002. Confidence intervals are calculated with 5% significance level.

Conclusions
Both synoptic situation and air mass type strongly influence on the air pollution. The dynamics of O_3 is opposite to other minor gases: its surface concentration is the highest at cyclone rears and in conditions of Arctic or local air masses. All the rest minor gases, as well as aerosol particles, vice versa, demonstrate minimal levels at cyclone rear and in Arctic air mass.

Acknowledgement
This work was supported by the Russian Scientific Foundation (Project 16-17-10275).

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TURBULENCE AND DIFFUSION IN ATMOSPHERIC SURFACE LAYER: NEW KNOWLEDGE TOWARDS ADVANCED TOOLS FOR MODELLING AIR POLLUTION

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Abstract
Since the first publication in 1954, Monin-Obukhov Similarity Theory (MOST) of the surface-layer turbulence remains universally recognised. MOST underlies calculation of turbulent fluxes at the Earth surface, definition of turbulent viscosity, heat-conductivity and diffusivity, and modelling air pollution. In spite of principal inconsistencies in unstable and strongly stable stratifications, MOST has not been seriously questioned. Silent reluctance to revise MOST is not surprising. Its major drawbacks root in fundamental restrictions inherent to the common vision of turbulence, principally based on the paradigm attributed to Kolmogorov (1941a,b, 1942). Revision of MOST factually implies revision of the basic paradigm. However, Kolmogorov considered only the shear-generated turbulence in neutrally stratified flows. Subsequent acceptance of his vision of this particular type of turbulence as an ultimate paradigm for turbulence in any stratified flows was done without proof by Kolmogorov's followers. In this paper we revise the conventional paradigm and demonstrate its failures, causing failures of MOST in unstable and strongly stable stratifications. We also outline advanced theory of turbulence and diffusion in stratified sheared flows with due regard to its self-control affording its maintenance in supercritical static stability typical of the free atmosphere, and inverse energy cascade in buoyancy-generated turbulence causing generation of self-organised structures in convective boundary layers.

Acknowledgement
This work has been supported by the Academy of Finland project ABBA No. 280700 (2014-2017), and Russian Science Foundation projects No. 15-17-20009 (2015-2018) and No. 15-17-30009 (2015-2018).

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INFLUENCE OF THE MIXING LAYER HEIGTH ON URBAN AIR QUALITY OVER BARCELONA

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Summary
Thickness of the Mixing Layer Height (MLH) in Barcelona was calculated on an hourly basis from ceilometer measurements. MLH data was compared with hourly and daily concentrations of a number of atmospheric pollutants concentrations recorded at a nearby urban background site. Time volution of MLH was studied for different meteorological scenarios. A high influence of the MLH on concentrations of specific primary and secondary pollutants was evidenced but in for some pollutants the net effect was opposite (NO, NO_2, BC and PM1 vs O_3) and in some cases no influence was observed (PM coarse).

Introduction
Thickness of the MLH may have a considerable effect on concentration of atmospheric pollutant in urban environments. This influence will vary depending on the meteorological scenarios and on the nature and origin of pollutants affecting their health outcomes.

Methodology and Results
The MLH in Barcelona (NE Spain) was calculated by means of the simple parcel method (Holzworth, 1964) by using the vertical profiles of pressure (P) and temperature (T) from radiosondes launched every day at 12:00 UTC. MLH was also calculated from the measurements carried out by using a ceilometer (VAISALA, CL31) installed at the roof of the Faculty of Physics of the Barcelona University. This technique permits us to calculate the MLH at a high time resolution. Results demonstrated a high correlation between the two techniques used for measuring MLH. Time evolution of MLH was calculated for daily and seasonal periods. We evidenced that the MLH was statistically lower during the occurrence of African dust outbreaks, as already being demonstrated by Pandolfi et al (2014).
The MLH data obtained at hourly resolution were compared with the hourly concentration of the different pollutants measured at the Palau Reial air quality monitoring supersite, located 100 m from the ceilometer location. MLH exerts a high influence on the concentrations of most primary and secondary atmospheric pollutants (NO, NO_2, BC, and PM1), increasing concentration when MLH decrease, independently of the wind speed. No influencewas observed for coarse PM (1-10 µm), more affected by wind speed. Conversely, other secondary pollutants, such as O_3, tend to increase with the MLH showing the importance of surface fumigation of high altitude O_3-rich layers due to the growth of the mixing layer as reported for the study area by Querol et al. (2017).

Conclusions
We evidenced the influence of the MLH on the concentration of primary and secondary atmospheric pollutants by comparing high time resolution data. Therefore, the continuous measurement of MLH could be a proxy of atmospheric pollution in a given area and may have a significant correlation with health effects, as evidenced by Pandolfi et al. (2015). Measuring and forecasting of MLH under specific meteorological scenarios may be used to alert air quality networks and most sensible population and to implement Air Quality improvement measurements.

Acknowledgement
This work was supported by the Ministry of Economy, Industry and Competitiveness (and FEDER funds under the project HOUSE, CGL2016-78594-R), the Generalitat de Catalunya (AGAUR 2015 SGR33 and Departament de Territori i Sostenibilitat

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PARTICULATE MATTER FORECASTING BASED ON METEOROLOGICAL CONDITIONS

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Summary
In this study a parameterized method has been developed to forecast air pollution based on the assumption that changes in air pollution levels from one day to another are mainly affected by the local meteorology. From this study it was emerged that there is a significant correlation between PM10 levels and relevant weather factors based on data acquired from 2011 onwards. Surface temperature and wind speed were identified as key weather factors for air quality forecasting,

Introduction
The present forecasting methodology is based upon the physical principle that the dispersion of air pollutants depends, to the largest extent, upon the current meteorology (e.g. Latini et al. 2002, Zeng et al. 2017). It is well recognized that pollution variations are not generally caused by sudden variations in the emission of pollutants, but result from the meteorological conditions, which differentiate the ability of the atmosphere to disperse the pollutants. Having this as a guide, we developed a semi-empirical algorithm that is based on a statistical analysis of the air quality for a specific area for a historical time interval of one year.

Methodology and Results
The developed algorithm enables 1-day PM10 forecast, based only on the value of temperature and wind speed for the following day. Knowing the temperature and wind speed of the following day, the PM10 levels can be estimated with an acceptable accuracy. In case that air pollution levels of the previous day are available from official or low-cost properly calibrated ground-based sensors or from satellite missions (e.g. CAMS), they can be integrated in the algorithm to increase the accuracy of the provided forecast. The methodology was validated by comparing the produced forecast concentration of PM10 with a set of field data from official air quality monitoring stations for several cities. It was deduced that this algorithm estimates PM10 concentration with an accuracy of approximately 70% for most of this cities. The accuracy of the algorithm will be tested with user-generated data in Norway, Germany, Belgium and Greece produced within the EU funded project hackAIR.

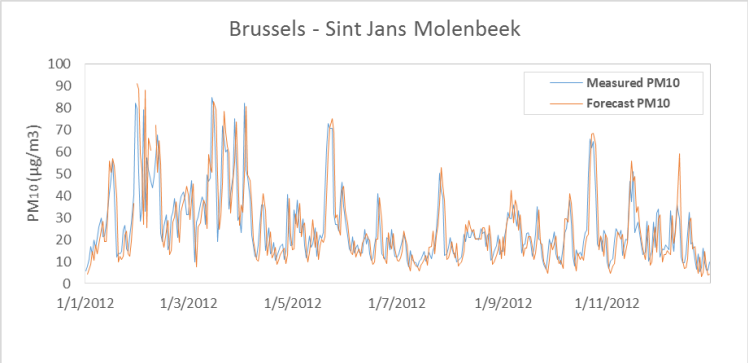

Fig.1 Correlation of PM10 estimates with official data in Brussels

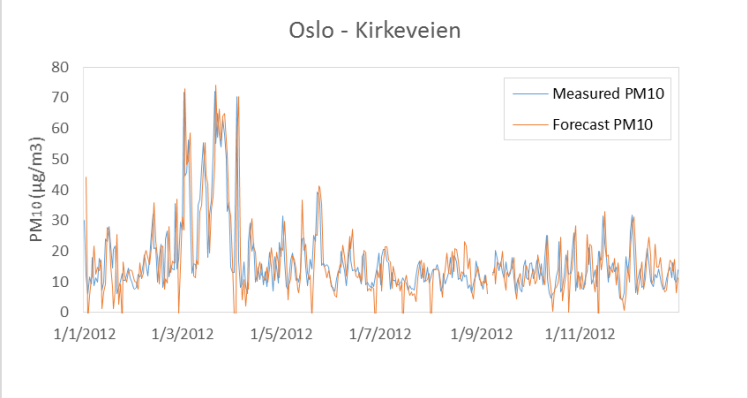

Fig.2 Correlation of PM10 estimates with official data in Oslo

Conclusions
The current study shows that regular meteorological conditions influence pollutants' dispersion, and thus PM10 levels can be estimated only from the forecast meteorology. The proposed algorithm requires very limited resources and it should be customized for every city of interest and a simple formula is produced as a result. This formula needs an update every one to two years depending on the city.

Acknowledgement
Further tests of the proposed algorithm will be executed with data acquired by the H2020 CAPS project hackAIR (Reference Number 688363).

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A MULTI-MODEL COMPARISON OF METEOROLOGICAL DRIVERS OF SURFACE OZONE OVER EUROPE

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Summary
This study aims to better understand how air quality models represent the relationship between meteorological variables and surface ozone concentrations over Europe. A multiple linear regression (MLR) approach is applied to observed and modelled time series across ten European regions in springtime and summertime for the period of 2000-2010 for both models and observations. Overall, the air quality models are in better agreement with observations in summertime than in springtime, and particularly in certain regions, such as France, Mid-Europe or East-Europe, where local meteorological variables show a strong influence on surface ozone concentrations. Larger discrepancies are found for the southern regions, such as the Balkans, the Iberian Peninsula and the Mediterranean basin, especially in springtime. All air quality models show more limitations to capture the strength of the relationship ozone-relative humidity detected in the observed time series in most of the regions, in both seasons. Here, we speculate that dry deposition schemes in the air quality models might play an essential role to capture this relationship. Further analysis of the relationship between ozone and maximum temperature (mo3-T, climate penalty) in observations and air quality models shows that the air quality models are able to reproduce reasonably well the observed climate penalty in summer in certain regions such as France, Mid-Europe and North Italy, but they overestimate the magnitude of the of observed climate penalty in spring.

Introduction
Quantification and isolation of the effects of meteorology on ozone is a challenge, due to the complex interrelation between ozone, meteorology, emissions and chemistry. The present study evaluates the capability of a set of Chemical Transport Models (CTMs) to represent the regional relationship between daily maximum 8-hour average ozone (MDA8 O3) and meteorology over Europe. Here, we aim to provide a simple method to examine the influence of meteorological variability on modelled surface ozone concentrations over Europe.

Methodology and Results
A multiple linear regression (MLR) approach is applied to observed and modelled time series across ten European regions (Fig.1) in springtime and summertime for the period of 2000-2010 for observations and a set of chemistry transport models (CTM) participating in the Eurodelta-Trends modelling experiment (Colette et al. 2017). Data used to estimate parameters of the MLR were spatially averaged over each region. Thus, we compare MLRs developed separately for CTMs and observations at each region and season, examining the contribution of the predictors in each MRL. Our results show systematic differences between the CTMs in reproducing the seasonal cycle when compared to observations (not shown here). In general, they tend to overestimate the MDA8 O3 in most of the regions. The effects of predictors revealed spatial and seasonal patterns, in terms of their relative importance in the MLRs. Particularly, we noticed a larger local meteorological influence in the regions located towards the interior, here termed as the internal regions and a minor local meteorological contribution was found in the rest of the regions, referred as the external regions (see Fig. 1).

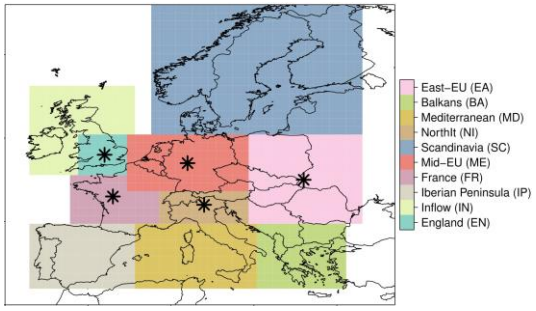

Fig.1 Regions considered in the study: a black star refers to the internal regions in the text. The rest of regions are referred to the external regions of the European domain.

Conclusions
Our results have shown that CTMs tend to overestimate the influence of maximum temperature and surface solar radiation in most of the regions, both strongly associated with ozone production. None of the CTMs captured the strength of the observed relationship between ozone and relative humidity appropriately, underestimating the effect of relative humidity, a key factor in the ozone removal processes. We speculate that ozone dry deposition schemes used by the CTMs in this study may not adequately represent the relationship between humidity and stomatal conductance, thus underestimating the ozone sink due to stomatal uptake. Further sensitivity analyses would be recommended for testing the impact of the current dry deposition schemes in the CTMs.

Acknowledgement
We acknowledge Jordan L. Schnell for providing the interpolated dataset of MDA 8 O3. Modelling data used in the present analysis were produced in the framework of the EURODELTA-Trends Project initiated by the Task Force on Measurement and Modelling of the Convention on Long Range Transboundary Air Pollution.

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AIR POLLUTION TRANSPORT FROM THE PO VALLEY TO THE WESTERN ALPS

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Summary: In this study, we investigate the transport dynamics of pollutants from the Po Valley over the North Western Alps (Italy). This is performed by coupling continuous monitoring of aerosols with modelling tools to discriminate between local emissions and transboundary pollution. Through specific case studies and a three-year statistics, we show that the Po Valley pollution regularly reaches and affects even Alpine sites considered as 'pristine', pointing to the need of air pollution mitigation policies acting, at least, over the regional scale.

Introduction : The Po Valley is a major hotspot of atmospheric pollution in Europe. Due to its topographical characteristics, pollutants are regularly transported to the Alps through thermally-driven winds and by Synoptic flows. This worsens the air quality in otherwise pristine sites and influences the radiative balance of mountain atmosphere by direct/indirect effects and by altering the surface albedo on snow-covered areas, therefore potentially modifying mountain climate.

Methodology and Results

The study was performed at the atmospheric observatory of ARPA Valle d'Aosta (Saint-Christophe, Italy), a measurement station at the bottom of an Alpine valley, about 100 km far from the northern border of the Po basin. Several observational techniques are used synergistically to monitor the transport of aerosols. Among these: in-situ (surface) concentration measurements (e.g., optical particle counters, PM samplers) with relevant chemical analyses, ground-based photometry, aerosol vertical profiling by automated-lidar-ceilometers (ALC), and satellite imagery. These observations are complemented by modelling tools (e.g. chemical transport models, lagrangian models) to reproduce the observed features based on emission inventories and local meteorology. We describe the phenomenology of aerosol advections using both specific case studies and a longer, three-year (2015-2017) statistics of the events. Our results show that regular advection of air masses from the Po Valley leads to the arrival of an elevated, aerosol-rich polluted layer. This is often associated with an increase in humidity, which in turn leads to particles hygroscopic growth, increase in backscatter signal (ALC), and formation of low-level clouds from cloud condensation nuclei. In the day following the advection, the residual layer sinks into the mixing layer after the beginning of the valley convection. Since a large quantity of 'fine mode' particles (0.2-0.3 µm diameter) is involved, the phenomenon is more evident from measurements of the aerosol number rather than mass concentration. Chemical analyses of ions reveal that the advected aerosol is mainly secondary. The chemical transport model is found to well reproduce the behaviour of the observed aerosol advections, though the simulated mass concentration is lower than the observed one. This is likely due to underestimation of the emissions from the inventories at the boundary conditions. The long-term statistics includes the study of the advected aerosol layer over the period 2015-2017 in terms of height and arrival time, frequency of the events, correlation with winds, backtrajectory analysis and statistical trajectory models.

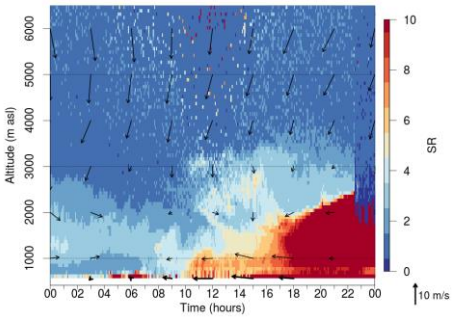

Fig. 2: Example of aerosol transport from the Po basin to the Aosta Valley as measured by the ALC (25 May 2017). The scattering ratio (colour scale) is plotted as a function of time and altitude. The arrows represent the profile of wind velocity.

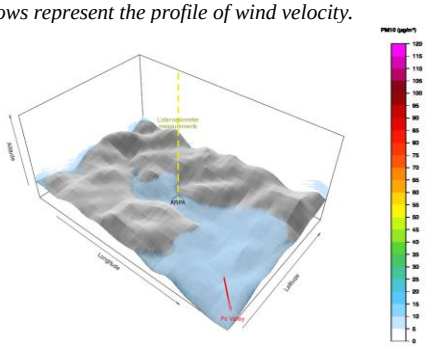

Fig. 3: Same episode as in Fig. 1 as simulated by the chemical transport model over the Aosta Valley. The colour scale refers to the PM concentration. The lowest corner of the figure borders on the Po Valley.

Conclusions The study demonstrates the overall capacity of the instrumental set to observe and follow the advection of polluted air masses from the Po Valley to the Alpine region, this also highlighting the potential capabilities of networks with similar characteristics. The results of this study also indicate the importance of improving our emission inventories and chemical transport models, and provide further evidence that mitigation policies cannot be defined on a local scale and should be rather formulated at a regional and international level.

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ATMOSPHERIC VENTILATION AND PARTICULATE MATTER CONNECTIONS IN THE ATACAMA DESERT, CHILE

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Summary
The study aims to analyze the role of atmospheric ventilation and stagnation on air quality levels over the Atacama Desert in Chile. Moderate to high linear correlations were found between the ventilation coefficient and observational particular matter levels. The Atacama desert experiences a high frequency of stagnation days per year, were precipitation is almost null. The RCP4.5 scenario is used to investigate the impact of climate change on the ventilation. This finds different stagnation frequency trends are projected for higher and lower latitudes. Results suggest that recent extreme air pollution events are connected driven by extraordinary anthropogenic emissions rather than exceptional atmospheric stagnation conditions. Whilst climate change has the potential to exacerbate or reduce the prevalence of poorly ventilated atmospheric conditions, the main control on future air quality trends in the Atacama is the uncertainty in future anthropogenic particulate emissions.

Introduction
Particulate Matter (PM) is one of the air pollutants of primary concern to human health, and it is closely connected to climate change. The Atacama Desert, northern Chile, is the driest desert in the world and plays a significant role in the economic development of the country, which is the largest producer of copper in the world. About 69% of the Chilean copper production takes place in the area. The Atacama has experienced substantial anthropogenic PM emissions, mainly from mining industry and coal power generation plants. Natural emissions arise not only from mineral dust, but also natural marine aerosols are transported over from the long coastline. Despite the above, there is a scarcity of studies addressing atmospheric ventilation dynamics and the high levels of air pollution recorded in the area. This study aims to identify the role of atmospheric ventilation on PM10 and PM2.5 concentrations in polluted urban areas in the Atacama Desert, strongly influenced by natural and anthropogenic emissions.

Methods and Results
The ventilation coefficient (VC) (Kassomenos et al., 1995), based on the Planetary Boundary Layer Height (PBLH) and surface wind speeds, was computed for six polluted areas in the Antofagasta Region. The boundary layer was identified from radiosonde observations from the Cerro Moreno station (-23.5ºLat, -70.4ºLon), whilst local wind speed was obtained from six stations from the Chile's National Air Quality Information System (NAQIS). Deseasonalized VC and PM10-PM2.5 time series were correlated in periods comprised in between 2000 and 2017. Additionally, the Air Stagnation Index (ASI) (Horton et al., 2014) was also computed from a regional climate model (UCAN-WRF34) for both an evaluation-baseline period (1981-2010) and a RCP4.5 experiment (2071-2100) for the whole Atacama Desert region (-17ºLat to -30ºlat). The PBLH, set in the region by the temperature inversion layer base, has a clear seasonal cycle with higher values in summer and lower in winter. However, surface wind speeds, and therefore VC, vary by locations. Six of the 47 stations with valid PM10-PM2.5 data were selected due to spatially represent an extremely polluted area in the Antofagasta region, where the annual mean levels of PM10 and PM2.5 have been measured over the standard values given by both the Chilean and the WHO policies. In these stations, VC and PM10-PM2.5 were moderately (r=0.44) to highly (r=0.91) correlated. Stagnation (determined by the ASI computed from the regional climate model simulation) occurs for between 150 to 240 days per year. ASI increases in the lower latitudes where the desert is drier and stronger mechanisms for inhibition of precipitation take place. Similar to VC, the seasonality of stagnation events matches with seasonal PM cycles. However, extreme air pollution events do not seem to be particularly linked to strong stagnation episodes, suggesting extraordinary emissions as the main factor instead. Under the RCP4.5 forcing scenario, higher latitudes see a decrease of about 30% in stagnation days, whilst lower latitudes see an increase of up to 20% more stagnation events. Although ASI computed from models outcomes may represent a measurement of potential air quality impact in uninhabited regions (Horton et al., 2014), model bias of surface wind speed and precipitation simulations has been found significant in some areas, and an extended analysis is suggested.

Conclusions
Despite the varying anthropogenic and natural patterns of particulate emissions in the Atacama Desert, ventilation seems to play a significant role in air quality levels at synoptic time-scales. Stagnation days are present at least during the half of the year in most of the area which leads to a quasi-permanent stagnant condition arising from the extremely stable atmosphere and lack of rainfall. Results suggest that extreme episodes would respond to extraordinary anthropogenic emissions rather than atmospheric ventilation condition. However, a dynamical modelling approach considering pollutants transport is suggested in order to address this phenomenon and extend the temporal analysis beyond the air quality observations.

Acknowledgement
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METEOROLOGICAL CONDITIONS CLASSIFICATION: APPLICATION FOR EVALUATION OF BIOMASS BURNING EMISSION ABATEMENT ON AIR QUALITY IN ARVE VALLEY (FRANCE)

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Summary
An operation to renew the old residential wood appliances was launched since 2013 in the urbanized Arve valley, and about 16% of high emitters' wood-appliances were renewed until summer 2017. This study aims to compare ambient PM_{10}, black carbon (eBC) and specific tracers of biomass burning concentrations under similar meteorological conditions for the 4 winters 2013-2017, for 3 measurement sites. Ten meteorological and social variables have been prioritized according to their influences on wintertime atmospheric concentrations using a random forest algorithm. An automatic classification of this ranked variables conducted to determine 4 weather types. Only the weather type corresponding to days with favourable dispersion of particles enable to compare daily concentrations between winters. On 2 of the sites, PM_{10}, eBC, and specific tracers of biomass burning concentrations decreased during the winters, between 8 and 23%/winter in average according to the site and the species. These concentration decreases are not immediately observable when all weather conditions are considered.

Introduction

Fig.1.Measurement sites

Evaluations of local emission abatement policy with air quality model are not accurate enough in Alpine valleys, with large uncertainties of emission inventory at local scale and strong impact of meteorological conditions. To evaluate the efficiency of a wide operation to reduce biomass burning emission in the Arve Valley, continuous chemical and meteorological measurements were performed at three sites (Fig 1). A proper comparison of the evolution of concentrations between winters requires to take into account the impact of meteorological conditions (including the influence of cold air pool (Chemel et al, 2016)).

Methodology and Results

TEOM-FDMS, Aethalometers AE33, and analysis of specific biomass burning tracers on daily PM_{10} filter samples in wintertime were maintained at the 3 sites since 11/2013. An array of temperature sensors along the slopes was used to characterize atmospheric vertical profiles close to each sampling site. It was validated after comparison of measurements with aerosol LIDAR (WLS200S) and radio sounding measurements at Passy (Chemel et al, 2016). Supplementary meteorological parameters, like wind speed, were obtained from Meteo-France stations near the 3 sites. Finally, 10 of such variables were ranked by random forest according to their impact on concentrations for wintertime daily measurements. Temperature gradient and concentrations of the previous day have the greatest impact on daily concentrations. A cluster analysis of the ranked variables is then conducted in order to define classes of similar days. The class of days with favourable dispersion of PM is the only one being statistically comparable for the 4 winters. It shows large decreases of biomass burning indicators, including eBC and levoglucosan concentration (figure 2) from winter to winter, a good indication that the program of appliance renewal has an impact on Air Quality.

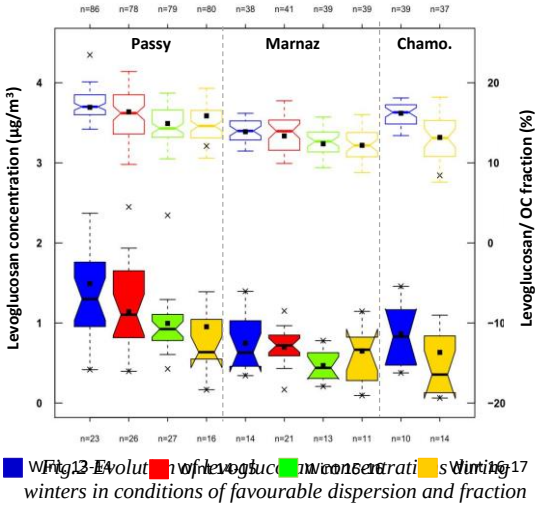

Fig.2 Evolution of levoglucosan concentrations during winters in conditions of favourable dispersion and fraction levoglucosan/OC for all weather conditions

Conclusions

A classification of influential variables on ambient concentrations has been achieved to evaluate the effectiveness of actions of reduction of biomass burning emission in order to improve air quality. Decreases of concentrations of specific tracers and contributions to organic matter during winters are observed, that will be compared with data from renewal of old wood appliances near measurement sites.

Acknowledgement

This work is supported by the Agency for the Environment and Energy Management (ADEME) with the DECOMBIO program (1362C0028).

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PM10 EXCEEDANCES AND CEILOMETER OBSERVATIONS DUE TO A PROLONGED SAHARAN DUST EPISODE OVER THE EASTERN ALPS

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Summary
In April 2016, a Saharan dust cloud reached Central Europe, leading to enhanced PM10 concentrations and reduced visibility. Particle matter concentrations significantly increased at the Austrian mountain stations Hoher Sonnblick (3106 m a.s.l.), Dobratsch (2166 m a.s.l.) and Feuerkogel (1592 m a.s.l.) between April 3 and April 6, 2016. On April 5, 2016, daily concentrations exceeded 50 μgm^{-3} PM10 at most air quality stations in the Eastern Alpine area. The emission and transport of the Saharan dust cloud towards Central Europe is forecasted as well as analysed with the online coupled model WRF-Chem. The evolution of the atmospheric boundary layer (ABL) at the Eastern Alpine ridge is observed by a network of ceilometers; from the vertical backscatter profiles of these instruments, the aerosol load (qualitatively) and the mixing height are deduced. These data are especially valuable to distinguish whether PM10 concentrations are mainly influenced by long-range transport or by advection of aerosols from the ABL. Lagrangian particle dispersion modelling (FLEXPART) in backward mode is used to identify major source regions. The measurements and model results deliver a detailed picture of the onset, course, peaks and decay of this dust event over the Eastern Alpine region.

Introduction
About 10% of the desert dust which is entrained into the free atmosphere in North Africa is transported towards the Mediterranean Sea and Europe depending on the prevailing large-scale pressure fields and flow patterns. In this study, special model output products from WRF-Chem are used to investigate the dust transport into the atmosphere and to the Alpine region. Additionally, the Lagrangian model FLEXPART is used in backward mode to clarify, based on the source-reception sensitivity, whether the dominant source regions are situated in the Saharan desert in the dust episode under investigation. Ceilometers are used to help investigate whether a dust plume is primarily advected or is mixed upwards from ground-level sources to the mountain tops by vertical mixing. Ceilometers are aerosol lidars which are operated since decades at airports to detect the cloud base height. The software of modern ceilometers is able to analyse the first few kilometres above ground for the existence of so-called aerosol layer heights which mark transitions between layers of different aerosol content.

Methodology and Results
Atmospheric trace gases, particulate matter and meteorological parameters are continuously observed at the Sonnblick Observatory (3109 m asl). Due to the remote position of this site in high Alpine environment these data allow the monitoring of the background pollution level in the Alpine boundary layer unaffected from local sources as well as in free tropospheric air masses. Manned meteorological stations are operated about 105 km north of Sonnblick, at top of the mountain Feuerkogel (1618 m asl) and about 40 km south of Sonnblick, at top of the mountain Dobratsch (2117m asl). Ceilometer observations of the aerosol structure within and above near-by valleys support the distinction between boundary layer air and free tropospheric air contributing to the pollution observations at the mountain tops.

Conclusions
This case study demonstrates that the combination of the used measurements and analysis tools renders the optimum basis for the interpretation of exceptional air pollution events caused by long-range transport as Sahara dust transport to the Alps. This result is of particular relevance as these events can be classified as "natural events" in the official reporting of air quality measurements to the European Union and do not add to the number of PM10 daily mean threshold exceedances.

Acknowledgement
The federal authorities of Austria are thanked for the air quality measurement data from the operational network as well from the mountain stations Dobratsch and Feuerkogel. The PM10 measurements at Sonnblick are conducted by the Environment Agency Austria. This study has been funded by the Austrian ministry of concerning the interpretation of ceilometer backscatter profiles are significantly (TOPROF).

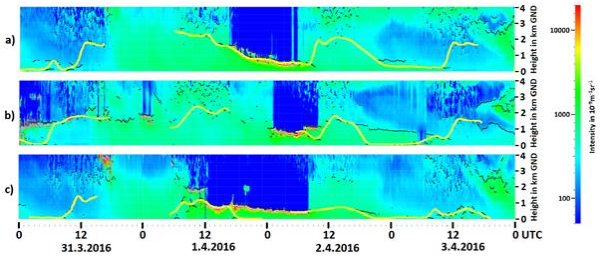

Fig.1 Measured PM time-series on the mountain tops of Sonnblick, Dobratsch and Feuerkogel from 31.3.16 0 UTC to 8.4.16 0 UTC

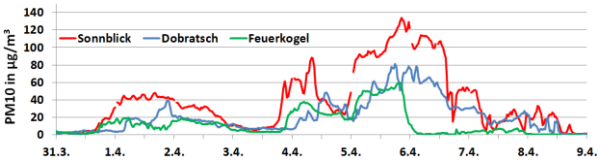

Fig.2 Time-height cross sections of ceilometer aerosol backscatter intensity and mixing heights (yellow lines) a) at Radstadt, b) at Nötsch and c) at Salzburg between March 31, 2016 0 UTC and April 4, 2016 0 UTC.

COMPARABILITY OF MOBILE SENSOR BOUNDARY LAYER MEASUREMENTS WITH LAGRANGIAN PARTICLE MODELLING

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Summary
Airborne meteorological and air quality measurements have been collected by a SkyArrow/ERA aircraft flying around a waste incinerator. The fast-response instruments equipping the airplane allowed to monitor the buoyant plume dispersion up to a height of about 500m a.g.l. Relying on a sound emission estimate based on data provided by the incinerator continuous emission monitoring system (CEMS), the atmospheric dispersion of pollutants was reconstructed through the application of a Lagrangian particle model. The model satisfactorily simulated the plume track and its horizontal dispersion, while concentration peaks where underestimated, highlighting problems in comparing nearly-instantaneous measurements with model estimates representative of longer time averages. Difficulties arising from the interpretation of fast moving sampling and its comparison with boundary layer models are discussed and possible approaches to address the problem are proposed.

Introduction
The use of moving sensors to probe meteorological variables and pollutants concentration in the atmosphere are rapidly spreading thanks to the availability of lightweight and low-cost measuring devices. Moreover, the possibilities offered by unmanned aerial vehicles and small airplanes make airborne monitoring affordable for local air quality investigations. The need to analyse pollutant concentration variability along the aircraft track however limits the applicable time-averaging period to few seconds. This approach, in principle, does not guarantee the comparability of mobile sensors measurements with ground based monitors providing hourly average measurements (e.g. Mylne and Mason, 1991) and with dispersion models based on Reynolds averaging or on the statistical description of the atmospheric turbulence. Possible discrepancies are expected to be larger with increasing instability in the atmospheric boundary layer, when the time scales of the largest turbulent eddies increase to the order of one hour. The problem has been investigated through a case study where CO_2 airborne measurements have been compared with the Lagrangian particle model SPRAY results.

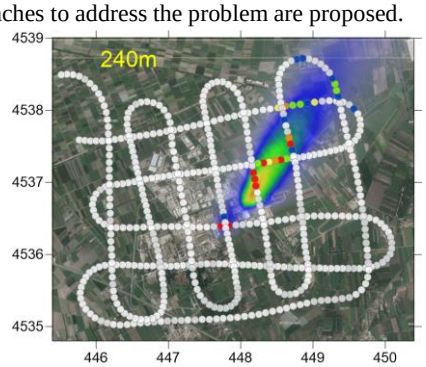

Fig.1 CO_2 (ppm) modelled concentration fields compared with aircraft measurements at about 240m a.g.l. on 27/07/2016

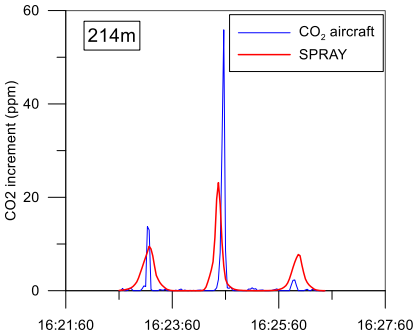

Fig.2 Comparison of modelled and measured concentrations along the flight track on 05/07/2016 at about 214m a.g.l.

Methodology and Results
An advanced monitoring program set up to assess the environmental impact of a waste incinerator allowed to collect airborne meteorological and pollutants measurements by means of a SkyArrow/ERA airplane. The aircraft equipment included high frequency sensors measuring wind components, temperature and CO_2 concentration at 50 Hz frequency. The flights plan has been finalised to monitor the buoyant plume dispersion in the area surrounding the incinerator stack up to a height of about 500m a.g.l., while ancillary profiles up to 1500 a.g.l. were performed to complete the boundary layer diagnostic. Preliminary analyses of measured CO_2 concentrations indicated 2s as the proper time averaging period to identify the incinerator footprint along the aircraft trajectory. Local meteorology was diagnostically reconstructed from aircraft measurements and pollutants emissions were estimated on the basis of data acquired by the incinerator continuous emission monitoring system. The Lagrangian model satisfactorily described the plume track and its horizontal dispersion at all the heights covered by the flights (Fig. 1). Measured peaks were identified but often underestimated (Fig. 2) and significant concentration values were detected at heights above those predicted by model simulation and by the expected plume rise. High concentration detected by the airplane over limited space areas at elevated height could be attributed to the transport of updrafts occurring in convective conditions.

Conclusions
The model well described the plume trajectory, while underestimated peak measured concentrations. A generalisation of the peak-to-mean concentration ratio, usually applied to estimate surface sources fluctuations, seems necessary to compare model results with short-time averages provided by moving sensors and to obtain longer time average concentration estimates from those measurements. Alternatively, LES techniques could be applied to reconstruct the observed concentration values.

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HOW DO TEMPERATURE INVERSIONS CONTROL AEROSOL VERTICAL DISTRIBUTION IN THE ARCTIC IN WINTER AND SPRING?

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Summary
The most ubiquitous meteorological phenomena in the Arctic that influence the vertical distribution of aerosols during winter and early spring are the temperature inversions. In this study, we investigate how the varying magnitude of the atmospheric stability can affect the dispersal of the aerosols. Ten years of aerosol retrievals from CALIOP-CALIPSO and temperature and humidity profiles from AIRS-Aqua, both sensors being part of the A-Train constellation are used for this study. It is shown that, as the degree of atmospheric stability increases, the fraction of aerosol vertical distribution trapped below inversion layer during winter also increases by up to 21%, 17% and 14% in the Atlantic, Barents/Kara Sea and Labrador Sea sectors respectively. The average aerosol optical depths also increase consistently with increased frequency. In contrast, aerosol layers are often accumulated above inversion layers during spring months additionally by up to 15% in the Eurasian and Pacific sectors as the stability increases. These contrasting sectorial differences can be explained by the nature of long-range pollution transport into the Arctic.

Introduction
Arctic has a unique environment. Although we have a relatively good understanding of the transport pathways of pollutants and aerosols in the Arctic, we know very little about the role aerosols play in the air-sea interactions, including cloud processes locally (Coopman et al., 2016). This is mainly down to the fact that we still have very limited in-situ measurements of both aerosols and meteorological variables available in the Arctic. Various measurement campaigns so far have largely been limited to the summer months, thus not measuring aerosols during those time periods when the transport into the Arctic is most efficient. The launch of the CALIOP-CALIPSO made it possible to characterize the vertical distribution of aerosols even in the cold Arctic atmosphere (Winker et al., 2013).

Methodology and Results
We use 10 years of AIRS and CALIOP data for the period from 2006-2016. The level 2, Version 4.10, 5 km standard aerosol layer product from CALIOP-CALIPSO is used to characterize the vertical distribution of aerosols. The temperature and humidity profiles are retrieved from the AIRS Standard Twice Daily Level 3 product (AIRX3STD). Temperature inversion is defined as follows: Starting from the surface temperature as a reference, temperatures at the upper layers are compared with the reference. If it exceeds the reference value, an inversion is considered to be present. The level at which this difference is maximum is considered as the peak inversion height. The process is recursively repeated taking into account all layers as a reference. This is to detect elevated and multiple inversion layers in the atmosphere. If an inversion is detected, its maximum strength is computed and compared with the climatological median value for that month. It is further checked to what degree the inversion strength deviates from the climatological value. The inversion strength thresholds of 10, 50, 70 and 90 percentiles (P10, P50, P70 and P90 respectively) are used to define different atmospheric stability regimes and to investigate how these regimes affect aerosol vertical distribution. The present study focusses on four sectors over the Arctic, namely, AT (Atlantic, 30W-25E), BK (Barents and Kara Sea, 25E-90E), PC (Pacific, 145E-130W) and LB (Labrador Sea, 90W-30W). An increase in aerosol layers and hence, aerosol optical depth is observed below the level of peak inversion height in all the sectors as the atmosphere becomes more stable, except PC sector, where a decrease in aerosol layers are observed in winter. However, during spring, this feature of increased aerosol layers with increasing stability is observed only in the AT sector. The vertical fraction of aerosols below the inversion layer, in fact, decreases as the stability increases in all the other sectors. At the same time, there is an additional increase in aerosol layers above the inversion layers amounting to about 15 % and 8% in the PC and BK sectors respectively.

Conclusions
The increase in specific humidity with increasing stability strengths in winter irrespective of the sectors points at the transport of pollutants via warm air-masses from mid-latitudes into the Arctic. This low-level isentropic transport within the Arctic dome during winter constitutes one of the major pathways of pollution transport into the Arctic and could explain increasing aerosol accumulation below inversions in the AT, BK and LB sectors. However, in the PC sector, the intense low pressure over East Siberia and high pressure over Alaska and Beaufort Sea during increased moisture transport (Johansson et al., 2017) can favour elevated transport of aerosols over inversion layers. In spring, with the Arctic surface warming up, the extent of the polar dome starts decreasing, thereby reducing the low level injection of pollutants into the Arctic from the lower latitudes. The most prominent pathway involves elevated injection and rapid free tropospheric transport into the Arctic during spring which is evident in the PC and BK sectors where aerosol layers were observed above the inversion layer.

Acknowledgement: This work is supported by the Swedish National Space Board (www.snsb.se), Dnr 94/16.

References

STUDY AND ANALYSIS OF THE CONCENTRATIONS OF TROPOSPHERIC OZONE IN THE CITY OF MEDELLIN AND THE ABURRÁ VALLEY AND THEIR RELATIONSHIP WITH ATMOSPHERIC PHENOMENA

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Summary
In this study, data from sampling stations distributed along the Valley of Aburrá region in Colombia is analysed, as reported by the regional air quality monitoring network, between 2014 and 2015. Variations in ozone hourly concentrations are presented, according to average and maximum values, grouped by hour of day and by day of the week, including peak-hours behaviour. Correlations were established with meteorological phenomena (sunshine, rainfall and cloud cover). Out of the more than 100,000 hourly data values, a 1.29% exceeds the hourly quality standard of 61 ppb. From this point of view, the situation should not be considered as a serious one from the point of view of public health, although it should be monitored and studied in relationship to climate and vehicular sources. Quality Air indexes were also determined as well as a comparative analysis with 25 cities in the world.

Introduction
Pollution due to the presence of tropospheric ozone is an issue of vital importance in understanding the atmospheric situation of the city of Medellín and its metropolitan area. The Regional Air Quality Network has monitored ozone concentrations for several years. Ozone forms in the atmosphere by photochemical reactions in the presence of sunlight and precursor pollutants such as nitrogen oxides (NOx) and volatile organic compounds (COVs). It is observed that in hours of maximum radiation (near noon) the highest levels of ozone occur, while at night these levels are decreased. Despite the abundance of data and the prevalent idea that ozone levels are too high in the region, no comprehensive study has been done so far and this one is a significant step to understand and focus adequately the ozone pollution problem.

Methodology and Results
Data from 9 sampling stations located in the city of Medellín and four nearby municipalities along the Aburrá Valley, was analysed. Hourly measurements went from 2014 to 2015. Data sets were tabulated in days, hours, and parts per billion (ppb). The average concentration was 15,7 ppb, with a standard deviation of 14,1 ppb (Fig.1) and values are within established hourly limits. The standards for ozone are also specified for 8 hour average, Comparing the data from 9 a.m. to 4 p.m. which is the most severe of the 8-hour periods, against the eight-hour norm of 41 ppb, it is observed that, on average, none of the stations exceeded this limit. It is observed (Fig. 2) that some violations occur with some frequency, but it is not something that happens constantly. Average daily concentrations of ozone tend to increase with solar brightness and to decrease with cloudiness and with precipitation. Air Quality indexes were calculates. From them, it is deduced that no harmful situations have been recorded in this period, even considering the situations of maximum hourly concentrations.

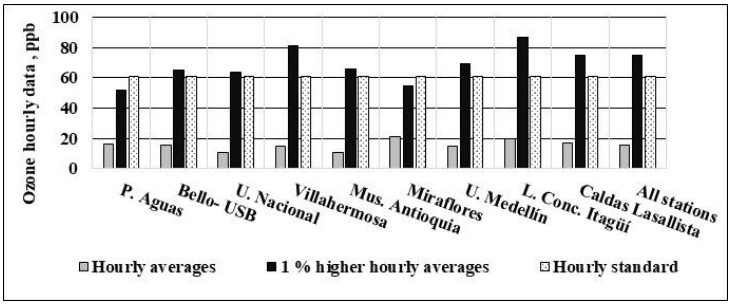

Figure 1. Hourly ozone concentration and maximum values (higher 1 %)

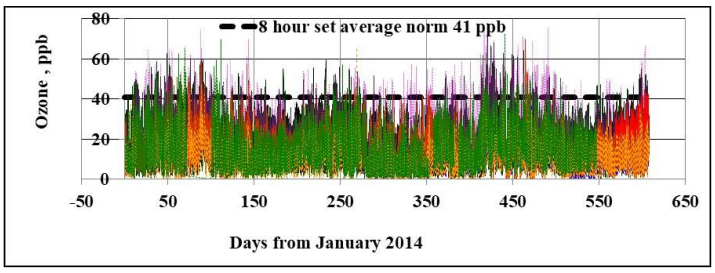

Fig.2 Eight hour average concentrations

Conclusions
Although the quality indexes are acceptable, the region is growing continuously, space in the Valley is scarce and the ozone situation could get out of hand in the coming years if there are not actions to understand and control it. Therefore, it is worth to do studies to correlate the concentrations and emissions of particulate matter, NOx and HC to ozone. This will allow for better criteria on how to control ozone concentrations.

Acknowledgement
Thanks are given to local environmental authority, Área Metropolitana del Valle de Aburrá (AMVA.

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Development, Application and Evaluation of Air Quality Related Models

LANGRANGIAN MODELLING EMBEDDED IN RANS CFD FOR AIR PUFF RELEASES IN URBAN ENVIRONMENTS

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Summary
A dispersion modeling of airborne pollutants in urban environments using RANS CFD codes is usually based on mean and variance concentration Eulerian transport equations. An alternative could be to use simple Lagrangian approaches with the detailed flow parametrization provided by the CFD codes. The Lagrangian approaches have been approved quite successful at least in regional scale and/or mild topography. The present work can be considered as a first step towards a systematic testing of the performance of the abovementioned Lagrangian approaches at local scale environments characterized with canopies of high geometry complexities such as urban environments. The present work is based on the Joint Urban 2003 field study in Oklahoma city. The Lagrangian approach was implemented in the ADREA-HF CFD code. The obtained results are quite encouraging not only with respect the concentration mean but the variance as well.

Introduction
Dispersion modeling of airborne pollutants in urban environments using RANS CFD codes is usually based on mean and variance concentration Eulerian transport equations. An alternative could be to use simple Lagrangian approaches based on Langevin Equation fully coupled with the detailed flow parametrization provided by the CFD codes. The main advantages with respect to the Lagrangian approach are (a) they can produce concentration time series like LES, generating concentration statistics, (b) the particle path geometry being independent on the flow grid, can theoretically recognize better the complex terrain subgrid features, (c) the puff releases can be directly simulated and (d) the numerical diffusion error experienced in the corresponding Eulerian models are here non existent. The main disadvantage is that these simple approaches are not based on first principles making necessary the extensive testing on the specific type of problems to be addressed. Simple Lagrangian model applications in build up domain have been performed mainly in connection with diagnostic wind field (e.g. Kaplan and Dinar, 1996). To the authors knowledge the relevant effort up to now was on predicting concentrations and not concentration fluctuations. The present work can be considered as a first step towards a systematic testing of the performance of simple Lagrangian approaches coupled with CFD-RANS wind field at local scale environments characterized with canopies of high geometry complexities such as urban environments, with the following initial objectives: (a) examine the possibility of predicting not only mean concentrations but concentration variance as well. (a) keep the Langevin equation formulation as simple as possible.

Methodology and Applications
The initial Langevin formulation follows the one of Kaplan and Dinar (1996) suitable for build up domains. The turbulent dispersion parameterization is derived from the wind field CFD-RANS primary parameters: the turbulent kinetic energy (k) and the turbulent energy dissipation (ε). The applications concern instantaneous puff releases in the Joint Urban 2003 field study in Oklahoma city (Allwine et al., 2004) which includes urban canyon experiments with high resolution winds and turbulence measurements together with tracer data in order to investigate the processes that disperse material within the canyon and the exchange of material between the canyon and the overall urban circulation.

Acknowledgements
We gratefully acknowledge the European Commission Directorate General for Migration and Home Affairs (DG HOME) for their support to the Urban Dispersion International Evaluation Exercise (UDINEE) activity. Authors want to acknowledge the contribution of various groups to UDINEE. The following agencies have prepared the data sets used in this study: U.S Army Dugway Proving Group as manager of the JU2003 database; Data from tracer monitoring stations were provided by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory Field Research Division; Data from meteorological monitoring stations were provided by Dugway Proving Ground. Joint Research Center Ispra/Institute for Environment and Sustainability provided its ENSEMBLE system for model output harmonization and analyses and evaluation. This work was also supported by computational time granted from the Greek Research & Technology Network (GRNET) in the National HPC facility ARIS (http://hpc.grnet.gr) under project CFD-URB (pr004009).

Results and Conclusions
The results in this particular application show that it is possible to estimate concentration fluctuations with the Langrangian model. Further testing is needed before definite results can be drawn.

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PM_{10} TRENDS IN SWITZERLAND USING RANDOM FOREST MODELS

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Summary

Meteorological normalisation random forest models were developed for 31 PM_{10} monitoring sites in Switzerland for the period between 1997 and 2016 to aid with robust trend analysis. The models were used to compute meteorologically normalised time series which was formally tested with the Theil-Sen estimator. Significantly decreasing PM_{10} trends ranged from -0.09 to -1.16 µg m^{-3} $year^{-1}$. The learning processes of the models were investigated to explain the observed trends and general physical and chemical processes which drive ambient PM_{10} concentrations in Switzerland.

Introduction

Air quality trend analysis is frequently conducted in exploratory data analysis situations. However, often, it is unknown if a calculated trend represents changes in emissions or changes in meteorology/weather over time. Changes in pollutant emissions is usually the feature of importance because it represents the effect of abatement or management activities. A method to account for changes in meteorology over time is to build predictive statistical models which use meteorological variables to explain pollutant concentrations. When a predictive model has adequate performance, a time series can be computed which represents average meteorological conditions and trend tests can be performed on the prepared time series. This technique is called meteorological normalisation. In this study, random forest, an ensemble decision tree machine learning method is used to build predictive models which are used for trend analysis of daily PM_{10} observations across Switzerland.

Methodology and Results

Daily PM_{10} observations between 1997 and 2016 from 31 monitoring sites in Switzerland were retrieved from **smonitor** Europe, a database which uses the AirBase and Air Quality e-Reporting (AQER) repositories as data sources. The explanatory variables used for the random forest models were surface meteorological variables, synoptic scale weather types, boundary layer height, back trajectory clusters, and time variables specific for each site. The random forest models were grown for each site and 20 % of the input data was withheld from the training and used for validation. The random forest models were used to predict the PM_{10} concentrations for individual sites a thousand times with randomly sampled explanatory variables and all predictions were aggregated to calculate a meteorologically normalised time series. The normalised trends were then tested with the Theil-Sen estimator.

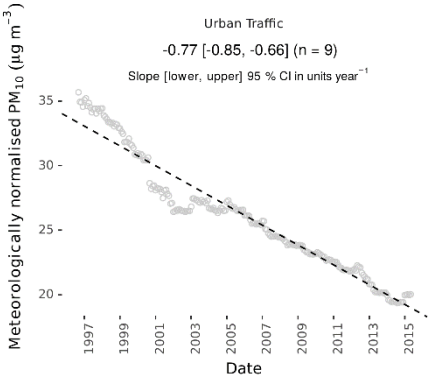

Figure 7. Meteorologically normalised PM_{10} trends for Switzerland's urban

The random forest models performed well for most monitoring sites with R^2 values up to 71 % and the most important variables for prediction were generally wind speed, back trajectory cluster, and Julian day which was the seasonal component of the models. With the exception of two monitoring sites which did not have data for the entire analysis period, all sites demonstrated a significantly decreasing trend which ranged from -0.09 to -1.16 µg m^{-3} $year^{-1}$. This range is similar to what has been reported in the past (Barmpadimos et al., 2011). The sites which were classified as 'urban traffic' demonstrated the greatest negative trends at -0.77 µg m^{-3} $year^{-1}$ (Figure 1).

The learning process of random forest was investigated and general physical and chemical processes related to PM_{10} concentrations such as an inverse relationship with wind speed, more polluted wintertime conditions, and sequential loading during the weekdays were confirmed. Notably, the models indicated that there are two regimes which drive increased PM_{10} concentrations in Switzerland: a local and stable weather regime which is characterised by high emissions and stable weather and a warmer regime with high boundary layer heights and secondary sulphate formation.

Conclusions

Random forest meteorological normalisation models were used to conduct a robust trend analysis of PM_{10} observations across Switzerland between 1997 and 2016. PM_{10} concentrations are decreasing at rates similar to what has been reported for previous periods. The models were investigated to explain why the observed trends are present and this suggests that the meteorological normalisation technique could be useful for other exploratory data analysis applications.

Acknowledgements

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DEMONSTRATION OF REAL-TIME AIR QUALITY MODELLING SYSTEMS – HELSINKI AND NANJING TESTBEDS

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Summary
Using a dense network of air quality measurement stations and complementary AQ sensors a real-time modelling system has been set up in the Helsinki region. The most recent information on the meteorological conditions, long range transportation of pollutants and the observed pollutant concentrations are used by the FMI-ENFUSER model to predict the current and future air quality with a high resolution. In this study, we present the modelling system and quantify the accuracy of the predictions provided by the modelling system for the hourly concentrations of $PM_{2.5}$, PM_{10}, NO_2 and O_3. Finally, we present the advances in another simultaneous implementation of such an AQ testbed in Nanjing, China.

Introduction
After the introduction of affordable complementary air quality sensors, the coverage of monitoring networks in urban areas can be increased substantially. For a complete overview of the highly variable urban air quality, however, fusion of information must be used to facilitate highly adaptive dispersion modelling and air quality forecasting. For practical smart-city applications the timeliness of the provided information is crucial; the modelling system has to be computationally efficient to provide updated, easily accessible modelling results.

Methodology
The FMI-ENFUSER is a model that combines statistical air quality modelling, Gaussian dispersion modelling techniques and information fusion algorithms (Johansson et al, 2015). In essence, the model can be set up without knowledge of local emission sources. Using large quantities of historical measurement time series the model can detect local emission sources and their temporal variations through multivariable regression. The use of data fusion algorithms makes it possible to assimilate data from multiple sensors and measurement stations with variable quality standards. Further, the key meteorological parameters and emission output rates can be fine-tuned so that the modelling output aligns with the measurement evidence as well as possible.

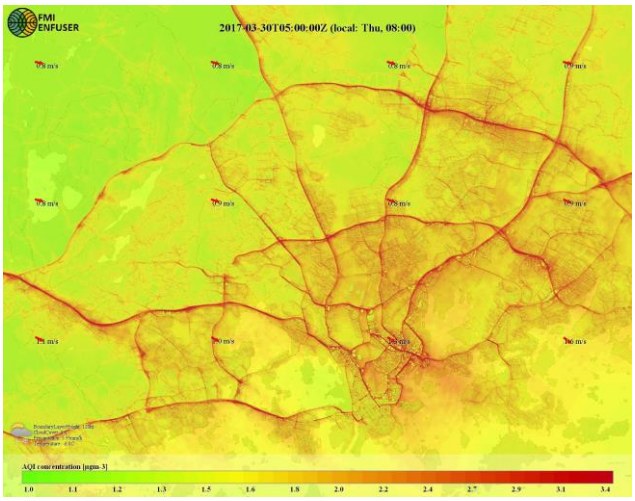

Fig.1 Modelled Air Quality Index in Helsinki region (2017-03-30:05:00Z).

In this study the model has been coupled in real time with the regional chemical transport model (SILAM), the local AQ monitoring network, and several sources providing meteorological data (HIRLAM, ECMWF). In Helsinki, an existing traffic volume mapping with temporal variations separately for vehicles, trucks and buses has been used; real time traffic congestion information is also being utilized. For residential heating the inventory from local authorities has been used and coupled with ambient temperature modifications. An example visualization of the hourly Air Quality Index (AQI in a scale of [1,5]) from the model has been shown in Fig 1.

The simultaneous testbed implementation occurring in Nanjing uses information sources described above with few exceptions; data on vehicular patterns and accurate emission inventories are generally not available in the same level of detail as in the Helsinki Air Quality Testbed. Additionally, since the shipping traffic in the Yangtze River very close to Nanjing is a substantial source of emissions, we have coupled the FMI-ENFUSER with the FMI-STEAM3 model using near real-time commercial AIS-data (Johansson et al, 2017).

Conclusions
A computationally efficient modelling system for real-time air quality has been set up in Helsinki region, using the data infrastructure of the CITYZER Ecosystem platform. According to preliminary results in 2016 the forecasted predictions (12h in the future) of the modelling system are in well agreement with measured concentrations; however severe road dust episodes during spring are occasionally difficult to predict. The system can be setup in other regions as well, for which the Nanjing testbed (2017-2019) will be a concrete example of.

Acknowledgement
This work was supported by TEKES-CITYZER, Smart & Clean HAQT and TEKES Nanjing Air quality testbed projects.

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COMBINING AIR QUALITY MODELLING DATA AND SENSOR MEASUREMENTS IN AN INTERNET OF THINGS METHODOLOGY TO MITIGATE AIR POLLUTION IN THE BALKAN REGION

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Summary
This paper aims to present the combined use of dispersion modelling results and air pollutant concentration data from a sensor monitoring network, in view of mitigating air pollution impacts in the Balkan region. Particular emphasis is given in exploiting emerging technologies through the Internet of Things by deploying networks of real-time air quality sensors in selected cities of five Balkan countries. A combination of data fusion and data assimilation methods is employed in order to incorporate emission data and real-time measurements in an operational pollutant dispersion modelling system. The provided estimates of concentration and exposure can support city-specific assessment and identification of areas of interest for sensor installation.

Introduction
While the EU Directive 2008/50/EC imposes strict limit values for atmospheric pollutants in ambient air, the management of the corresponding emissions requires the implementation of innovative and effective mitigation measures based on technology transfer. In this direction, the project AIRTHINGS aims to deploy effective air-monitoring Internet of Things (IoT) networks and provide real-time, inexpensive access to air quality data. Although the exploitation of new sensor technology options provides undisputable benefits, computational models still represent the scientifically relevant tools for pollutant estimation, source apportionment and evaluation of mitigation strategies. Therefore, model applications have to be ideally combined with IoT methods for effective air pollution mitigation.

Methodology and Results
The IoT air quality measuring sensors are deployed in urban hotspots and areas of high population density. The collective datastream combines real-time information on air pollutants and meteorological parameters through point-to-point communication, thus connecting all participating cities in a joint monitoring air quality consortium. Dispersion modelling tools incorporate and complement the sensor data with city-wide high-resolution operational predictions. Following the requirements of the EU Directive, ambient concentrations and exposure of the citizens to several gaseous and particulate pollutants are estimated using a set of modelling tools covering various scales. The modelling system consists of four components: 1. MEMO (Moussiopoulos et al., 2012), a 3D Eulerian meteorological model for the dispersion of inert pollutants over complex terrains 2. MARS-aero (Moussiopoulos et al., 2012), a 3D chemical transport model featuring an advanced chemical simulation module for gases and particulate matter 3. MIMO (Ehrhard et al., 2000), a 3D Eulerian Reynolds Averaged Navier Stokes CFD code for simulating microscale wind flow and dispersion of pollutants in built-up areas and 4. MEMICO, a two-way coupled mesoscale-microscale model system. A continuous quality testing and data assimilation process integrates data flows from the sensor network and dispersion calculations. In a later stage, model results are statistically analysed using spectral methods in order to detect diurnal, seasonal or spatial pollution patterns. This information can be used to disaggregate individual source contributions in the areas of interest, in this way supporting targeted mitigation strategies. A pilot application of the modelling platform has been undertaken in the city of Augsburg, Germany where the multiscale dispersion simulations have incorporated a combination of ambient monitoring data and in-situ DOAS measurements.

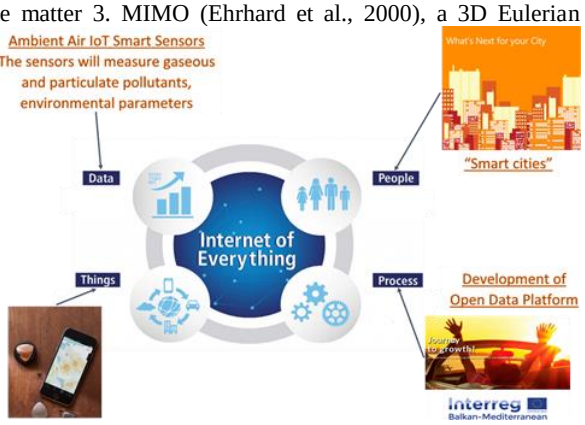

Fig.1 Exploitation of IoT technology in the AIRTHINGS

Conclusions
As air quality management problems become more complex, there is a need for enhanced air quality and exposure monitoring competences on the local and regional level. This study focuses on exploiting rapid developments in technology to combine low-cost innovative air pollution Internet of Things sensors with advanced air quality modelling tools, in order to provide both regulatory assessment services, as well as to support the evaluation of air pollution mitigation measures.

Acknowledgement
This work is supported by EC, under the INTERREG V – B BALKAN MEDITERRANEAN 2014 -2020 Programme.

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DOWNSCALING OF THE EMEP MODEL USING UEMEP: WHERE SCALES MEET

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Summary
Regional scale air quality models are regularly used for assessing health impacts over country or continental scales. However, these models lack sufficient resolution to represent pollution gradients near sources, particularly in the case of road traffic emissions, and are based mostly on top down emission inventories. From the regional modelling perspective it is therefore desirable to downscale gridded concentrations to a resolution that are sufficient to resolve these sources, approximately 50 m, for improved exposure assessment. At the same time local scale models, often based on Gaussian plume parameterisations and using bottom up emissions inventories, are also regularly applied for health impact assessments but are rarely used beyond the city scale. In this paper a methodology for downscaling regional scale concentrations from the EMEP/MSC-W model to local scales is presented, *u*EMEP (urban EMEP). The methodology requires bottom up emission proxy data, which is often incompatible with the top down inventories, for the redistribution of gridded concentrations. Results are presented for Norway and The Netherlands and the problems encountered when regional and local scales meet are discussed.

Introduction
The EMEP/MSC-W model is used extensively in Europe, but also globally and in China, for operational air quality forecasting and assessment at regional scale. Currently the maximum operational resolution is 0.1 x 0.1^{o} but there is a desire to significantly improve this resolution for exposure and exceedance applications. Recent activities for downscaling regional models to local scales (Kiesewetter et al., 2014) have made use of both modelling and measurements to determine street level increments. A more recent study (Bino et al., 2017) has shown the possibility of calculating NO_2 concentrations for all of Europe at high resolution and assessed the limitations of such a method in regard to data availability.

Methodology and Results
*u*EMEP is a downscaling methodology made up of two parts. The first is a new scheme within the EMEP/MSC-W model for determining the local contribution from emissions within a grid to each EMEP grid cell and to the neighbouring grids. The second is based on a Gaussian plume model that redistributes these local contributions at high resolution. To achieve this adequate emission proxy data is required. By applying the method differences between top-down/bottom-up and regional/local scale methodologies become clearly apparent. The ultimate aim of the methodology is not just to acquire high resolution concentration fields over large regions but also to help reconcile the disparities between the local and regional modelling approaches. *u*EMEP has been applied over a large region of Norway for NO_2 and $PM_{2.5}$ with a downscaling resolution of 250 - 50 m. It has also been applied in The Netherlands for Ammonia at 500 – 100 m resolution (Fig 1.). In both cases the TNO MACC3 emissions inventory was used. For NO_2 the comparison of NO_X emissions for traffic and shipping differ significantly for top-down and bottom-up inventories and this is reflected in the *u*EMEP calculations. Only when *u*EMEP is corrected for this difference, one of the advantages of the methodology, are the results of similar quality to local modelling applications. By applying *u*EMEP as a redistribution method (preserving the grid volume average) or as an independent dispersion model exposes the differences between the grid and Gaussian approaches.

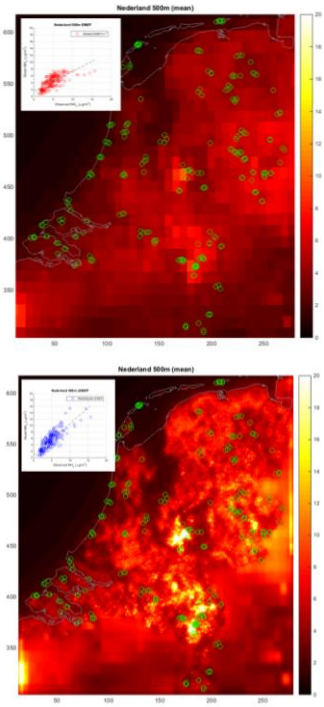

Fig.1 Calculation of annual mean (2015) ammonia concentrations in the Netherlands using EMEP 0.1^{o} (top) and using uEMEP at 500 m (bottom).Comparison with passive samplers (green circles on maps) is also shown.

Conclusions
By applying *u*EMEP it is not only possible to calculate large areas at high resolution for improved exposure assessment but it also provides a path for assessing the quality of urban emissions used in regional models, since comparison with urban and even traffic stations is possible. Data availability on the European scale remains a problem in applying the method and it is hoped that the application of *u*EMEP will help to improve urban emission inventories on regional scales and to promote better data availability.

Acknowledgement
The development of *u*EMEP has been supported by The Norwegian ministry of environment (PN. 14657200) and by the Norwegian Science Council through AIRQUIP.

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CONTRIBUTION OF LAND TRANSPORT EMISSIONS TO GROUND LEVEL OZONE, CALCULATED BY MEANS OF A MULTIBLY ONLINE NESTED MODEL

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Summary
We quantified the contribution of land transport emissions to ground-level ozone and its precursors in Europe for two different emission datasets. A consistent model chain is used, consisting of a regional chemistry climate model, which is on-line coupled into a global chemistry climate model. Both models are equipped with a complex tagging method, which allows for quantifying contributions of several different emission sources to ozone within one simulation. The results show that land transport emissions contribute up to 16—19 % (95th percentile) in central Europe, making the land transport sector to one of the most important contributors of ground level ozone.

Introduction
Emissions from the land transport sector (road traffic, inland navigation and railroad) are a significant contributor to the anthropogenic emissions of NO_x, CO and VOCs, influencing the air quality directly, as well as being precursors for ozone formation. Contributions to ozone cannot be directly measured or calculated from the amount of emissions themselves. Rather, comprehensive simulations using chemistry climate models comprising diagnostics of the ozone production are needed. For the first time, we investigate the contribution of land transport emissions to ozone using a consistent global – regional model chain including an advanced tagging method, which diagnoses the contribution of emission sources to ozone and its precursors.

Methodology and Results
We apply the MECO(n) model system, in which the global chemistry-climate model EMAC and the regional chemistry climate model COSMO/MESSy are on-line coupled (Kerkweg und Jöckel, 2012; Mertens et al. 2016). Both models are equipped with a tagging method (Grewe et al., 2017). This method diagnoses the contribution of several different emission sources to ozone and its precursors within one simulation. This is achieved by a complete decomposition of the source terms of the regarded species in unique categories (Grewe, 2013). Two simulations for different anthropogenic emission scenarios, covering three years each, were performed at a resolution of 2.8°x2.8° using the global model, and for Europe at 0.44°x0.44° using the regional model. Our analysis of the simulation results indicates a contribution of road traffic emissions to ground-level ozone of around 11% on average during summer for Europe. Especially in central Europe larger values of up to 15 % are simulated. In these regions extreme values (expressed as 95th percentile, see Fig. 1) of up to 19 % are found. During winter, the contribution to ozone is dominated by long range transport of ozone, while during summer local production is more important.

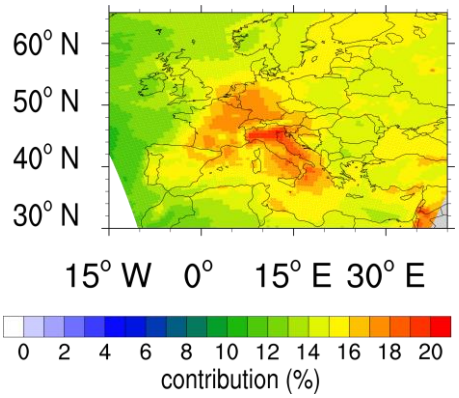

Fig. 1: 95th percentile of the contribution of land transport emissions to ground level ozone (in %) during the summer season (June-August) for 2008 - 2010.

Conclusions
Our results show that emissions of the land transport sector are an important contributor to ground-level ozone in Europe. In comparison to other studies, which vary the amount of land transport emissions, our method allows a direct quantification of the contributions of different emission sectors.

Acknowledgement
M.M acknowledges funding by the DLR internal project “Auswirkungen von NOx”. Computing time for the simulations was provided by the Leibniz-Rechenzentrum (LRZ).

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NUMERICAL SIMULATION OF POLLUTANT DISPERSION ON BUILT-UP ENVIRONMENTAL UNDER CHANGES OF ATMOSPHERIC STABILITY

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Summary
The main objective of this study is to numerically investigate the dispersion of pollutants of stack emissions on the building roof with various atmospheric stabilities, (stable, neutral and unstable). The three-dimensional flow and dispersal of gaseous pollutants were modelled using a computational fluid dynamics model. Computational simulations were conducted using an isolated cubical building model. The diffusion flow fields in the building-up environment were examined with three atmospheric stabilities: (1) stable condition, (2) neutral condition, and (3) stable condition. Atmospheric dispersion was examined at different distances downwind of the leeward side of the cubical building. The numerical data was validated against wind-tunnel data to optimize the turbulence model. The numerical results agreed reasonably with the wind tunnel results. The results indicate that there is an increase in concentrations with stable conditions, and a decrease in concentrations with unstable conditions in the wake region.

Introduction
Air quality within built-up environments with dense population has become an important research issue in the recent years. This is due to its significant in the health of people living in indoor and outdoor environmental. In the built-up environment increasing contamination of toxic and odorous gases released from fixed sources that can seriously affect indoor air quality by entering the emitting building or an adjacent building in the near vicinity. Fig.1 show recirculation zones and plume dispersion as described by the ASHRAE geometric stack design method.

Methodology and Results
The computational tool used in this study is the CFD code ANSYS FLUENT. The computational description of the flow is based on the pseudo-steady-state incompressible Reynolds averaged Navier–Stokes (RANS) equations equipped with two turbulence models: the standard κ-ε turbulence model and the renormalisation group (RNG) turbulence model. Air intake contamination is significantly affected by variability of atmospheric thermal stability in built environments. To simulate the pollutant transportation and dispersion with changes in the atmospheric conditions, a gas pollutant was emitted from stack locations on the building roof. When a stable condition occurred, the vertical air temperature increased and vertical movement and spread of plume reduced, but the lateral movement and spread of the plume increased. Lower concentrations of the vertical spread were observed under stable conditions. When unstable conditions occurred, the vertical air temperature decreased and vertical movement and spread of plume increased, but the lateral movement and spread of the plume decreased. The vertical spread of the plume under unstable conditions was observed to be narrower than under stable conditions. When neutral conditions occurred, the air parcel movement was upward and downward without buoyancy force. The vertical spread of the plume was observed to be narrower than under stable conditions and wider than under unstable conditions.

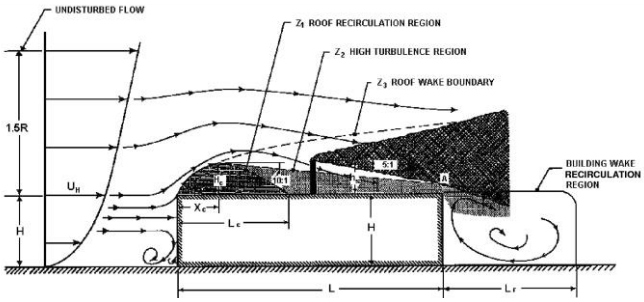

Fig. 1 Diagram showing recirculation zones and plume dispersion as described by the ASHRAE geometric stack design method (Wilson; 1979)

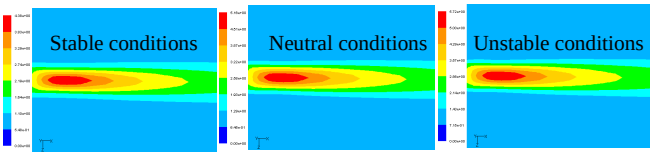

Fig.2 Contour lines of mean concentration, K

Conclusions
The vertical distributions of concentration clearly show downwash in the near wake of the building. The minimum concentration on the roof surface was far from the stack emission. The effect of thermal stability in the near wake of the building is to increase concentration under stable conditions, and decrease it under unstable conditions. The vertical spread of plume under stable conditions observed winder than under neutral and unstable conditions.

Acknowledgement
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VALIDATION OF THE AIRGIS EXPOSURE MODELLING SYSTEM AT DIFFERENT TIME SCALES

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Summary
This study evaluates the performance of recently redeveloped human exposure modelling system AirGIS for various air pollutants (NOx, NO_2, PM_{10}, and $PM_{2.5}$) at different time resolutions (monthly, daily, and hourly). Furthermore, strengths and limitations of the model are discussed. Results from the evaluation study suggest that new AirGIS shows satisfying performance in predicting the observed air pollution concentrations at varying time scales and achieved correlation in the range 0.46 – 0.83 (NOx, NO_2) and 0.40 – 0.61 (PM_{10}, $PM_{2.5}$). While, the mean bias was found to be in the range 0.1 – 2.5 ppb (NOx, NO_2) and 0.7 – 4.2 µg/m^3 (PM_{10}, $PM_{2.5}$). These results show that the model is ready for use in both long-term and short-term air pollution exposure assessment over a large geographical area to facilitate health related studies. Although, the evaluation shows satisfying results, further improvements in the new model system are suggested.

Introduction
Since high-density monitoring networks observing air pollution concentrations are costly to establish and maintain, researchers across the globe make use of various dispersion models to estimate air pollution concentrations over a region of interest. Among such models, the AirGIS – a GIS based air pollution and human exposure modelling system – was developed (Jensen et al., 2001) in Denmark and here frequently used. It is part of the integrated air quality modelling system THOR (Brandt et al., 2001) and works synergistically with the OSPM® to estimate air pollution at all address locations in Denmark. However, the effectiveness of this recently redeveloped model at various time scales (monthly, daily and hourly) needs to be validated.

Methodology and Results
The new AirGIS is implemented in open source PostgreSQL/PostGIS with R-scripts used for pre- and post-processing of the datasets. The model operates at three different levels of pollution: (1) local- or street-scale air pollution (2) urban background contributions (1x1 km^2 grid) (3) regional background concentrations (5.6x5.6 km^2 resolution for Denmark). AirGIS makes use of available GIS information (addresses, streets and buildings) stored in a PostgreSQL/PostGIS database and produces input files (street configuration information) for OSPM. QGIS software serves as the visualization interface during the whole data handling. In this work, the performance of the new AirGIS in predicting the observed concentrations of various air pollutants (NOx, NO_2, PM_{10}, $PM_{2.5}$) is evaluated in the period 2005 – 2015. The air pollution data were measured within the Danish Air Quality Monitoring Network in four major cities of Denmark. All calculations were performed on an hourly basis and concentrations were averaged over the time period corresponding to the measured data. Monthly trends for NO_2 at two urban street stations in Copenhagen, Denmark are shown in Fig.1. Good correlation (r=0.82 and 0.83) between 11 years monthly averaged predicted and observed NO_2 concentrations was estimated. However, the new AirGIS is underestimating or overestimating the observed values in a few instances (see Fig. 1). One of the possible reasons for these under- and over-predictions might be related to uncertainties in traffic emissions and/or modelled regional concentrations. The oral presentation will give an overview of further results and associated discussions.

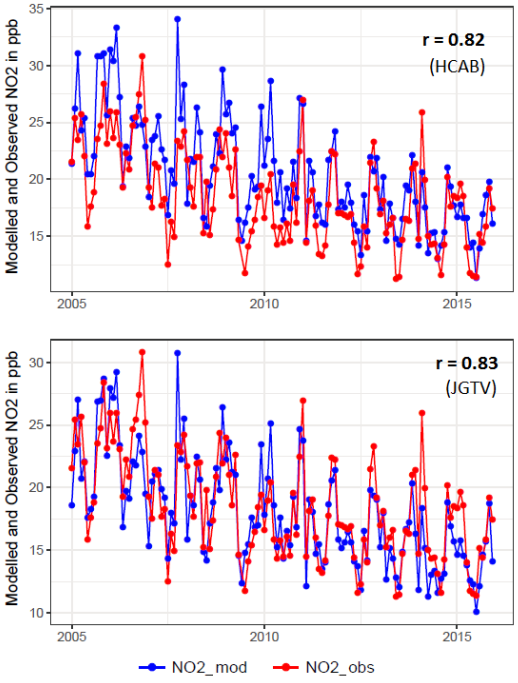

Fig.1 Monthly trends for NO_2 at two streets

Conclusions
In summary, new AirGIS system showed satisfying performance in its evaluation phase. However, more future work needs to be done (i) evaluate the model for other pollutants (e.g., CO, Black Carbon etc.) (ii) to reduce the bias between modelled and measured values.

Acknowledgement
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MACHINE LEARNING EXPOSURE MODEL PREDICTIONS FOR GROUND-LEVEL OZONE DURING WILDFIRE EVENTS: RESULTS FOR A MAJOR WILDFIRE IN CALIFORNIA

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Summary

The aim of this paper is to develop prediction models for ground-level ozone that results from major wildfire events. We evaluate the predictive accuracy of 12 machine-learning methods. We used ground level ozone monitoring as the dependent variable and a variety of emissions model estimates, satellite products, meteorological parameters, and land use variables as predictors. The gradient boosting model supplied the best results with a cross-validation R^2 of 0.653. Our results demonstrate that machine learning methods can produce models that predict ground level ozone well, even in highly dynamic wildfire events. The results can supply important information for public health protection during wildfires and for studying the health effects of the ozone exposures resulting partly from wildfires.

Introduction

Wildfires are projected to increase in frequency and intensity in many parts of the world in response to climate change. Particulate air pollution generated from wildfires has been associated with numerous adverse health effects, but ozone may also result from wildfire emissions of various precursor gases. To date, however, no studies have investigated how to model ozone resulted from wildfire events. Ozone is known to elicit a wide range of adverse health effects, particularly in the respiratory system. This study evaluates for the first time the predictive accuracy of twelve machine-learning algorithms for predicting ground-level ozone exposure during a major 2008 wildfire event in northern California.

Methods and Results

We used monitoring data from 71 locations as the dependent variable and a variety of emissions model estimates, satellite products, meteorological parameters, and land use variables as predictors. Models were evaluated using a leave-one-location-out cross-validation (LOLO CV) procedure to take into account spatial dependence and avoid overly optimistic bias of traditional techniques like 10-fold cross-validation and bootstrap when applied to dependent data. Gradient boosting models performed best with the lowest LOLO CV root mean squared error and the highest LOLO CV R2 (0.653). Random forest was the runner up with a LOLO CV R2 of 0.627.

Conclusions

These results demonstrate that machine learning techniques can effectively be used to predict ground-level ozone concentrations. Such information can be important for public health managers in informing the public of potential risks and for epidemiologists studying the health effects of ozone generated in part from wildfire emissions.

Funding

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MODEL VALIDATION ACTIVITIES IN THE FRAME OF THE COPERNICUS ATMOSPHERE MONITORING SERVICE

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Summary
This work concerns the wide-ranging tropospheric evaluation and model inter-comparison activities taking place in the frame of the Copernicus Atmosphere Monitoring Service (http://atmosphere.copernicus.eu, CAMS). The focus is on above the surface validation of regional scale models over large time periods.

Introduction
Towards the goal of continuous atmospheric monitoring, CAMS has been established as a component of the European Earth Observation program Copernicus and was developed in the past 10 years by a series of MACC research projects. CAMS is currently providing operational forecasts, analyses and reanalyses of atmospheric composition (reactive gases, greenhouse gases and aerosols) on the global and European scale. For the global component of CAMS, the numerical weather prediction Integrated Forecasting System (IFS) of the European Centre for Medium-Range Weather Forecasts (ECMWF) has been extended to provide daily forecasts, analyses, and reanalyses of atmospheric composition, by introducing an atmospheric chemistry module into the IFS and by combining with satellite observations of atmospheric composition (Flemming et al., 2015). Validation activities concerning CIFS have been outlined in Eskes et al. (2015). For the regional component of CAMS, an operational system is run on a daily basis providing air quality forecasts and near-real-time analyses for the European domain, based on an ensemble of seven regional chemical transport models (Marecal et al., 2015), an operational activity that is coordinated by Meteo-France.

Methodology and Results
Within CAMS, a unique opportunity is presented for comprehensive tropospheric evaluation and model inter-comparisons over long time periods since the participating models have been running in operational mode. Towards this direction, the CAMS-84 sub-project deals with the validation of the services provided. It provides 3-monthly updates of validation reports for the global and regional services, where the validation is based on a large number of observations and measurement techniques, including surface in-situ, surface remote sensing, observations by airplanes, balloon sounding, observations from ships and satellite observations (Eskes et al., 2016).

Conclusions
Important insight into the performance of regional chemical transport models is gained through the activities of the CAMS-84 sub-project of the Copernicus Atmosphere Monitoring Service, where model output is evaluated above the surface and checked for consistency against the global component of the operational CAMS system.

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PM10 AND BLACK CARBON VERTICAL PROFILES IN THREE ITALIAN VALLEYS: ANALYSIS OF MEASUREMENTS AND HIGH RESOLUTION MODELLING.

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Summary

The main purpose of this work is to investigate the behaviour of PM10 and black carbon (BC) vertical profiles in three Italian valleys and the impact of local circulation on their vertical distribution. In winter of 2010, University of Milan Bicocca conducted three intensive measurements campaigns over three Italian basin valleys (Terni, Po Valley, Passiria Valley) (Ferrero et al., 2014). The choice of the valleys was made taking into consideration the orography and the river basin structure. Subsequently, at University of L'Aquila simulations were produced to help interpretation of these vertical aerosol profiles (mass, composition and distribution) using a chemistry-transport model (WRF-CHIMERE) at high horizontal resolution (1 km). The analysis focused primarily on the study of local circulation and then on the large observed day-to-day variability of aerosol profiles.

Introduction

Last decades were characterized by a growing interest in aerosols: mainly for their effect on human health and on the energy balance of solar and planetary radiation, thus their role in climate change (Bond et al.2013). Black carbon is regarded as the second most important anthropogenic climate forcing agent and its concentration varies significantly depending on the altitude and the sources on the territory. Information on black carbon concentration is fundamental on radiative forcing evaluation, and so is the information on its vertical distribution (IPCC, 2015). In this study, we analyze the evolution of vertical profile of BC through tethered balloon observations and chemistry-transport modelling.

Methodology and Results

The measurement campaign was based on a helium-filled tethered balloon. The instrumentation consisted on a meteorological station, an OPC, a cascade impactor and a micro-Aethalometer.

All campaign periods were affected by consistent weather variability, cloudy sky, low precipitations, and temperatures that reflected mean of winter period. Wind speed and direction showed a daily behaviour correlated with PM and BC concentrations (see Fig. 1)

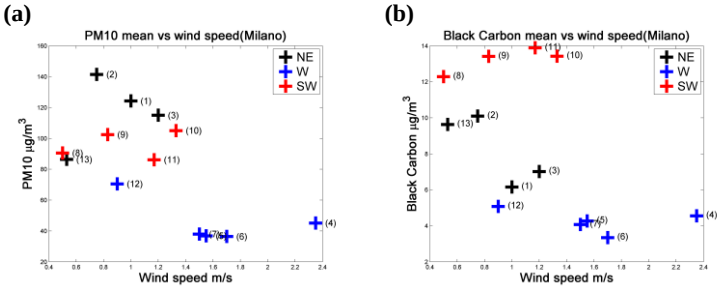

Figure 8 Scatter plot of PM10 (a) and BC (b) with respect to wind speed in Milan, during the launches. Data points are colored according to wind

For each site have been identified three phases of the aerosol trend, which were partly confirmed also in the high resolution modelling results.

Critical events for air quality were analysed (episodes of exceedances of the European PM10 daily limit of 50 µg/m^3). The model suggests that these are primarily influenced by local traffic and domestic heating emissions, combined with weather conditions that facilitated the accumulation of pollutants from day to day. Black carbon concentrations are generally 5-10 % of the PM10.

Conclusions

Measurements aimed at analysing the vertical profiles of PM10 and black carbon in sites with particular meteorology, have highlighted some interesting features of the day-to-day variability. These will be integrated with the analysis of the optical properties of aerosols, which is the basic information for a more accurate calculation of radiative budget.

Aknowledgements

Computational resources were provided by CINECA in the frame of ALTARIS7 IscraC project.

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NEIGHBOURHOOD-SCALE DISPERSION OF ULTRAFINE PARTICLES IN LONDON: A WRF LARGE EDDY SIMULATION

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Summary
This study aims to simulate the dispersion and evolution of nanoparticles at a neighbourhood-scale in London (specifically covering Marylebone Road and Regent's Park). Microphysics of multicomponent ultrafine nanoparticles (UFP diameter < 100 nm) is incorporated into the WRF-LES modelling framework (Weather Research and Forecasting, WRF; Large Eddy Simulation, LES). Real-world gridded emissions are implemented in this neighbourhood-scale simulation representing a real-world street network, and revealing the behavior of neighbourhood-scale UFP dispersion.

Introduction
Ultrafine nanoparticles are respirable particles which can accumulate in lungs, penetrate cells/tissue and cause health effects. Traffic is normally the most important source of UFP emissions in urban areas. The condensation/evaporation process is important in determining the fate of ultrafine particles in urban air (e.g. Harrison et al. (2016); Dall'Osto et al. (2011)). Traffic-generated nanoparticles vented out from an urban street network, could evaporate to smaller particles (as has been simulated previously using a CittyStreet-UFP model in Nikolova et al. (2016)) while they are transported during the neighbourhood scale dispersion.

Methodology and Results
The WRF-LES model is a powerful atmospheric modelling system with large eddies explicitly calculated and small eddies parameterised by sub-grid scale (SGS) models (the 1.5 order TKE closure scheme is used in the current study). We implemented UFP multicomponent microphysics (i.e. evaporation/condensation processes) into WRF-LES to simulate their neighbourhood-scale dispersion in London (specifically covering Marylebone Road and Regent's Park). The number of nanoparticle compositions considered in the model is 18, including 1 non-volatile core and 17 representative Semi-Volatile Organic Compounds, SVOCs. The number of sectional size bin is 15, ranging from about 6 nm to 500 nm in log-scale. 3D fields of particle mass for each SVOC component and for each size bin (a total of 15×18=270 fields) and gas concentrations (a total of 18 fields) are tracked; i.e. the advection and diffusion of these quantities are solved by WRF-LES. The particle number for each size bin is diagnosed according to particle's mass and the sectional diameters. A gridded neighbourhood-scale street network in London with traffic-induced UFP emissions is incorporated into the model. A snapshot of the neighbourhood-scale dispersion pattern in the studied domain is shown in Fig. 1 as an illustration.

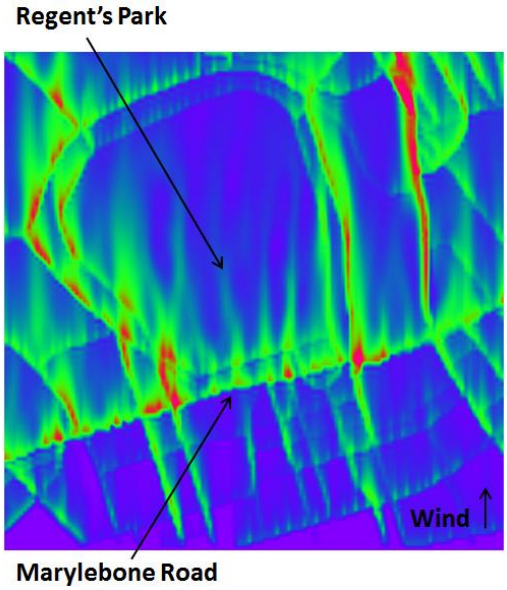

Fig.1 Neighbourhood-scale dispersion pattern

Conclusions
The WRF-LES model coupled with UFP multicomponent microphysics (i.e. evaporation/condensation of SVOCs) can be used to simulate the evolution of nanoparticles in urban air. This study also reveals the dispersion of sized-resolved nanoparticles at the neighbourhood-scale in urban areas (e.g. London).

Acknowledgement
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CFD MODELLING OF THE IMPACT OF HEDGES ON POLLUTANT DISPERSION IN AN ISOLATED STREET CANYON

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Summary

Computational Fluid Dynamics (CFD) simulations and wind tunnel experiments are used to study the effects of hedges on pollutant dispersion in an idealized street canyon with H/W=2. Various hedge configurations with a focus on height and permeability under several wind directions are investigated. Results show that (i) the higher the hedge the lower the turbulent Schmidt number Sc_t has to be to achieve agreement with wind tunnel data and (ii) higher hedges with large leaf area density are preferable to beneficially affect pollutant concentrations at pedestrian level.

Introduction

The ventilation and the spatial distribution of pollutants of a street canyon are influenced both by building configuration and by vegetation. To study the effects of hedgerows on traffic pollutant dispersion in an idealized street canyon, here we use CFD simulations that are first validated with wind tunnel experiments (Gromke et al., 2016). Then, CFD is employed to extend the wind tunnel analysis to study the impact of different hedgerow heights under an oblique wind direction.

Methodology and Results

Wind tunnel experiments were performed by Gromke et al. (2016), see Figure 1 for the street canyon model. To simulate the release of traffic exhausts, four tracer gas emitting line sources were embedded at street level and samples were analysed by Electron Capture Detection (ECD) yielding normalized mean concentrations according to: $c^+ = cU_H H/Q_l$ with c the mean concentration and Q_l the source strength per unit length of the tracer gas emission. 3D simulations were performed with the CFD code FLUENT. The computational domain was built fulfilling the COST Action 732 recommendations. The standard k-ε model was used. The vegetation was modelled by adding a momentum sink term to the standard fluid flow equations in terms of leaf area density (LAD, m^2m^{-3}) as follows: $S_i = -LADc_dUu_i$, where u_i is the wind velocity component, U is the wind speed and c_d = 0.2 is the drag coefficient for vegetation. Table 1 summarizes the cases investigated. Results show that there is a good agreement between numerical and experimental concentrations. Higher hedges require lower values of the turbulent Schmidt number Sc_t: the higher the hedge, the more the flow field is disturbed. The positive impact of hedges increases with increasing hedge height from h_h=1m to h_h=1.5m and LAD, i.e. decreasing hedge porosity, for both perpendicular wind (90°) and oblique wind (45°) at leeward A (Figure 3). For oblique wind direction at the windward B, the impact of hedges turns to be adverse, with percentage increases up to about 20%. The negative impact increases with increasing hedges height and decreases with increasing LAD. Overall, concentrations at the windward side are much lower than those at the leeward side, and thus a decrease in concentrations occurs in the street canyon.

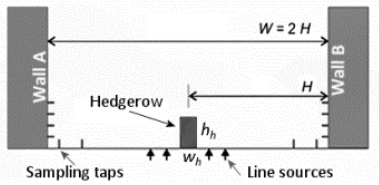

Fig. 1 Street canyon model

	Hedge height h_h (m)			Pressure loss coefficient λ (m^{-1})			Wind direction (°)	
	1	1.5	2.25	0 (ref.)	1.67	3.34	90 (perp.)	45 (oblique)
WT	n	y	y	y	y	y	y	n
CFD	y							y

Tab. 1 Cases investigated (dimensions in full scale)

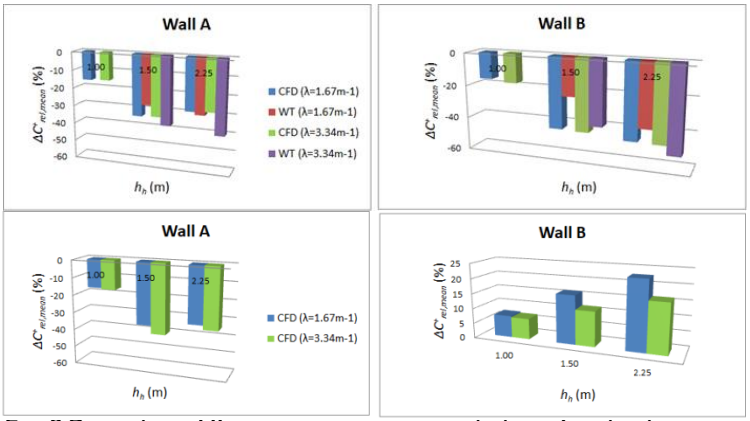

Fig. 3 Percentage differences in mean concentrations for street canyons with hedges referred to the reference case under perpendicular (top) and

Conclusions

The investigation carried out in this work allowed to: set-up a CFD modelling methodology, based on the k-ε turbulence closure, for the study of the aerodynamic effects of hedgerows on traffic pollutant dispersion in street canyons. Results show that it is desirable to plant hedges up to pedestrian height (about 2m) with large leaf area density, which enhance positive effects and diminish the negative impact at the windward side under oblique wind direction.

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AIR QUALITY IMPACTS FOR 2030 BASED ON EMISSION PROJECTION SCENARIOS - A MODELLING APPROACH

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Summary
The impact of the new NEC Directive on the air quality in Portugal in 2030 is estimated based on emission projections under Current Level Emissions (CLE) and Maximum Technically Feasible Reduction (MTFR) scenarios, developed under the EU Clean Air Package. The spatial distribution of air pollutant concentrations for 2030 was obtained by the application of an air quality modelling system with disaggregated emissions based on the emission totals by sector and pollutant for each scenario. Preliminary results show a compliance with the EU air quality objectives.

Introduction
Recently, the National Emission Ceilings (NEC) Directive (2001/81/EC) (EU, 2001) was revised leading to the publication of a new NEC Directive (2016/2284/EU) (EU, 2016) that aims to ensure further reduction of air pollution negative impacts. European Member States committed to stricter targets for 2020 and 2030 for the pollutants included in the previous regulation (SO_2, NOx, NMVOC and NH_3), and to an additional ceiling for PM2.5. Estimates of related air quality improvements in Portugal are country-based, only considering emission totals, and thus there is a lack of information on the spatial variability of emissions and their air quality and health impacts. In this framework, the ongoing project FUTURAR – Air quality in Portugal in 2030 – a policy support (http://futurar.web.ua.pt/en/project) - aims to investigate the air quality impacts, and costs and benefits of emission reduction projections for 2030. FUTURAR makes use of air quality modelling tools and cost-efficiency analysis to quantify the costs and benefits of NEC emission scenarios for 2030 by investigating the spatial patterns of emission reduction measures and corresponding environmental and health impacts.

Methodology and Results
The analysis of emission trends and projections is based on the CLE and MTFR scenarios developed by GAINS for Portugal. Current annual emissions and future projections point to some difficulties in complying with the NEC targets in 2030 for the CLE scenario. The MTFR scenario allows reaching the legislated ceilings although at a very high cost.
The evaluation of the impacts on air quality implied the application of a model system that allowed estimating the pollutants' concentrations based on the emission projections for Portugal and for both scenarios. The WRF-CAMx air quality modelling system was applied to Portugal with a spatial resolution of 0.05 ° (~ 5- 6 km) for 2005, the base year of NEC, and for 2030 considering CLE and MTFR scenarios. For this purpose, national emissions for 2005, by activity sector and pollutant, based on the TNO European emission inventory were considered, and a spatial disaggregation of future emissions for the required modelling domain and resolution was performed.
Preliminary air quality modelling results, taking into account projected emissions for 2030, indicate a compliance with the air quality limit values. Notwithstanding, when considering also the climate change for 2030, the air quality predictions, especially for ozone during Autumn and Summer, slightly increase, due to the average temperature increase and the higher frequency of heat waves in those seasons.

Conclusions
The preliminary assessment of air quality impacts of emission scenarios for 2030 points to a compliance of the EU air quality objectives in Portugal.
The future work will focus on the design and characterization (spatial distribution of emissions and associated costs) of an optimal emissions reduction scenario for Portugal, able to meet the NEC for all addressed pollutants at the least cost. Integrated assessment, comprising impacts, costs and benefits, will be performed.

Acknowledgement
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ESTABLISHING NITROGEN DEPOSITION OVER GERMANY USING MODELLING AND OBSERVATIONS

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Summary

This study uses the chemistry transport model LOTOS-EUROS in combination with wet deposition observations to calculate deposition of nitrogen, sulphur and base cations over Germany for the time period 2000-2015 at a 1x1 km resolution. This is the first time that such a long deposition time series has been calculated using a consistent methodology. Nitrogen deposition over Germany on average declined from 1296 to 1058 Eq/ha/yr from 2000 to 2015, which is completely attributed to a reduction of oxidized N deposition. In the same period, S deposition declined from 385 to 188 Eq/ha/yr. While ecosystem damage due to acidification has declined significantly over the research period, eutrophication remains an issue because reducing ammonia emissions proves problematic.

Introduction

Deposition of nitrogen contributes to eutrophication of terrestrial and aquatic ecosystems. This leads to a reduction in biodiversity, especially in ecosystems that thrive on nutrient-poor conditions. While observations of wet deposition are abundant, dry deposition measurements are extremely scarce because of the challenging and expensive observation procedure. To quantify nitrogen deposition, one therefore needs to rely on modelling. Here, we present the method used to quantify nitrogen deposition over Germany using a combination of chemistry transport modelling and wet deposition observations.

Methodology and Results

A model simulation for Germany nested into a European simulation using LOTOS-EUROS (Manders et al., 2017) was performed for the years 2000-2015. Emission data were for Germany were taken from the new GRETA emission database (Schneider et al., 2016) nested in the TNO-MACC emission database (Kuenen et al., 2014) for the rest of Europe. Because of the lack of observations, dry deposition values are directly taken from the model. Residual kriging was used to generate the rain water concentration distribution across Germany based on the modelled and observed wet deposition. Occult deposition was calculated based on the modelled and observed wet deposition and an empirical approach (Katata et al., 2011). The sum of wet, dry and occult deposition is the total estimated deposition. Over the time period 2000-1015, average deposition over Germany of oxidized nitrogen and sulphur has reduced by 40 and 50%, respectively, while for reduced nitrogen no trend could be found. On average the nitrogen and acid deposition in Germany in 2015 were 1058 and 1206 Eq/ha/yr, respectively. Figure 1 shows the geographical variability of N deposition. Land use specific deposition maps were also produced, with coniferous forests close to source regions for ammonia receiving the highest amount of nitrogen. Through comparison of the deposition distributions with critical load maps it is estimated that 68 % of the ecosystems receive too much nitrogen, whereas critical load exceedances for acidification are only estimated for 26 % of the ecosystems.

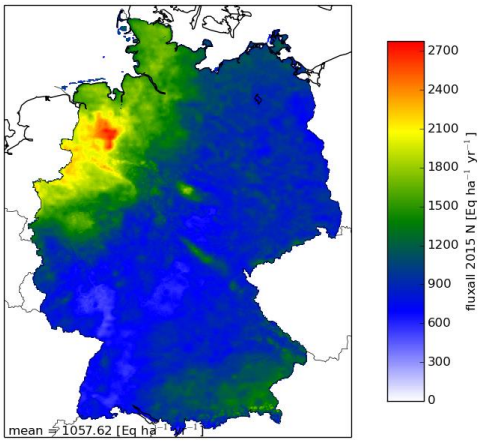

Figure 9. Total N deposition over Germany for 2015

Conclusions

Eutrophication of ecosystems remains a problem in Germany. The methodology presented here successfully combines wet deposition measurements with atmospheric modelling to come to a best estimate of total deposition. Trends in deposition can be investigated based on this work. While acid deposition has been strongly reduced over the past 15 years, deposition of (especially reduced) nitrogen has decreased much less. This emphasises the need for further monitoring and emission reductions.

Acknowledgement

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TREND ASSESSMENT AND CLUSTERING OF TROPOSPHERIC OZONE CONCENTRATIONS IN EUROPE BASED ON TIME SCALE DECOMPOSITION

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Summary
Response of O_3 concentrations to reductions of its precursors in Europe during 1990s is masked by strong meteorological influence on O_3. To understand the effect of legislation air quality measures, a statistically robust approach to estimate O_3 long-term trends is needed. In this study, a decomposition of the underlying frequencies in the O_3 time series has been applied, allowing to study its different time scale variations. De-seasonalization and meteorological adjustment of the observations are performed and compared for the effect they have in uncertainty reduction on the trend estimation procedure. We found that through de-seasonalization alone a significant uncertainty reduction is accomplished. In addition, a two period trend estimation approach has been applied for identifying non monotonous temporal evolution of O_3 concentrations. It is observed that for most stations during 1990s, O_3 has been increasing and after mid-2000s the trend started to decline. A clustering approach based on the different time scale variations of O_3 revealed groups of stations that are affected by special meteorological conditions, as well as the station's pollution burden.

Introduction
O_3 is one of the most troublesome air pollutants causing severe health effects to humans and damaging agricultural production. In the 1990s, emission control measures on O_3 precursors, i.e. nitrogen oxides (NO_x=NO+NO_2) and volatile organic compounds (VOCs), were implemented in order to regulate air pollution. As a result, concentrations of NO_x and VOCs have significantly reduced in Europe, but the response of O_3 to these reductions is not fully understood. Influence of meteorological factors create a substantial uncertainty in the trend estimation of O_3, and can mask the effect of legislation measures. In this study, a statistical approach based on time scale decomposition of the observations is applied, in order to account for meteorological influence in the observed trends and to isolate the response of O_3 to the reduction of precursors. Furthermore, a clustering technique is used for identification of O_3 spatial patterns across the European domain.

Methodology and Results
A non-parametric time scale decomposition method, called the ensemble empirical mode decomposition (EEMD, Wu and Huang (2009)), was applied to extract the underlying frequencies in the time series of O_3 observations, i.e. the long-term, seasonal and short-term variation (Fig. 1). The removal of the seasonal signal obtained with the EEMD is an effective de-seasonalization approach that accounts for most of the meteorologically driven variability of O_3. In addition, the long-term variation signal was used to identify two different time periods in the temporal evolution of O_3, which allowed the estimation of long-term trends in two regimes. More precisely, O_3 concentrations have been increasing during 1990s and only around mid-2000s O_3 has started to decline in Europe. The two regimes approach revealed an interesting dependency to the stations' environment, i.e. the change in the trend occurred later in urban polluted sites than in rural environments. The different time scale variations obtained from the EEMD were used as basis for the stations clustering approach. The main idea of the clustering is to identify groups of stations based on level of similarity of the input time series. Distinct groups of stations were identified, depending on the time scale variation used as input. Interestingly, the resulted clusters can be associated to the different drivers of these variations. For instance, the temperature-driven seasonal variation of O_3 shows a clear dependence on the geographical region, while the emissions-driven long-term variation on the type of station.

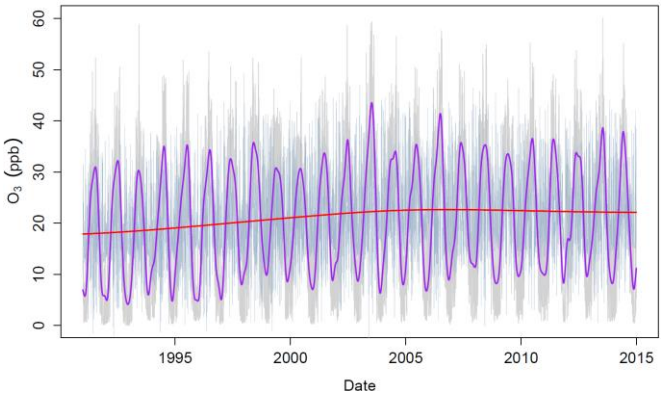

Fig.1 Example of time scale decomposition method. Shown are the daily mean O_3 concentrations (grey), together with the long-term (red), seasonal (purple), and short-term (blue) variation.

Conclusions
Regional differences and temporal changes of O_3 and its seasonal cycle across Europe are addressed in this study. At urban and suburban locations, reduced titration of O_3 by NO had an impact on the trends, while at rural and remote sites the trend of background O_3 is the main driver. The cluster analysis revealed regions in Europe with similar characteristics in the seasonal cycle of O_3, with a clear dependence in climatic conditions and geographical location.

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INFLUENCE OF GLOBAL METEOROLOGICAL NCEP DATA IN MODELING THE DISPERSION AND SEDIMENTATION OF VOLCANIC ASH AT MESOSCALE RANGE IN THE ECUADORIAN ANDEAN REGION

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Summary

We used GFS, FNL and Reanalysis 2 data from NCEP, for modeling the dispersion of volcanic ash during 4 eruptions which took place in Ecuador during the last 6 years. Unexpectedly, the performance decreased when using the Reanalysis 2 data. It suggests that, for this kind of studies in this region, it is advisable the use of GFS or FNL rather than Reanalysis 2 data.

Introduction

Volcanic ash can cause critical air pollution and other significant impacts. Atmospheric transport models (ATMs) are pivotal for modeling ash dispersion and deposition. One of the components of any ATM involves is the meteorological model, which describes the state and evolution of the atmosphere in which the ash is introduced. For mesoscale studies, models work with resolutions of few km. They use outputs from global meteorological models to set the initial and boundary conditions of the computational domains. One of these models is the Global Forecast System (GFS), produced by the National Centers for Environmental Prediction (NCEP), which takes current observations to forecast the weather. The FNL (Final) Operational Global Analysis data is another NCEP product which ingests about 10% more observations than GFS analysis. The NCEP-DOE Reanalysis 2 (NCEPR2) provides past weather data based on the assimilation of additional observations which were not operationally ingested by GFS or FNL. So, it is expected that NCEPR2 data would result in better modeling quality. Typically for past weather modeling, using reanalysis data-as NCEPR2-is considered the best choice.

Method and Results

We used the NCEP global data (GFS, FNL and NCEPR2) to generate the initial and boundary conditions over Ecuador, for simulating the meteorology with the Weather Research & Forecasting (WRF3.7.1) model. After, WRF meteorological outputs were ingested into the Fall3dV7.1.4 model, to simulate the ash dispersion and sedimentation of 4 eruptions at Tungurahua (15-Dec-2012, 14-Jul-2013 and 1-Feb-2014) and Cotopaxi (14-Aug-2015) volcanoes. Modeled ash fallout quantities were compared with records from ashmeters installed around these volcanoes (Parra et. al, 2016). For all the eruptions, the modeling performances using GFS and FNL data were equivalent (Figs. 1, 2). For all the eruptions, the performance decreased when using the NCEPR2 data. As example for the Cotopaxi eruption of 14-Aug-2015, the performances (linear correlation coefficient R^2) were 0.50 and 0.47 for the GFS and FNL respectively. It decreased to 0.05 when modeling with NCEPR2 data.

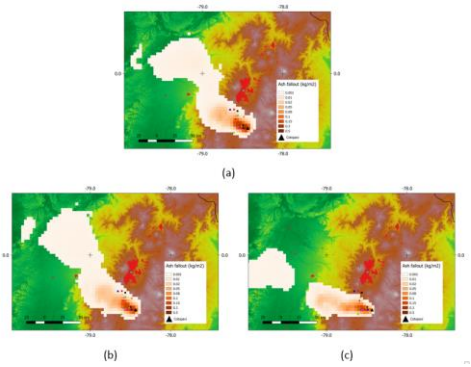

Fig.1 Cotopaxi volcano. Modeled ash fallout for 14-Aug-2015 (kg/m^2): (a) GFS (R^2=0.50), (b) FNL (R^2=0.47), (c) NCEPR2 (R^2=0.05)

Volcano	Date	GFS	FNL	NCEPR2
Tungurahua	15-Dec-2012	0.99	0.97	0.65
Tungurahua	14-Jul-2013	0.67	0.63	0.41
Tungurahua	1-Feb-2014	0.54	0.54	0.14
Cotopaxi	14-Aug-2015	0.50	0.47	0.05

Fig. 2 Modeling performance measured by the linear correlation coefficient (R^2)

Conclusions

The decrease of performance when using the NCEPR2 data in modeling the dispersion of volcanic ash over the Ecuadorian Andean region was unexpected. It suggests that, for this kind of studies in this region, it is advisable the use of GFS or FNL rather than NCEPR2 data. One reason could the lack or scarcity of meteorological records from this region that today are assimilated when preparing the reanalysis data. Our results indicate the need of assessing in more detail, the NCEPR2 and other reanalysis data when used for modeling purposes over the Equatorial region.

Acknowledgement

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Remote Sensing and Satellite Observations

VARIATIONS AND TEMPORAL TENDENCIES IN BACKGROUND AND URBAN CO AND CH_4

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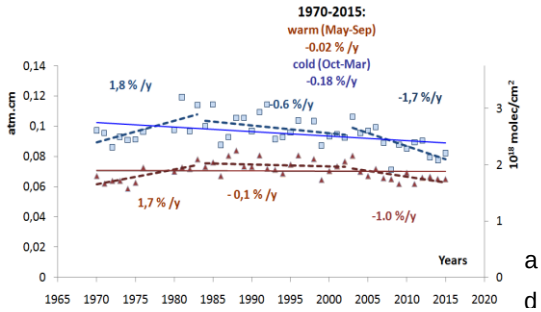
Summary
Results of ground-based spectroscopic measurements of CO and CH_4 atmospheric total content (TC) in Moscow, Beijing, Zvenigorod (ZSS station, Moscow region, 53 km west from the center of Moscow) and the station ZOTTO (Central Siberia) are analyzed as well as data of Eurasian NDACC stations. Estimates of CO and CH_4 TC trends obtained with use of ground-based and satellite AIRS v6 data are in agreement between themselves.
Total decrease of CO TC for 2003-2016 for different urban and background Eurasian regions was found; but for summer and autumn months of 2007-2016 CO TC trends in North Europe and Asia became positive. A decrease of magnitude of seasonal CO variations was found for ZSS. An increase of CO in warm seasons after 2007 cannot be explained by growth of anthropogenic or wild-fares emissions. Characteristics of CO and CH_4 TC variability in urban and background regions are discussed.

Introduction
Global climate changes always accompanied by regional and local changes in atmospheric composition. The relationships between them are important especially in urban regions are different for different time-periods and sites. This work continues a series of previous works devoted to the study of air pollution in different regions of Eurasia (Golitsyn et al, 2015, Rakitin et al. 2011, Rakitin et al., 2017).

Results
The difference between seasonal values of rural CO TC (ZSS station) for warm and cold seasons has decreased, see Fig.1.
The decrease of CO TC in Moscow and Beijing was observed in 2003-2016 (2,8±1,7%/yr and 2,0±2,7%/yr respectively). Global decrease of CO TC in Eurasia in 2003-2016 was observed. For summer and autumn months of 2007-2016 CO TC has increased in almost all of measuring sites (Tab.1) in spite of reduction of anthropogenic emissions and decrease of emission from wild fires (in domain Central North Eurasia, 10º–90º E., 42º–75º N).
A growth of CH_4 TC after 2007 over different Eurasian regions was found.



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Conclusions
According ground-based and satellite spectroscopic observations after 2007 CO TC trends over North Eurasia changed their sign from decrease to increase in summer and autumn seasons. These changes cannot be explained by growth of wild-fires or anthropogenic emissions. CH_4 TC trends growth after 2007 was obtained for North Europe and tropical belt of Eurasia.

Acknowledgement
This work was supported by the Russian Scientific Foundation under grants №14-47-00049 (in satellite trends analysis) and №16-17-10275 (in trends analysis for Moscow region).

Sites, time-periods for ground-based		Ground-based			AIRS		
		Season	Trend, %/year		Time periods	Trend, %/year	
			Season	Year		**Season**	Year
ZSS	2003-2016	Sep-	**0,15±1,10**	-1,60±1,31	2003-2016	-0,48±0,84	-0,70±0,33
	2007-2016	Nov	**0,94±1,26**	-0,58±1,87	2007-2016	-0,21±1,54	-0,46±0,52
Peterhof	2003-2015	Sep-	**0,20±0,87**	-0,37±0,81	2003-2016	-0,39±0,72	-0,62±0,33
	2007-2015	Nov	**0,83±1,44**	-0,33±1,81	2007-2016	**0,26±1,04**	-0,26±0,43
ZOTTO		Jun-			2003-2016	**0,50±2,06**	-0,37±0,57
	2008-2016	Aug	**1,1**		2007-2016	**1,66±4,09**	**0,02±0,96**
Beijing	2003-2016	Oct-	-1,96±2,67		2003-2016	-0,81±0,84	-1,03±0,44
	2007-2016	Nov	-2,29±4,57		2007-2016	-0,27±1,29	-1,00±0,78
Moscow	2003-2016	Sep-	-2,53 ±2,39	-2,83±1,67			
	2007-2016	Nov	-1,65±2,82	-2,11±2,47			
Kiruna	2003-2015	Jul-	-1,14±1,38	-1,16±0,74	2003-2016	-0,48±0,75	-0,61±0,32
	2007-2015	Oct	**0,47±1,33**	-0,26±0,98	2007-2016	**0,24±1,09**	-0,27±0,38
Harestua	2003-2014	Jul-	-0,59±2,18	-0,79±1,29	2003-2016	-0,52±0,82	-0,72±0,35
	2007-2014	Oct	**1,56±3,07**	0,35±2,43	2007-2016	**0,10±1,27**	-0,39±0,46
Ny Alesund	2003-2014	Jul-	**0,17±2,15**	-0,67±1,80	2003-2016	-0,06±0,63	-0,52±0,32
	2007-2014	Sep.	**2,36±3,36**	1,07±1,72	2007-2016	**0,63±0,80**	-0,30±0,49
Bremen	2003-2015	Jul-	-0,25±2,55	-0,05±1,18	2003-2016	-0,57±0,68	-0,79±0,34
	2007-2015	Oct	**2,08±4,68**	-0,52±2,81	2007-2016	-0,07±1,01	-0,49±0,47

Tab.1. Annual and seasonal CO TC trends over Eurasian stations for 2003-2016 and 2007-2016

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WIDESPREAD CHANGES IN UK AIR QUALITY OBSERVED FROM SPACE

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Summary
Satellite observations, such as tropospheric column NO_2 ($TCNO_2$), aerosol optical depth (AOD) and sub-column (0-6 km) ozone (SCO_3), provide widespread monitoring of air quality (AQ) on a national scale. In this study, we analyse trends in UK AQ between 2005 and 2015 finding significant decreases in $TCNO_2$ and AOD over UK pollution hotspots. The largest changes in NO_2 are located over populated (i.e. source) regions. Aerosol, given its relatively longer lifetime, is subject to long range transport yielding changes in AOD over a larger region. Trends in SCO_3 show no significant changes over England/Wales, but positive trends over Scotland are consistent with observed positive trends in background tropospheric O_3 in other remote regions of north-western Europe.

Introduction
Degradation in air quality in the United Kingdom (UK) is an important public health concern, estimated to result in approximately 50,000 premature deaths per year (HoC, 2010). Exposure to pollutants such as O_3, NO_2 and particulate matter ($PM_{2.5\ \&\ 10}$) lead to health ailments such reduced cardiovascular and respiratory functions (WHO, 2014). Therefore, government policy has led to efforts to reduce their emissions (e.g. Air Quality Standards Regulations 2010 and Large Combustion Plants Regulations 2007). While many studies have used surface observations to assess the impact of such polices, we used satellite observations with greater spatial coverage to investigate national changes in NO_2, O_3 and AOD.

Methodology and Results
Satellite swath data are mapped onto high resolution grids (i.e. 0.05° × 0.05° for NO_2 and AOD, 0.5° × 0.5° for O_3) by slicing satellite pixels up into many sub-pixels and interpolating them onto a regular grid. This results in more spatial information for statistical analysis.

Between 2005 and 2015 there have been significant decreases in $TCNO_2$ and AOD over the large urban regions of London, Manchester and Birmingham. This is linked with emission reductions from government policy (the Air Quality Standards Regulations 2010) to improve AQ. At Drax (Figure 1), decreasing $TCNO_2$ has been linked with policy such as the Large Combustion Plants Regulations 2007, the switch from coal to biomass fuels and closure of other nearby power stations. When pollution trends are weighted by population fraction exposed, it suggests that the general public benefit more from larger changes in NO_2. Trends in SCO_3 are significant over Scotland (insignificant over England and Wales), which are consistent with other studies showing increasing background tropospheric ozone over north-western Europe.

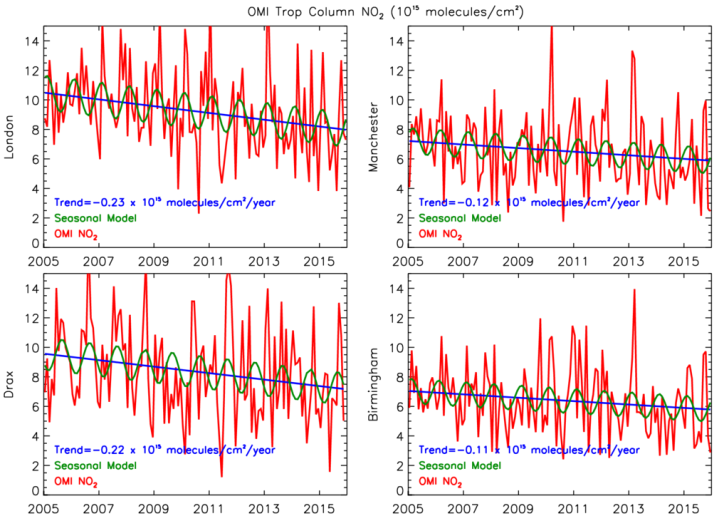

Fig.1 OMI tropospheric column NO_2 trends ($x10^{15}$ molecules/cm^2/year) for London, Manchester, Drax power station and Birmingham (2005-2015).

Conclusions
By using high resolution datasets of satellite-observed air quality, this study has identified recent (2005-2015) widespread decreases in UK $TCNO_2$ and AOD linked to reduced emissions from government policy. When pollution trends are weighted by population fraction exposed, it suggests that the general public benefit more from larger changes in NO_2. Trends in SCO_3 are significant over Scotland, consistent with other background tropospheric ozone trends over north-western Europe.

Acknowledgement
We acknowledge the use of the TEMIS (http://www.temis.nl/index.php) OMI and NASA (https://earthdata.nasa.gov/) MODIS datasets. This work was supported by the UK NERC National Centre for Earth Observation.

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INTERCOMPARISON OF FOUR AIRBORNE IMAGING DOAS SYSTEMS FOR URBAN NO2 MAPPING – THE AROMAPEX CAMPAIGN

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Summary
We present an intercomparison study of four airborne imaging DOAS instruments, dedicated to the retrieval and high resolution mapping of tropospheric nitrogen dioxide (NO_2) vertical column densities (VCDs) in an urban area. The AROMAPEX campaign took place in Berlin, Germany in April, 2016 with the primary objective to test and intercompare the performance of the four experimental airborne imagers. AROMAPEX is also a preparatory step for forthcoming calibration/validation campaigns for the new generation of spaceborne air quality sensors, such as TROPOMI, S4 and S5.

Introduction
60 % of the world's population is currently living in urban areas, while the latter contain most of the anthropogenic emission sources. 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. NO_2 is a short-living specie with concentrations that can vary strongly both in space and time. For the reasons stated, the monitoring and accurate mapping of air pollutants, such as NO_2, at the scale of cities is of high relevance.

Methodology and Results
The imaging DOAS instruments were operated simultaneously from two manned aircraft, performing synchronised flights: APEX (VITO/BIRA-IASB) was operated from DLR's DO-228 D-CFFU aircraft at 6.2 km altitude while AirMAP (IUP Bremen), SWING (BIRA-IASB) and SBI (TNO/TU Delft/KNMI) were operated from the FUB Cessna 207T D-EAFU at 3.1 km. Two synchronised flights took place on 21 April 2016, the only cloud-free day during the campaign, in the morning from 09:34 to 12:01 LT and in the afternoon from 14:24 to 16:39 LT. APEX, AirMAP and SWING have a comparable swath width of 3 km, while SBI has a swath of 435 m. The spatial resolution is better than 100 m for APEX, AirMAP and SBI (pushbroom scanning), and approximately 300 m for SWING (whiskbroom scanning). First, NO_2 slant columns were retrieved by applying absorption spectroscopy in the visible wavelength region on the observed spectra, being solar radiation backscattered by the atmosphere or ground surface. Then, appropriate air mass factors (AMFs) were calculated by a radiative transfer model in order to convert the slant columns to VCDs. AMFs account for enhancements in the optical path length due to the surface albedo, aerosol and NO_2 profile shapes and viewing and sun geometry. Finally, retrieved NO_2 VCDs were georeferenced and gridded. The 4 datasets were harmonised to ensure comparability. The NO_2 horizontal distribution, observed by the different DOAS imagers, shows very consistent spatial patterns (see Fig. 1). The NO_2 field is dominated by two large plumes related to industrial compounds, crossing the city from west to east. Retrieved NO_2 VCDs range between 1 x 10^{15} molec cm^{-2} upwind of the city and 2 x 10^{16} molec cm^{-2} in the dominant plume, with a mean of 7.3 ± 1.8 x 10^{15} molec cm^{-2} for the morning flight and between 1 and 23 x 10^{15} molec cm^{-2} with a mean of 6.0 ± 1.4 x 10^{15} molec cm^{-2} for the afternoon flight. The four data sets are in good agreement with correlation coefficients better than 0.9 and slopes close to unity.

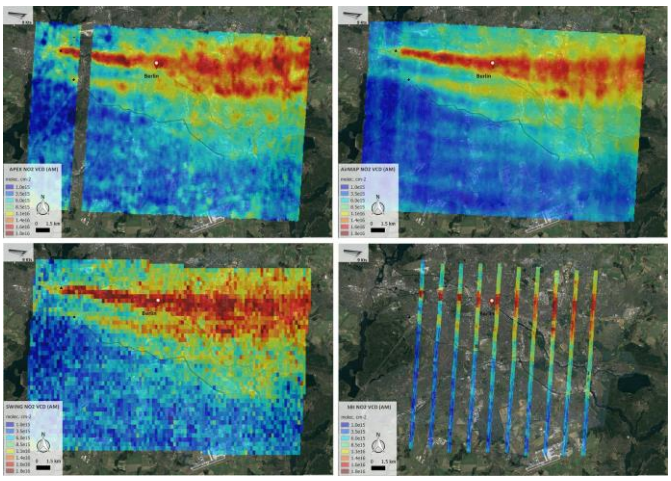

Fig. 1 Tropospheric NO_2 VCD maps retrieved from (a) APEX, (b) AirMAP, (c) SWING, and (d) SBI for the morning flight over Berlin on 21 April 2016 (Google, TerraMetrics). The key contributing NO_2 emission sources are indicated by a black triangle (Reuter West power plant) and black diamond (Messe Berlin). The highways A100 and A113, running south of the city, are marked by the grey line.

Conclusions
This study shows that the compared airborne DOAS imagers yield consistent results. The study also demonstrates that the urban NO_2 distribution, and its fine scale variability, can be mapped accurately with high spatial resolution and in a relatively short time frame. The observations allow to differentiate local emission sources and reveal the strong horizontal variability of tropospheric NO_2, contributing to an increased understanding of trace gas distribution and related chemical processes in urban areas.

Air Quality in Global Cities

SPECIAL SESSION

THE ROLE OF METEOROLOGICAL CONDITIONS AND POLLUTION CONTROL STRATEGIES IN REDUCING AIR POLLUTION IN BEIJING DURING APEC 2014 AND PARADE 2015

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Summary
In this study, we used the air pollution control periods during APEC Asia-Pacific Economic Cooperation Forum) in 2014 and Parade (Victory Parade for the Commemoration of the 70th Anniversary of the Chinese Anti-Japanese War and the World Anti-Fascist War) in 2015 to estimate the role of meteorological conditions and pollution control strategies in reducing air pollution in the megacity of Beijing. We first measured the changes in air pollutant concentrations, including $PM_{2.5}$, gaseous pollutants, and the components of $PM_{2.5}$. We then estimated the role of meteorological conditions and pollution control strategies in reducing air pollution by comparing the pollutant concentrations during days with stable meteorological conditions. Finally, we developed a statistical model based only on meteorological parameters to evaluate the role of meteorological conditions and pollution control strategies in reducing the levels of air pollution in Beijing.

Introduction
Various air pollution control strategies have been implemented at the national, provincial, and city levels However, it is not clear how effective these strategies are in reducing air pollution. The efforts made to ensure satisfactory air quality for special events in the short term, such as the Beijing 2008 Olympics, provide a unique opportunity to evaluate the effectiveness of pollution control strategies (Kelly and Zhu, 2016). During the Beijing Olympics comprehensive pollution control strategies were implemented intensively over a short period of time. Based on the successful experience during this event, One challenge when evaluating the effectiveness of air pollution control strategies over a short period of time is separating out the contribution of meteorological conditions from to the reduction in air pollution levels

Methodology and Results
Atmospheric particulate matter of aerodynamic diameter $\leq 2.5\ \mu m$ ($PM_{2.5}$) samples were collected and gaseous pollutants (SO_2, NO, NOx, and O_3) were measured online at a site in Peking University (PKU) in Beijing, China. A generalized linear regression model (GLM) was used to establish the relationship between air pollutant concentrations and meteorological parameters. The objective dependent variables included concentrations of $PM_{2.5}$, individual $PM_{2.5}$ components, and gaseous pollutants, which could explain more than 70% of the variation in air pollutant concentration levels, after incorporating the nonlinear relationships between certain meteorological parameters and the concentrations of air pollutants. Evaluation of the GLM performance revealed that the GLM, even based only on meteorological parameters, could be satisfactory to estimate the contribution of meteorological conditions in reducing air pollution, and hence the contribution of control strategies in reducing air pollution

Conclusions
The meteorological conditions and pollution control strategies contributed 30% and 28% to the reduction of the $PM_{2.5}$ concentration during APEC, and 38% and 25% during Parade, based on the assumption that the concentrations of air pollutants are only determined by meteorological conditions and emission intensities. We also estimated the contribution of meteorological conditions and control strategies in reducing the concentrations of gaseous pollutants and $PM_{2.5}$ components with the GLMs, revealing the effective control of anthropogenic emissions.

Acknowledgement
This study was supported by the National Natural Science Foundation Committee of China (41421064, 21190051), the European 7th Framework Programme Project PURGE (265325), and the Collaborative Innovation Center for Regional Environmental Quality.

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RISK INDEX DUE TO CONTINGENCIES OF POOR AIR QUALITY IN GUADALAJARA, MEXICO

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Summary
Air pollution is a growing concern as poor air quality episodes have become more frequent in megacities such as Guadalajara, in Mexico. Government agencies are responsible for activating the city contingency plans, which consist on a series of actions focused on preventing and mitigating the effects of poor air quality. This works aims to develop a geospatial risk index that includes demographic and air quality data that provides information of specific city areas, which require direct actions, due to poor air quality.

Introduction
Poor air quality episodes have become more frequent in last years, in Guadalajara Metropolitan Area, in Mexico; in year 2014 there were 16 episodes of environmental contingency and pre-contingency and 23 episodes in 2015. In addition, several areas of the city fail to comply with the pollutant concentration regulations for up to 30% of the time through the year. In order to focus mitigation efforts, and to prevent further damage due to poor air quality, we seek to develop a spatially explicit risk index that provides information of areas with highest susceptibility. The risk index includes a vulnerability factor, due to geographical and demographical characteristics, and a hazard factor due to high levels of air pollution exposure.

Methodology and Results
We define our risk index as the mathematical product of the Hazard and the vulnerability. Hazard is a phenomenon or condition that can cause death, injury or other health impacts, as well as any other damage. Vulnerability considers the characteristics and circumstances of a community or system that makes them susceptible to the harmful effects of a threat.
We recollected spatial data regarding the principal demographic information that characterizes the city; the data is reported and generated for the Basic Geostatistical Areas (AGEB). The vulnerability index was defined using principal component and minimum variance stratification analysis (Dalenius & Hodges, 1959).
The Danger index was calculated using air quality measurements for a specific period in time; we used concentration values of O_3, CO, SO_2, NO_2 and PM_{10}. We normalized the air quality data within the limit values of the respective standards, and then applied once again principal component and minimum variance stratification analysis. Since the air quality data available is reported only for each one of the respective monitoring stations, we proceeded to interpolate this data by using the Inverse Distance Weighted (IDW) method. The equations to calculate both indexes are reported on table 1. The risk index is the direct product of both indexes.
After the three indexes were calculated for each of the AGEB's, we classified them according to the colour code presented in table 2. Finally, these values are represented graphically on the map of Guadalajara Metropolitan Area, as shows in figure 1. The sections that show high values of the risk index correspond to areas with high population density and large number of local sources of pollutant emissions.

Index	Equation
Vulnerability	*(0.743 × School density + 0.507 × Infant population + 0.558 × Total population + 0.686 × Total local emission sources) / 4*
Hazard	*(0.756 × CO + 0.562 × NO2 + 0.785 × O3 + 0.713 × PM10 + 0.756 × SO2) / 5*
Risk	*Vulnerability × Danger*

Table 1. Risk index equations.

Conclusions
We developed a methodology for calculating the risk index for poor air quality. This tool can offer useful information to focus on preventive and mitigation actions. This index has a static component, the vulnerability, and a dynamic component, the danger, which reflects snapshot of the air quality in the city.

Category	Colour code	Hazard	Vulnerability	Risk
5.-Extreme		> 0.4	> 46	> 8
4.-Very high		0.3 - 0.4	35 - 46	6 - 8
3.-High		0.2 - 0.3	24 - 34	4 - 6
2.-Medium		0.1 - 0.2	12 - 23	2 - 4
1.-Low		0 - 0.1	0 - 11	0 - 2

Table 2. Risk index color code.

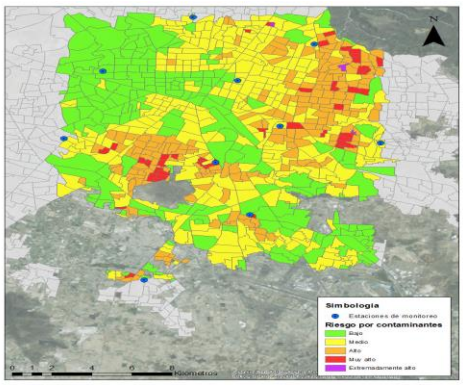

Figure 1. Risk index for poor air quality episodes in Guadalajara city, in Mexico.

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IN-VEHICLE PARTICULATE MATTER AIR POLLUTION EXPOSURE IN BIRMINGHAM, UK.

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Summary
This study has characterised in-cabin passenger exposure to vehicle emissions and the influence of different ventilation settings. We employed a mobile laboratory and a range of passenger cars, mounted with instruments to simultaneously measure air pollutants both inside and outside the vehicle during on-road driving in urban situations in Birmingham, UK. The results for particulate matter (PM_{10}, $PM_{2.}5$ and PM_1) indicated that the ratio of inside/outside (I/O) average concentrations were around 0.78/0.65, when windows were opened/closed respectively, with no additional ventilation, while with the fan bringing fresh ambient air into the vehicle but windows closed, the average ratios were higher than 1 (I/O >1) and lower than 1 (I/O <1) and were dependent upon the external traffic conditions.: the I/O ratio varied from 0.45 - 0.68 (ventilation off) to 1.1 – 1.7 (ventilation on),

Introduction
Urban air quality has a significant impact on public health. Pollutants such as airborne particles are of key importance due to the effects they have on human health, which includes reduced lung function and increased risk of cancer. Vehicle emissions are a major source of air pollution and airborne particles in an urban environment. As a result, drivers and commuters both experience significant exposure to vehicle emissions. Taking into account all the above, we investigated the vehicle in-cabin driver/passenger exposure to PM concentrations in relation to outdoor abundance under real driving conditions.

Methodology and Results
The University of Birmingham mobile laboratory (see Fig. 1) and various passenger cars were equipped with instruments to measure NO_x, CO_2, O_3, PM_{10}, $PM_{2.5}$ and PM_1 both from ambient outdoor air and in-cabin air. CO_2 was used as a tracer for the outside pollution (vehicle emissions) and in-cabin ventilation (breath). Measurements were taken in "chase" mode, under different ventilation conditions, around the city of Birmingham, at different times of day. The results show an anti-correlation between in-cabin CO_2 and PM. CO_2 increases in the enclosed cabin (due to respiration) mitigated by the supply of outside air; however this increases PM concentrations since the latter penetrate the cabin via the ventilation system (see Fig 2). The I/O (inside/outside) ratio for particles with windows closed and the ventilation system on/off, under different traffic condition, was found to vary from below 1, when the fans were off (I/O <1), to above 1 (I/O >1), when the fans were on, while, when the ventilation system was off and the windows are opened/closed the I/O ratio varied was < 1 around 0.78/0.65 across the PM size classifications.

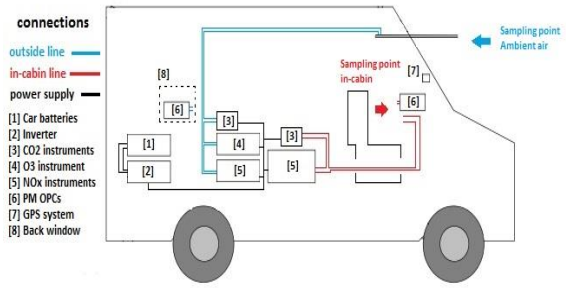

Fig.1 Schematic representation of mobile laboratory set up.

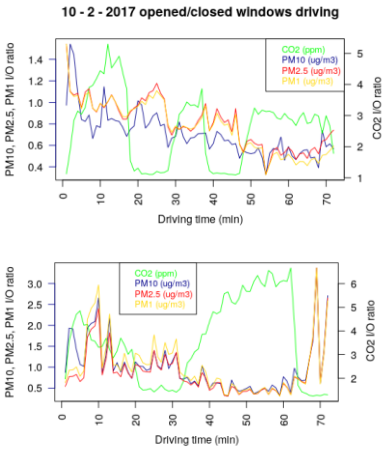

Fig.2 Ratios of mobile measurements (top), sub-urban with open/close windows (bottom) urban with fan on/off

Conclusions
Our results suggest that the in-cabin ventilation plays an important role to the in-cabin concentration levels, and can cause these to be either lower than, or higher than, those experienced outside the vehicle – with interesting consequences for driver and passenger exposure. In-cabin concentrations of PM_{10}, $PM_{2.5}$ and PM_1 are higher than external concentrations when the fan is on. This is probably due to the accumulation that occurs, since there is limited dispersion of pollutants in an enclosed cabin and only a small portion of air is exchanged. A small reduction is observed (I/O ratio < 1) when the windows are open. Recirculating ventilation options minimise in cabin exposure to external particulate matter under urban driving conditions.

Acknowledgement
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SEASONAL AND SPATIAL COMPARISON OF AMBIENT AIR POLLUTION IN RURAL AND URBAN BEIJING

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Introduction

The Global Burden of Diseases study reported that exposure to ambient particulate matter was the fourth-leading risk factor for premature mortality in China. Beijing, as the largest Chinese megacity, is facing some of highest air pollution levels in the world, with particulate matter ($PM_{2.5}$) concentrations regularly exceeding World Health Organization air quality guidelines. Owing to the large spatial area, different local emission source and activity pattern etc, residents at urban and rural Beijing may expose to different level of ambient air pollution and their health response may also differ subsequently.

Aim

This study is a part of the AIRLESS[1] project, aiming to: 1) quantify the levels of ambient air pollution in urban and rural Beijing during winter and summer 2) understand the underlying cause of the seasonal and spatial difference in outdoor exposure levels. The result of this study will provide outdoor exposure for the further analysis of association between air pollutants and health endpoints.

Methodology and Results

A rich set of air pollution metrics, including gaseous pollutants, $PM_{2.5}$ and its chemical components, were measured with online instruments simultaneously at urban and rural Beijing (PKU vs. Pinggu Site, 70 km apart) for 47 days during winter 2016 and 38 days during summer 2017. The monitoring period covered the time when subjects of AIRLESS panels were taking clinical examinations. The monitoring sites were within 1 km from each local clinics and most of the residential address.

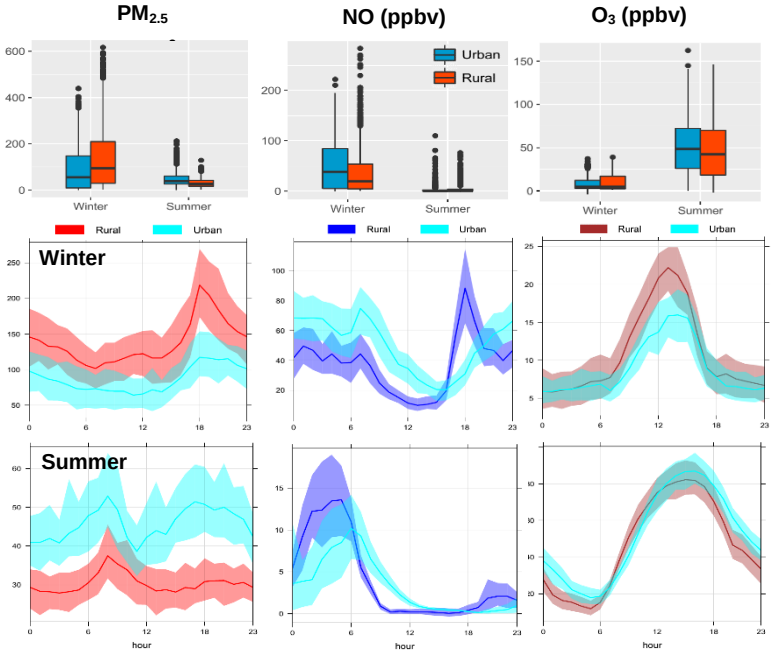

Figure 1: Comparison of seasonal and spatial concentration (top panel), and diurnal trends (bottom two panels) of $PM_{2.5}$, NO and O_3 at urban and rural

$PM_{2.5}$, NO and O_3 were chosen as examples for preliminary results. Significant seasonal difference was observed at both sites (Fig 1, top row), with higher level of $PM_{2.5}$ and NO in winter than summer, and the opposite for O_3. In winter, the concentration of $PM_{2.5}$ was 85.8±78.7 μg/m^3 at rural site (49 μg/m^3 lower than rural site), as compared to summer as 48.7±19.2 μg/m^3 (17 μg/m^3 higher than rural site). The spatial gap of $PM_{2.5}$ in winter may be attributed to diurnal pattern where a peak shown at 18:00 was more pronounced in rural than urban site, indicating potential local source, such as heating. The constantly higher $PM_{2.5}$ level at urban site in summer may need further chemical components analysis as reference. In terms of O_3, the concentration was higher at rural than urban site during winter (11.2 vs. 8.8 ppb). A lower peak at noon was observed clearly at rural site when comparing the diurnal trend with urban site. On contrary, during summer, rural O_3 level was lower than urban (47.3 vs. 53.4 ppb), and the difference started from afternoon (14:00) and became pronounced during night hours (22:00-05:00). The spatial O_3 gap in both seasons might explained by dominant seasonal wind directions, titration effect of NO at urban site, and high peak of NO during summer night, as shown in Fig 1 middle column.

Conclusion

This study shows a clear seasonal, spatial and diurnal difference of air pollution in Beijing, which may be attributed to atmospheric physical and chemical processes, local sources and residential activity pattern. Detailed analysis of the chemical particulate component together with the personal monitoring exposure is ongoing to better understand the seasonal and spatial difference. Health responses, especially some acute cardiopulmonary effect, of residents at urban and rural Beijing might differ given the contrast of air pollution.

1 "Effects of air pollution on cardiopulmonary disease in urban and peri-urban residents in Beijing", part of "Air Pollution and Human Health in a Chinese Megacity" project

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LEVELS AND MAJOR SOURCES OF PM10 AND PM2.5 IN İSTANBUL METROPOLITAN AREA

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Summary

Air pollution is a major environmental problem affecting developed and developing countries around the world. İstanbul is the biggest city of Turkey and one of the most crowded cities in the World with its about 20 million population. Air pollution in İstanbul, one of the most important problems of modern life. Although there have been many improvements in the city air quality after 1990's, it is still one of the polluted cities in the world. Industrial production facilities in and around Istanbul, as well as all kind of road, marine and air transportation, Also because of geographical location of Istanbul and effects of long term transportation. This study is one the most comprehensive PM10 and PM2.5 measurements of on the Asian side of Istanbul. After determination of PM10 and PM2.5 further analytical studies will be done for metal analysis to determine source apportionment of pollution in Istanbul.

Intruduction

This research was the first long-term attempt to concurrently measure and identify major sources of both PM10 and PM2.5 in Istanbul Municipality Area. Simultaneous PM10 and PM2.5 measurements were performed at three different sampling locations for one year sampling time, mainly once at the week time and one at the weekend.

Methodology and Results

Sampling locations were selected to represent, industrial, traffic and combustion pollution effects whereas one sampling point were selected to represent relatively clean background air quality of Istanbul. A year of sampling helped to understand combustion and non-combustion period, heavy traffic, monthly and seasonal effects. Long term sampling shows the effects of long range transportation and also effect of different types of industrial pollutions on the ambient air quality of Istanbul. Simultaneous PM10 and PM2.5 measurement conducted through the year at 3 locations. Filters are collected and moved to the accredited lab after every week and weekend measurement. All quality control steps taken into consideration before, during and after measurement.

Average of a year-long measurements shows that PM10 results occurred as PM10 31,43 $\mu g/m^3$ ± 10,38 for background sampling station, 77,84 $\mu g/m^3$ ± 33,75 for traffic and combustion sourced areas and 71,69 $\mu g/m^3$ ± 31,32 relatively industrial part of the city. PM2.5 results for the same sampling points measured as 16,45 $\mu g/m^3$ ± 7,44, 45,26 $\mu g/m^3$ ± 24,77 and 42,30 $\mu g/m^3$ ± 24,77, respectively.

Conclusions

Comparison of average of PM10 and PM2.5 results with air quality indexes it shows air pollution for the selected sampling stations are moderate around the year. Also construction and marine activities are playing essential role for some part of the city. Seasonal measurements show that there is significant effect of traffic and fossil fuel burning on the pollution. Weekly analysis also allowed as to determine effects of some critical meteorological movements on the PM results. Those are Saharan desert dusts and industrial pollution transportation from the nearest zones. Results of those days are also compared to stationary PM10 measurement stations of the ministry. The results conrim that while there is localized effect on industrial pollution transportation, whole city effected by Saharan dusts for specific period of time.

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Key Words: Ambient Air Quality, PM10, PM2.5

CALIOPE-URBAN: COUPLING R-LINE WITH CMAQ FOR URBAN STREET-SCALE AIR QUALITY FORECASTS OVER BARCELONA

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Summary
In urban environments NO_2 present strong concentration gradients at street level that cannot be reproduced by mesoscale air quality models since large concentration variations can occur within a grid cell. In order to overcome this limitation, the combination of regional and urban scale models is presented as a solution to estimate air quality at the street level within the larger grid cell. This work describes a methodology to couple CALIOPE (Pay et al., 2012), a mesoscale air quality modelling system that provides 48 hour air quality forecasts at 1 km over Barcelona city, with R-LINE (Snyder et al., 2013). R-LINE has been adapted to provide air quality estimates at street level within Barcelona's geometrical conditions (i.e. street canyon pattern). The coupled modeling system is evaluated using ambient street-level pollutant and meteorological measurements collected during a field study in Spring 2013 and compared with the current mesoscale solution applied to Barcelona.

Introduction
Barcelona traffic stations report chronic exceedances of NO_2 European annual regulatory limits since the year 2000. An air quality forecasting system is necessary to inform public and decision makers about air quality levels in the city.

Methodology and Results
The combination between CALIOPE and R-LINE, namely CALIOPE-Urban, uses as input CMAQ for background concentration, WRF for meteorological data and HERMES for traffic emissions. R-LINE is run using the Generic Reaction Set (GRS) for NO-NO_2-O_3 chemical reactions.

Fig. 1 Mesoscale (squares) and

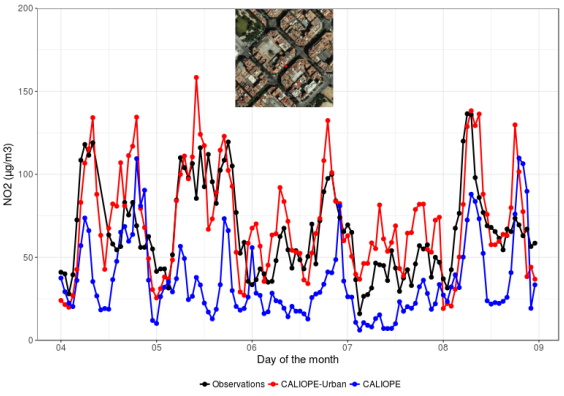

Fig 2. Mesoscale (blue), street-

Conclusions
The street-scale system reproduces large concentration variations that exist within a mesoscale system grid cell as can be seen in Fig.1. Additionally, it gives better results near trafficked areas in comparison to mesoscale as seen in Fig.2 for Valencia Street No. 455 site from 4th to 8th of April, where CALIOPE-Urban (red) is able to reproduce morning and evening concentration peaks found in the observations (black).

Acknowledgement
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AIR QUALITY MANAGEMENT IN MEXICO CITY: ASSESSING THE IMPACT OF SHORT-TERM MEASURES ON OZONE CONCENTRATIONS

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Summary

This study aims to assess the impact of short-term measures for air quality management in the Mexico City Metropolitan Area (MCMA). The Air Quality Modelling System for Mexico City (http://www.aire.cdmx.gob.mx/pronostico-aire/) was used to quantify the reductions of ozone (O_3) when applying the abatement actions included in the MCMA's Environmental Atmospheric Contingency Program (PCAA). Results show that despite the fact that the PCAA's measures helped to reduce air pollutant levels, O_3 concentrations still exceed the legislated alert activation threshold in some urban parts of the MCMA.

Introduction

Air pollution is still a major concern in the MCMA (Molina et al., 2010). During the last two years (2016 and 2017), the MCMA's government has issued more than 10 pollution warnings for elevated levels of O_3. The main measures to tackle these pollution episodes are compiled in the PCAA, which consist of a set of actions that are implemented when an air pollution episode occurs. These pre-planned abatement measures include restrictions of traffic and reductions of industrial activities and services, among others. Considering the nonlinear response of O_3 to emission precursors, and in order to quantitatively assess the effects of these measures and provide scientific guidance for their improvement, air quality modelling is presented as a versatile tool to complement other methodological approaches such as observations.

Methodology and Results

The Air Quality Modelling System for Mexico City (Guevara et al., 2017), formed by the WRF-ARW meteorological model, the HERMES-Mex emission model and the CMAQ chemistry transport model, was used to simulate the effects of PCAA's actions on O_3 and main precursors (NO_x and VOC) during an air pollution episode occurred in May 2017. Two different scenarios were estimated: (i) full fulfilment and (ii) partial fulfilment of the PCAA's actions. The simulated concentrations were contrasted against the observations reported by the existing ambient air monitoring system. During the days in which the PCAA was activated and completely fulfilled, daily NO_x and VOC emissions were reduced in average by -18% and -10% whereas in the non-fulfilment case reductions were of -15% and -7% (Fig. 1). The complete application of the PCAA allowed a maximum reduction of ~ -15ppb hourly O_3 concentrations in the south-west area of MCMA (Fig. 2). Nevertheless, reductions in the core urban region were lower (~ -7.5ppb), hourly concentrations remaining higher than the alert activation threshold (155ppb) in some parts of the city. No significant differences were observed when applying the partial fulfilment scenario.

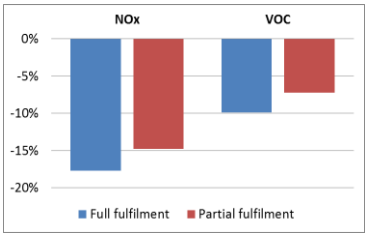

Fig.1 NOx and VOC reductions

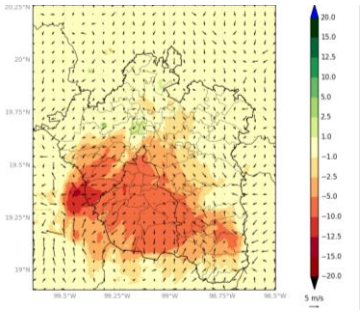

Fig.2 O_3 reductions

Conclusions

Short-term air quality action plans are crucial to address the problem of pollution episodes. Nevertheless, these set of measures need to be evaluate in order to quantify and improve their efficiency. The current modelling exercise shows that the PCAA program allows a decreasing of O_3 concentrations that is significant but slightly insufficient for the MCMA's urban region. Considering that in this area O_3 production is under VOC-limited regime, and that the current PCAA program implies larger reductions of NO_x than VOC emissions, more efforts should be put on actions based on emission reduction in the use of solvents and distribution/usage of liquid petroleum gas sectors.

Acknowledgement

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Dust and its Impact on Air Quality and Health

TECHNOGENIC DUST STORMS: ANALYSIS OF DUST EMISSION CONDITIONS AND NUMERICAL MODELING OF ATMOSPHERIC TRANSPORT PROCESSES AND EFFICIENCY OF PREVENTING MEASURES

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Abstract
Large sand and dust storms, which result from a combination of strong winds and loose dry soil surfaces in arid and semiarid areas, are a big problem and detrimental to human health, agricultural land, infrastructure, and transport (UNEP-WMO-UNCCD, 2016). However, this problem is important not only for desert regions. Dusting from technological surfaces, e.g. tailing dumps, still remains a vital issue especially for areas with intensive mining and industrial activities in different geographical regions including Arctic (Baklanov, 1988; Baklanov and Rigina, 1998; Amosov et al., 2014).
Based on multi-years measurements and simulations of different dust storm events the intensity and conditions of dust blowing and emissions are analyzed. The study examines the following factors and conditions: wind velocity, humidity and other meteorological parameters, material moister content, size and shape of particles, efficiency of dust catching, height and geometry of tailing dumps, etc., as well as specific measures to reduce dusting, e.g. protecting fences. The study presents also results of numerical simulations of atmospheric flow and dust transport and influence of tailing dumps on potential contamination of the atmospheric environment in different conditions.

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DUST RELEASE FROM DESERTS AROUND THE GLOBE, AN ATTEMPT OF A UNIFIED SOURCE PARAMETERIZATION

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Summary
This paper presents the global dust emission and transport modelling with System for Integrated modeLling of Atmospheric coMposition SILAM. The aim of the development part of the study was to construct a unified description of dust emission from surface of the deserts all over the globe. This source was subsequently evaluated and applied to quantify the contribution of different deserts in the total aerosol load in the atmosphere and its radiative impact.

Introduction
The main mechanism bringing desert dust into the air is saltation, which was relatively comprehensively described a couple of decades ago (Marticorena & Bergametti 1995; Gillette & Passi 1988). However, practical implementation of the emission parameterizations relies on a number of empirical parameters selected on the ground of the model best-fit to observations rather than on physical ground. As a result, different deserts were parameterised independently, so that specificity of their soil properties, elevation, water availability, vegetation, etc were embedded into the model coefficients. However, model applications in changing conditions require a unified approach.

Methodology and Results
The SILAM dust emission parameterization builds on works of (Marticorena & Bergametti 1995) and (Zender 2003). The most important parameter of the saltation process is the minimum surface stress required to involve the coarse particles into horizontal movement. It is expressed as the threshold friction velocity, for which the equation for critical Reynolds number (Iversen & White 1982) needs to be solved numerically. This solution was approximated with power-law terms dependent on the particle and air densities. The model additionally introduces the corrections to drag partitioning and humidity in soil. In both cases, new parameterizations developed based on characteristics of soil properties, so that the equations are applicable to any area in the world. Another important parameter is reference roughness of the surface, which is taken from the space-borne wind scatterometer (Prigent 2005) and adjusted with dynamically evaluated vegetation cover. Finally, strongly non-linear dependence of the dust flux on near-surface wind speed, the effect of wind gustiness was included by integration of the wind speed probability distribution of (Schreur & Geertsema 2008).
The obtained dust module is applied in global and regional computations of SILAM providing both long-term assessments and short-term forecasts of the dust plumes. The model predictions are routinely evaluated against satellites (see example in Fig.1) and Aeronet sun photometers observations (https://sds-was.aemet.es/). Radiative effects can be subsequently computed for direct and first-indirect aerosol effects.

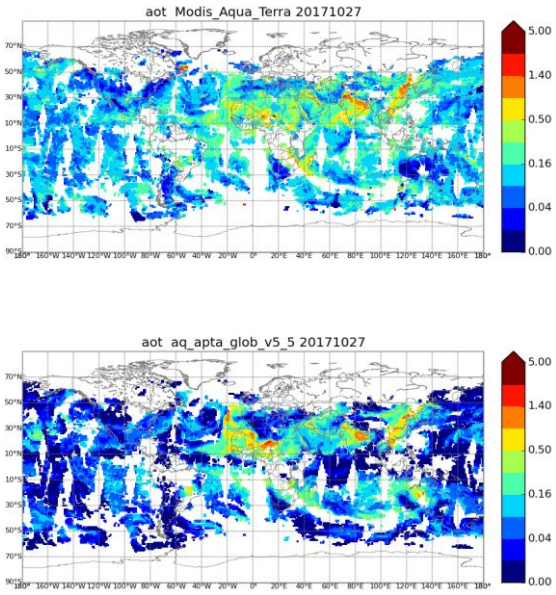

Fig.1 AOD distribution observed by MODIS Aqua and Terra (upper panel) and co-located SILAM AOD predictions. Example of 27.10.2017

Conclusions
A unified model for dust emission and dispersion is presented and its applications to atmospheric composition, air quality, and climate forcing are discussed.

Acknowledgement
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EXPLORING A DUST EPISODE WITH CHIMERE MODEL

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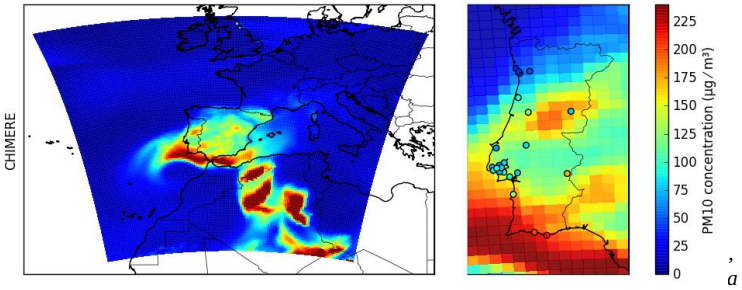
Summary
One of the most recent and intense dust episode affecting air quality over Portugal occurred during 20-22 February 2016, after the formation of a cut-off low at mid-upper levels over the Atlas Mountains. A large area over Iberian Peninsula was affected and PM10 daily mean concentrations reached levels up to 200 µg.m^{-3} in the south of Portugal. The purpose of this study is to investigate how the WRF-CHIMERE modelling system, simulates this Saharan dust episode, using satellite data and in-situ observations to validate its performance. A large domain covered Africa and Europe with resolution 27x27 km^2, and then a 3-nested domain over Portugal with 3x3 km^2, were defined for modelling setup. The validation of the modelling results in terms of AOD values (using satellite data) and the analysis of the vertical profile (using LIDAR data at Évora site) highlights that the dust outbreak and consequent transport and dispersion of dust was properly simulated. The comparison between observed and modelled PM10 surface concentrations indicates that the magnitude of the episode was reproduced but the peaks are under-estimated.

Introduction
Additionally to the anthropogenic pollution, natural sources of the atmospheric aerosol may play an important role in the occurrence of pollution episodes. Mineral dust outbreaks are one of the main causes of high PM10 particle mass concentrations in Southern Europe (Rodriguez et al., 2001) and several studies stress the importance of mineral dust long-range transport from North African deserts to specific Mediterranean Southern European countries like Portugal (e.g. Fialho et al., 2006). Air quality models are powerful tools to predict the fate of aerosols after their release into the atmosphere. Several models are designed, or include modules, to describe the atmospheric life cycle of the eroded desert dust, which take into account all major processes of the dust life cycle such as production, horizontal and vertical diffusion and advection and wet and dry deposition.

Methodology and Results
The aerosol module of CHIMERE model, implemented in 2004, had further improvements concerning the dust natural emissions and resuspension over Europe (http://www.lmd.polytechnique.fr/chimere/). The mineral dust emissions are calculated on-line and the fluxes are written as an output, and surface and soil global databases are used to allow the calculation of mineral dust emissions in every location in the world. The simulation domain was defined in order to include all the north Africa extension, the Sahara desert and also part of the Europe domain, with a spatial resolution of 27x27 km^2 and then, using nesting capabilities, Portugal domain with 3x3 km^2 (see Figure 1). The transport and dispersion of the particulate matter were properly simulated by the model, which is forced by WRF meteorological simulation. A quick and simple visual comparison with observed data (23 sites indicated in the colour circles) indicates that the magnitude of the dust episode is well simulated for that majority of the PM monitoring stations, but the peaks of PM10 are underestimated, with differences that can reach 20-30 µg.m^{-3} in some stations. A more detailed model evaluation analysis was performed through the comparison between the modelled AOD and Dust RGB satellite product; and also in terms of vertical profiles using the LIDAR data measured at Évora site for dust episode period.



zoom over Portugal and, in circles, the correspondent mean concentrations observed within the Portuguese air quality monitoring network.

Conclusions
The CHIMERE model with a dust module implemented was able to reproduce one important dust event that has affected the PM10 concentrations registered in the Iberian Peninsula and, in particular, over Portugal during 20-22 February 2016. The correct simulation of the transport and dispersion of dust will depend, mainly, on the coarse domain definition and its size. The magnitude of the PM10 episode peaks is still underestimated which may indicate the need of more detail at the vertical resolution.

Acknowledgement
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DUST AEROSOL-RADIATION-CLOUDS-PRECIPITATION INTERACTIONS OVER THE MEDITERRANEAN IN THE REPAIR PROJECT

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Summary
This work analyzes the simulations run in the framework of the REPAIR project over the whole Mediterranean Basin with the objective of quantifying the influence of including dust-radiation-clouds-precipitation interactions in a regional on-line coupled climate/chemistry model. The impact of dust interactions is assessed on several climatological variables, with a special focus on the impact on cloud liquid water path (CPW) and convective precipitation.

Introduction
Dust intrusions from African desert regions have an impact on the whole Mediterranean Basin and its climate. Dust may cause an anomalous increase of aerosol load in the tropospheric column and have the potential to change the energy fluxes in the Earth-atmosphere system by modifying cloud microphysical properties, such as the cloud liquid water path (CLWP), cloud fraction (CFRAC), cloud top temperature (CTT), droplet number concentration (CDNC), or cloud particle size distribution (CPSD). Through aerosol-radiation-cloud interactions, dust can modify convective and large-scale precipitation under certain conditions, thus affecting the hydrological cycle.

Methodology and Results
Simulations were run using the WRF-Chem model (Grell et al. 2005) version 3.6.1. The modelling domain corresponds to EURO-CORDEX at 0.22º/0.44º and simulations cover a present period between 1991 and 2010. Within this period, several case studies for desert dust outbreaks over the whole Mediterranean Basin have been studied with the objective of quantifying the influence of including dust interactions in a regional on-line coupled climate/chemistry model on several variables: convective precipitation, CLWP, CFRAC and CDNC. Two different runs have been evaluated: a base case, in which dust was not taken into account (WRF-alone); and a simulation with the GOCART dust scheme in WRF-chem, in which dust-radiation-clouds interactions were taken into account online (ACI case). The comparison between simulation results show a satisfying agreement when compared with satellite observations (MODIS) when assessing aerosol optical depth (AOD) at 550 nm, and supports the skills of the model to estimate the African dust contribution over the Mediterranean. The inclusion of ACI in the simulations leads to a reduction of the dust load over the entire Mediterranean basin, associated to the lower incoming radiation, weaker winds and therefore generalized lower dust emissions.
Differences between the ACI case and the base case (not including dust-radiation-cloud interactions) suggest variations around +/- 15 mm/day in convective precipitation (Fig. 1) for several events. For instance, considering ACI leads to a generalized reduction of the cloud liquid water path (-50 kg/kg over the areas affected by the dust aerosols) and modified patterns of clouds (differences between -65% and +35% in the CFRAC).

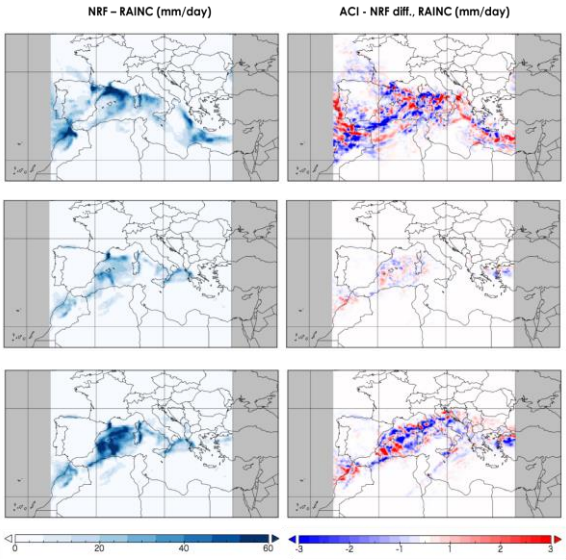

Fig. 2. Convective precipitation (left) and difference between ACI and base cases (right) for the October 2010 dust episode (from top to bottom): 11-12-13 October 2010.

Conclusions
Despite the aforementioned changes, there is a low estimated significance of the changes observed between the diverse cases for REPAIR simulations (including or not dust interactions in the simulations of precipitation climatologies) in the period 1991-2010. This low significance, estimated as the ratio between the change signal (difference between ACI and the base case) and the variability modelled in the base case, points to the need for further works to accurately characterize the aerosol-cloud interactions and reduce their uncertainty.

Acknowledgements
This work was supported by the REPAIR project (CGL2014-59677-R). Laura Palacios-Peña thanks to the scholarship FPU14/05505 from the Spanish Ministry of Education, Culture and Sports. Finally, we acknowledge the support of the COST Action ES1004 EuMetChem.

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SUBMICRON VOLCANIC DUST FROM THE LARGEST DESERT IN EUROPE AND ARCTIC

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Summary
Iceland is the largest desert in Europe and Arctic where interactions between the cryosphere and atmosphere are profound. Frequent strong winds make the long-term dust frequency in Iceland, based on the meteorological data from 30 weather stations in period 1949-2011, similar to the major desert areas of the world (Mongolia, Iran, China). Volcanic eruptions with the re-suspension of volcanic materials and dust haze contribute to the number of dust events resulting in 135 dust days annually. The *in situ* measurements showed that suspended volcanic dust in Iceland causes air pollution with extremely high PM1 concentrations comparable to the polluted urban stations in Europe or Asia than reported dust event observations from around the world. The PM1/PM2.5 ratios are generally low during dust storms outside of Iceland, much lower than > 0.9 and PM1/PM10 ratios of 0.34-0.63 found in our study. It shows that Icelandic volcanic dust consists of higher proportion of submicron particles compared to crustal dust. The submicron particles are predicted to travel long distances. Moreover, such submicron particles pose considerable health risk because of high potential for entering the lungs. Icelandic volcanic glass has often fine pipe-vesicular structures known from asbestos and has high content of heavy metals. Satellite images revealed dust plumes >1,000 km from Iceland, towards the Arctic and Europe (MODIS). Optical properties of Icelandic volcanic dust have been found similar to black carbon. Icelandic volcanic dust have negative effects on air quality and reduce visibility.

Introduction
High latitude dust sources are important part for the global airborne dust distribution with over 500,000 km^2 active source areas. Iceland is one of such high-latitude cold regions where both volcanic and glacial activity affect most of the areas. It is extremely active and with over 44,000 km^2 counts as the largest Arctic and European desert. Frequent dust events, up to 135 dust days annually, transport dust far distances, sometimes >1,000 km, towards the Arctic and Europe (MODIS). The dust deposition is about 31-40 million tons yr^{-1}, including land, oceans and glaciers (> 500,000 km^2). Major dust storm can transport > 1 million tons of dust.

Methodology and Results
Dust storms were measured in transverse horizontal profile about 90 km far from different dust sources in southwestern Iceland in the summer of 2015. Aerosol monitor DustTrak DRX 8533EP was used to measure PM mass concentrations corresponding to PM_1, $PM_{2.5}$, PM_4, PM_{10} and the total PM_{15} at several places within the dust plume. Images from camera network operated by the Icelandic Road and Coastal Administration were used to estimate the visibility and spatial extent of measured dust events. A numerical simulation of surface winds was carried out with the numerical model HIRLAM with horizontal resolution of 5 km and used to calculate the total dust flux from the sources. The $PM_1/PM_{2.5}$ ratios of >0.9 and PM_1/PM_{10} ratios of 0.34–0.63 are comparable to urban air pollution rather than dust storms. Previous OPC measurements also revealed high particle number concentration (PM~0.3-10 μm) about 150,000 particles cm^{-3} min^{-1} with the highest numbers of submicron particles (300-337nm). Numerical simulations were used calculate the total dust flux from the sources as 180,000 - 280,000 tons in this study. The mean PM_1 (PM_{10}) concentrations inside of the dust plumes varied from 97 to 241 μg m^{-3} (PM_{10} = 158 to 583 μg m^{-3}).

Fig.1 Dust front approaching Hveragerði in Iceland

Conclusions
The *in situ* measurements in the dust plumes showed that aeolian dust can be very fine. The study highlights that suspended volcanic dust in Iceland causes air pollution with extremely high PM_1 concentrations comparable to the polluted urban stations in Europe or Asia than reported dust event observations from around the world. Dust particles in Iceland are different in size, colour and geochemical composition to crustal dust areas. It has crucial effects on cryosphere because the optical properties have been found similar to black carbon during several experiments. Icelandic volcanic dust can have effects also on the air quality in the High Arctic as calculated by dispersion models.

Related publications
https://icedustblog.wordpress.com/publications/

IDENTIFICATION OF DUST EVENTS BY SYNERGISTIC OBSERVATIONS

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Summary
Dust is transported in the atmosphere over long distances and is often missed by ground observations by mixing with antropogenic pollutants. Many dust outbreaks are detected by ground or satellite based remote sensing techniques, but few physico-chemical properties can be revealed remotely. A combination of (1) ground based aerosol mass spectrometry (AMS), absorption measurements (BC), light scattering, scanning mobility particle sizer (SMPS) and aerodynamic particle sizer (APS); (2) ground based remote sensing by ceilometer-lidar and cloud radar; and (3) satellite based optical depth (MODIS) and satellite lidar (CALIOP) observations enables the verified detection of dust events and their characterization. Synergistic observations performed at the remote station Mace Head on the west coast of Ireland are advantageous in terms of studying dust climatic impacts due to the event occurrence against the clean background marine air masses.

Introduction
Dust has multiple origins (deserts, remote arctic, volcanic eruptions) and is the second largest type of particulate matter in the atmosphere after sea spray or rivals it. Dust events mostly occur over the bare land, but are transported over long distances and greatly affect visibility, sun radiation, cloud formation, ice-nucleating ability of clouds and ultimately precipitation. Very often dust events are transported over the boundary layer and are inaccessible to ground based measurements, hence, necessitating remote sensing techniques – ground or satellite based. However, while remote sensing techniques are great at detecting dust events, little information can be obtained in terms of their physico-chemical properties if dust does not mix into the surface layer. A major problem in studying dust is when dust mixes with anthropogenic pollution masking its generic properties which makes remote locations suited best for distinguishing dust events. The solution to the problem is a synergistic approach by combining all available measurements in detecting and characterizing dust events and dust properties.

Methodology and Results
All the measurements discussed in this presentation are long-term observations at Mace Head station (MHD) analysed over the period of 6 years (2010-2016) and the retrieved satellite data products over the same period. A combined six year-long dataset was examined for the tentative presence of 4 types of pollution events transported over long distances to MHD: European continental outflow, volcanic ash events, US/Canada wild fires and Saharan dust intrusions. All available datasets (BC, SMPS/APS, satellite and ground based remote sensing) were visually screened for the tentative signal and only those events which were cross-checked against the concurrent data were classified as real. The most useful methodological approach in detecting the events appeared to be the examination of MODIS products and then cross-checking with all other data for support.

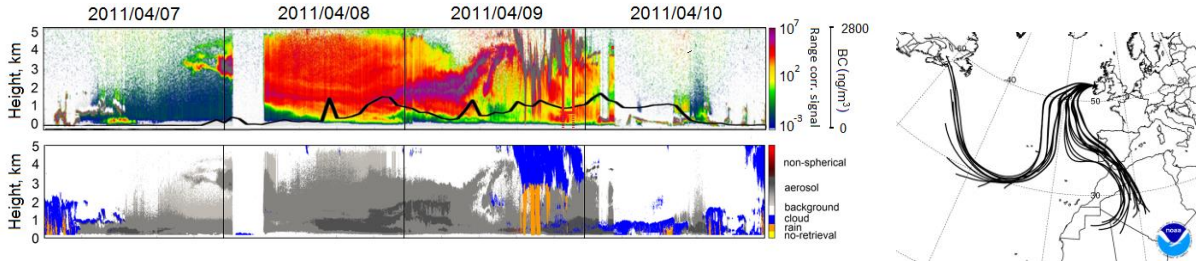

Fig.1. Time evolution of ceilometer vertical uncalibrated raw signal (1016 nm wavelength) and target classification during typical Saharan dust outbreak event observed at Mace Head in April 2011 (left). The target classification aerosol mask is derived from both the lidar and the Mira 36 cloud radar. Air mass back trajectories (right) are presented for the main period of the event – 08/04/2011.

Conclusions
Dust events manifest themselves in various atmospheric parameters requiring comprehensive and synergistic use of instruments. Some of the events are detected at the ground level, but many are transported above the boundary layer and often not detected by ground measurements. Synergistic observations not only enable the detection of the events, but shed light on the dust physico-chemical properties not achievable with remote sensing techniques alone.

Acknowledgement
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References

Characterisation and Monitoring of Air Pollutants

CHEMICAL COMPOSITION OF ROAD DUST AS INDICATOR OF ENVIRONMENT STATE IN MOSCOW

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Summary
The aim of the work is to reveal the main features of the heavy metal (HM) accumulation in road dust and its PM10 fraction on motorways in Moscow. Road dust samples (n = 210) were collected on roads with different traffic intensities and in courtyards of residential buildings with car parks. The PM1, PM1-10, PM10, PM10-50, PM>50 particles were separated by elutriation. Analytical techniques ICP-AES and ICP-MS were used to identify the metallic composition of road dust and its fractions. The composition of dust and its fractions was compared with the composition of the upper continental crust. The enrichment of fractions with HMs is several times higher than that of overall dust. Ag, Cd, Sb, Zn, Sn, Cu, Pb accumulate most intensively in PM10 in the Eastern Administrative District of Moscow. On major roads, compared with small ones, the share of all elements associated with fractions decreases due to the blowing out of particles with the increase of speeds and traffic intensity, and also due to the differences in the chemical specialization of emissions of different types of transport.

Introduction
Road dust is one of the sources of primary aerosol in the atmosphere of cities: the blowing of dust from the motorways causes the income of about 40% of PM10 (Amato et al., 2009). In the USA, road dust is the source of more than half of the PM10 emitted into the atmosphere (US EPA, 2014). In Moscow in 2016, the average annual concentrations of PM10 in the air were 0.028 mg/m^3 or 0.71 MPC (Moscow ..., 2017). Most of studies deals with large particles (<63 μm and larger), although the much more hazardous PM1 and PM10 has been poorly understood. In Russia concentration of HMs in road dust was studied only in a few cities of the Perm Krai and in some districts of Moscow. Therefore, the aim of this work is to reveal the main features of the HM accumulation in road dust and its fractions on roadways with various traffic intensity in Moscow.

Methodology and Results
Samples of road dust were collected in Moscow on major (n = 88), medium (47) and small roads (40) and in courtyards of residential buildings with car parks (35). The PM10 particles were separated by elutriation in all samples. Analytical techniques ICP-AES and ICP-MS were used to identify the metallic composition of road dust and its PM10 fraction. pH and TDS values of the aqueous suspension of dust were determined by potentiometry and conductometry methods, respectively. The average values of these parameters are 7.4 and 211 μS/cm respecrively. pH of road dust varies from 6.4 on small roads in North-Eastern Administrative District of Moscow to 8.0 and higher on major roads in Western and Eastern Districts. TDS varies from 33 μS/cm on medium roads in Eastern District to 712 μS/cm on highways of Central District. To evaluate the enrichment of road dust and PM10 fraction by HMs, $EF = [C/La]_{dust} / [C/La]_{crust}$ was estimated, where C/La is the ratio of HM and La concentrations in dust and the upper part of the continental crust, respectively. Some of the most significant *EF*s are typical for the dust and its PM10 fraction in the Eastern Administrative District of Moscow. Here *EF*> 8 in PM10 for Ag, Cd, Sb, Zn, Sn, Cu, Pb, while in overall dust samples this is true only for Cd and Sb, i.e., the enrichment of PM10 fraction with HMs is several times higher than that of overall dust. More detailed analysis of dust fractions for the Eastern District of Moscow included the study of PM1, PM1-10, PM10-50 and PM>50 chemical composition. To evaluate the enrichment of road dust and its fractions with HMs, $TE = \Sigma EF\text{-}(n\text{-}1)$ was estimated, were n – number of HMs with *EF*>1.5. *TE* index decreases with increasing of particle size from 160-181 in PM1 to 90-129 in PM1-10, 50-78 in PM10-50 and 33-41 in PM>50. On small roads the most hazardous PM1 and PM1-10 contain about 90% of Ag (from the total weight of metal in overall road dust sample); 50-60% – of Cd, Bi, As, Sb, Sn; 30-50% – Cr, Mo, Pb, Ni, Zn, Co, Cu; up to 30% – W, V, Fe, Mn, Be, Ti, Sr. On larger roads, the share of all elements associated with PM1 and PM1-10 decreases due to the blowing out of particles caused by increasing speeds and traffic intensity, and also due to the differences in emissions of different types of transport: on small and medium intra-district roads, the share of passenger transport (buses, trolleybuses, etc.) is great, and on major roads its share decreases simultaneously with the increase in the number of trucks and cars.

Conclusions
In environmental and geochemical assessments of the impact of motor transport, it is advisable to control the content of Ag, Cd, Sb, Zn, Sn, Cu and Pb that form the most contrasting anomalies in road dust and PM1 and PM1-10 particles which are the main sources of the primary anthropogenic aerosol in the atmosphere not only on major roads but in courtyards of residential buildings with car parks.

Acknowledgement
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NEW ONLINE METHOD AND INSTRUMENTATION TO MEASURE EQUIVALENT ORGANIC AND ELEMENTAL CARBON CONCETRATIONS

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Summary

In this study we present a new high resolution real time method for speciation of carbonaceous aerosols. New method combines an optical determination of black carbon (BC), by the Aethalometer AE-33 and a thermal determination of total carbon (TC) by the newly developed Total Carbon Analyzer TCA-08. We performed several field campaigns where we compared standardized off-line OC/EC method and new online method TC-BC and showed that are equivalent.

Introduction

The carbonaceous aerosol fraction often dominates the concentrations of fine particulate matter (PM). They impact air quality, visibility, the climate, cloud nucleation, the planetary radiation balance, and public health. The composition is highly heterogeneous and presents challenges for the analysis. The carbonaceous fractions are frequently separated into organic carbon (OC) and elemental carbon (EC) based on their volatility using thermal-optical methods. While the results for OC and especially EC concentrations vary significantly for different thermal evolution protocols, the total carbon (TC) concentration is very consistent between methods (Karanasiou et al., 2015).

Methodology and Results

The presented new TC-BC method combines an optical method for measuring black carbon (BC), by the Aethalometer AE33 (Drinovec et al., 2014; Hansen et al., 1982), and a thermal method for total carbon (TC) determination, by the newly developed Total Carbon Analyzer (TCA), resulting in equivalent EC and equivalent OC concentrations:

equivalent EC $= b \cdot \mathrm{BC}$,

equivalent OC $= \mathrm{TC} - b \cdot \mathrm{BC}$,

where the proportionality b is region and/or site specific (Watson et al., 2005)

The TCA operates on the principle of rapid combustion of PM collected on a quartz filter to create a CO_2 pulse detected above the background CO_2, with ambient air being used as carrier gas and source of oxygen for combustion. The method is highly time-resolved.

We performed comparisons of off-line and on-line data. Ambient 24 hours filter $PM_{2.5}$ samples from sites in Switzerland and Slovenia analyzed for OC/EC using the standard method (EN 16909, EUSAAR2) were compared to the TCA 24-hour averages.

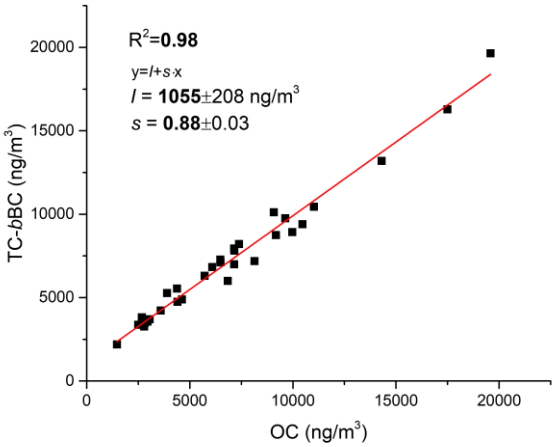

Fig.1 Correlation comparison for OC values obtained by OC/EC offline analysis using EUSAAR2 and TC-b·BC values obtained by a combined measurement of TC with TCA-08 and BC with AE-33

Conclusions

High R^2 values (Fig. 1) confirm the adequacy of the method comparing it to thermal-optical OC/EC analysers. This allowed us to demonstrate the equivalence between b.BC and EC, and OC and TC-b.BC. Additionally, we show the highly time resolved comparison between the TCA and aerosol mass spectrometers (ACMS) and demonstrate how to determine the ACMS collection efficiency.

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DETERMINATION OF AIR QUALITY FROM MARINE EMISSIONS ON A NEW WATERWAY IN ISTANBUL, TURKEY

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Summary
This study aims to determine air quality levels from ship emissions on a new waterway in Istanbul, Turkey that will be built to connect Marmara Sea and the Black Sea in parallel to the Bosphorus. This biggest project in the history of Turkey called *Canal Istanbul* will reduce vessel traffic on the Istanbul Bosphorus that is one of the busiest waterways in the world carrying 139 million tons of oil, 4 million tons of liquefied petroleum gas and 3 million tons of chemicals per year. In this study, firstly, current air quality from marine emissions of both the cargo ships and the ferries used for public transportation on the Bosporus was estimated by AERMOD air quality dispersion model. Secondly, future air quality levels were estimated from marine traffic on the new canal that will be a 43 km-long waterway with a depth of 25 meters and a width of 400 meters. Results indicated that approximately 95% of emissions for three pollutants, i.e., NO_x, CO, and PM_{10} and 67% of SO_2 emissions from the cargo ships on the Bosphorus will be moved to the new canal. It means that only emissions from the ferry activities will be available in the Bosporus. The dispersion model results indicated that the highest concentrations will be observed in some districts around the new canal while the current air quality levels will be reduced around the Bosphorus.

Introduction
The Bosphorus in Istanbul connecting the continents of Europe and Asia is one of the busiest waterways in the world. It is heavily congested with tanker traffic to and from Bulgaria, Romania, Georgia, Ukraine and southern Russia, carrying 139 million tons of oil, 4 million tons of liquefied petroleum gas and 3 million tons of chemicals per year. Due to this heavy traffic, the Bosphorus has been frequently the scene of many maritime accidents. In order to ease the congested vessel traffic (43,544 vehicles in 2015) on the Bosphorus, a new man-made waterway called Canal Istanbul has been planned to be built at the west part of the city in parallel to the Bosphorus. A quarter of a million people will also reside on both sides of the canal that will be 43 km-long, with a width of about 400 m and a depth of 25 m with six bridges. This study aims to determine (i) current air quality from ship emissions on the Bosphorus in Istanbul and (ii) future air quality over the city after implementation of the Canal Istanbul project.

Methodology and Results
Data on marine activities including ships passing through the Bosphorus and ferries used for public transportation was collected from national and local institutions. The annual number of transition, fuel consumption, etc. for ships and travel time, type of ferry, timetable of rounds, etc. for ferries were mainly obtained. Air pollutant emissions were calculated using the collected data on maritime vehicle activities and the selected emission factors from literature (EEA, 2013). Emissions from ferries that are in use of public transport in the city of Istanbul were calculated for a workday depending on hours of the day and for a total year. The total daily number of domestic trips for public transport was 2,500 on 29 different routes in 2015. While the number of ships passing through the Bosporus was recorded as 43,544. The results indicate that the annual emissions arising from the current marine traffic in the Bosphorus (both transit transport ships and ferries) were 2,525; 6,519; 125 and 623 tons/year for SO_2, NO_x, PM_{10} and CO, respectively. General cargo ships were significant contributor to total emissions (51%). After the Canal Istanbul project it was assumed that approximately 95% of emissions for three pollutants, i.e., NO_x, CO, and PM_{10} and 67% of SO_2 emissions from the cargo ships on the Bosphorus will be moved to the new canal. The highest emissions from ferries were observed at morning and evening hours due to increased number of cruising. Air quality modeling results by USEPA's AERMOD dispersion model indicated that the highest annual NO_x, SO_2, PM_{10} and CO concentrations were observed as 142 μg/m^3, 60 μg/m^3, 2.7 μg/m^3 and 15 μg/m^3 respectively for current Bosporus traffic and they were expected as 156 μg/m^3, 38.5 μg/m^3, 3 μg/m^3, 15 μg/m^3 after the Canal Project on the canal route. Since the ships passing through the channel will use fuel with a low sulfur content (0.5%) SO_2 concentrations will decrease after the project. After Canal Project, spatial distribution of annual average NO_x concentrations was shown in Figure 1.

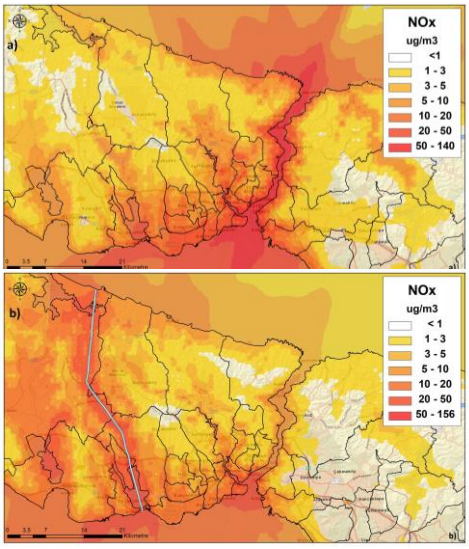

Fig 1. Spatial distribution of annual average NO_x concentrations before (a)-after (b) Canal Istanbul project

Conclusions
After transfer of the ships from the Bosporus to the Canal, the ferries will only operate on the lines in the Bosporus and this scenario will reduce the shipping emissions around the Bosporus. Finally, it was found that new areas that had been previously affected by low concentrations of maritime transportation will be affected with high concentrations originated from dense maritime traffic.

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EVALUATING THE OPTIMAL CONFIGURATION OF THE AIR QUALITY MONITORING NETWORK FOR TWO COMBINED-CYCLE NATURAL GAS (CCNG) PLANTS OF SIMILAR CHARACTERISTICS

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Summary

A study was conducted to assess the impact of two neighbouring combined cycle natural gas (CCNG) units of similar characteristics on the surrounding area. The pollutants ozone, nitrogen dioxide, PM10 particles and sulphur dioxide were evaluated. The main goal of the study was to assess the optimal configuration for the units' existing air quality monitoring network (AQMN). The current network comprises a total of six stations measuring ozone, NO/NO2, PM10/PM25 particles, CO and SO2 with one of them also housing a meteorological station measuring wind speed and direction, solar radiation, temperature, relative humidity and atmospheric pressure. The network was originally designed to monitor the impact of the emissions from fuel-oil power plants, that were operating in the site but were dismantled a few years ago, plus the modelled maximum impact from the two CCNG units that were at the time in construction. The study shows that the emissions from the two CCNG units impacts mostly the closest areas to the plants and is very limited, especially for sulphur dioxide and particles due to the negligible emissions of those pollutants from the units. For ozone and NO2 the impact is also moderate when compared to the air quality limit values for those pollutants. A final optimal configuration comprising a reduced number of stations is proposed based on the results of the study.

This study highlights the need to reassess the AQMNs for other large stationary sources around the country that have undergone significant retrofits and improvements to comply with air quality regulations and may no longer require the same level of monitoring.

Introduction

Generation of electricity with CCNG turbines is known to produce lower environmental impact than coal-based generation, with negligible emissions of particles and sulphur dioxide and much lower emissions of nitrogen oxides and carbon monoxide. In the last decade the electric power generation industry in Spain has undergone a thorough transformation, not unlike in other countries in the European Union, mostly spurred by regulation but also by a changing market[1]. The result has been an increasing share of renewable and natural gas-based generation and the retirement of coal-based plants or retrofitting, leading to reduced environmental impact and gains in efficiency. Further, operation of power plants is now closely tied to demand fluctuation and the availability of cheaper generation mostly from renewables. As a result, cycling and demand-following operations are now the norm rather than the exception.

However, many existing air quality monitoring networks around power plants were originally designed for more polluting configurations and have not been consistently reviewed. Recent regulations[2,3] opened the way for utilities to reassess their AQMNs, but the process places the burden on utilities to demonstrate the optimal configuration for their AQMNs, often through environmental impact studies.

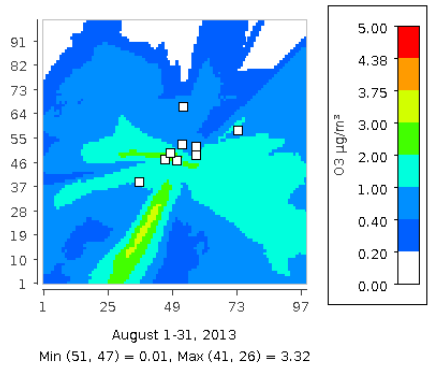

Figure 10: Maximum difference 8 hour O3 between base-case and zero emissions from CCNG plants.

Methodology and Results

The photochemical model CMAQ v5.0.2 was used for nested grid simulations encompassing Europe, the Iberian Peninsula and the area of interest. Emissions for the model were processed with the High-Elective Resolution Modelling Emission System HERMESv2.0 and the meteorological files were created with the Weather Research and Forecasting – Advanced Research model WRF-ARWv3.5. The study considered the impact of the two CCNG plants using the brute-force method. The optimal configuration of the AQMN was evaluated with a statistical analysis looking at modelled data over the 98th percentile at the monitoring stations.

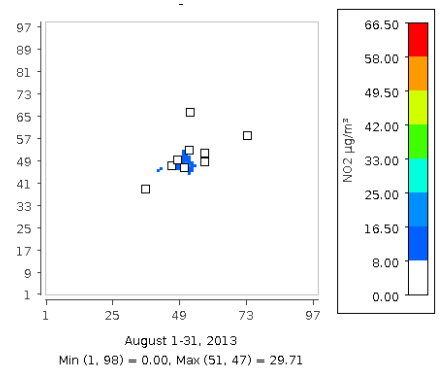

Figure 2: Maximum difference modelled NO2 values between base-case and zero emissions from CCNG plants.

Conclusions

The impact of the two CCNG turbines in the area is moderate for NOx and small for ozone levels and very small to negligible for particles and SO2. The analysis shows that the original 6-station configuration can be significantly reduced and yet provide a similar level of monitoring.

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Local Air Quality and Impact Studies

SMARTAQNET – HIGH-RESOLUTION MONITORING OF URBAN AIR QUALITY

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Summary

The Smart Air Quality Net (SmartAQnet) project aims to implement an intelligent, reproducible, finely-tuned (spatial, temporal), yet cost-effective air quality measuring network, initially in the model region of Augsburg, Germany. The SmartAQnet research initiative focuses on the subject of data access and data-based applications. Central to this is the development and utilization of partial, already existing (but not yet combined) data on the one hand and the collection and integration of relevant missing data on the other hand. This includes the integration of third-party sources as well as the development of novel measuring devices as well as an improvement of the overall data quality and the identification and implementation of meaningful interfaces between devices, databases and the end user.

Introduction

Air quality and the associated subjective and health-related quality of life are among the important topics of urban life in our time. However, it is very difficult for many cities to take measures to accommodate today's needs concerning e.g. mobility, housing and work, because a consistent fine-granular data and information on causal chains is largely missing. This has the potential to change, as both large-scale basic data as well as new promising measuring approaches are becoming available.

Methodology and Results

The project SmartAQnet is based on a pragmatic, data driven approach, which for the first time combines existing data sets with a networked mobile measurement strategy in the urban space. By connecting open data, such as weather data or development plans, remote sensing of influencing factors, and new mobile measurement approaches, such as participatory sensing with low-cost sensor technology, "scientific scouts" (autonomous, mobile smart dust measurement device that is auto-calibrated to a high-quality reference instrument within an intelligent monitoring network) and demand-oriented measurements by light-weight UAVs, a novel measuring and analysis concept is created within the model region of Augsburg, Germany. Figure 1 shows the data architecture of the project, which implements a complete Internet of Things Stack using the latest Smart Data technologies.

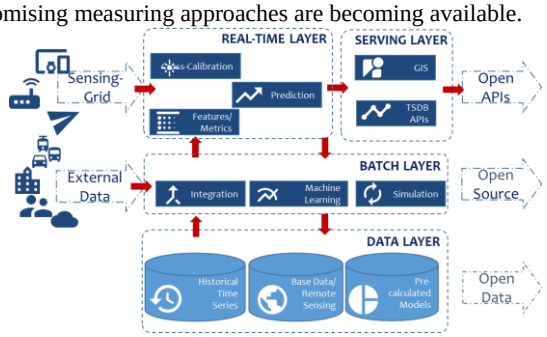

Fig.1 Data architecture of the project, which implements a complete Internet of Things Stack using the latest Smart Data technologies.

The challenges in the development of new sensor systems include low investment costs (to achieve a high density), while maintaining sufficient accuracy and precision at a high temporal resolution (to globally decrease the uncertainty of a given model).

Conclusions

The core of the project is a feasibility study aimed at investigating the potential of wide-spread distributed aerosol measurements with intelligent measurement networks of heterogeneous sensors in urban areas. The aim of the project is to build up the test network in the model region consisting of 50 scouts (autonomous, mobile smart dust measurement device) + 5 reference meters. The possibilities and challenges of bringing experts together with laypersons will also be investigated (see Budde et al. (2017) for first results).

Acknowledgement

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INFLUENCE OF TRAFFIC REDIRECTION IN SENSITIVE AREA/CITY

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Summary

The aim of this study is to evaluate impact of redirecting a part of the traffic out of the city centre on the air quality. The research was done by CALPUFF pollution modelling tool, which is an effective, fast and low cost approach. PM_{10} concentration fields were calculated for each hour in year 2016 in the city Celje. Due to its location on the intersection of 2 Pan European corridors (V. and X.) density of traffic is high. The results show noticeable reduction in PM_{10} concentration especially around the main crossroads. 30% of the traffic was redirected from two main roads to bypass road.

Introduction

Celje is situated in a basin surrounded by hills which cause unfavourable conditions for air pollution dispersion during winter. Nowadays cars are still the main means of transport although the city council is looking toward to more sustainable transport (*Celostna prometna strategija Mestne občine Celje*). Combination of traffic and other sources of PM_{10} particles lead to frequent exceedance of daily limit value (50 µg/m^3) especially during winter. One of the studied hypothetical measures is construction of bypass road that would redirect 30 % of the traffic from city centre to edges.

Methodology and Results

CALPUFF modelling system was used to calculate PM_{10} dispersion. Calculations of prognostic mesoscale model were used as first guess wind field in CALMET and data from one meteorological station were used. Emissions from road traffic were calculated by COPERT based on the traffic counting that was carried out on a day in June. Time varying area sources were used in CALPUFF to represent diurnal traffic cycle. Current situation was estimated firstly, with the aim to calculate PM_{10} concentrations that are a consequence of current traffic density and road network. Secondly it was assumed that 30 % of traffic from two main roads would be redirected to bypass road. Concentrations with hypothetical traffic density and road network were calculated and difference between both situations was evaluated (shown in figure 1).

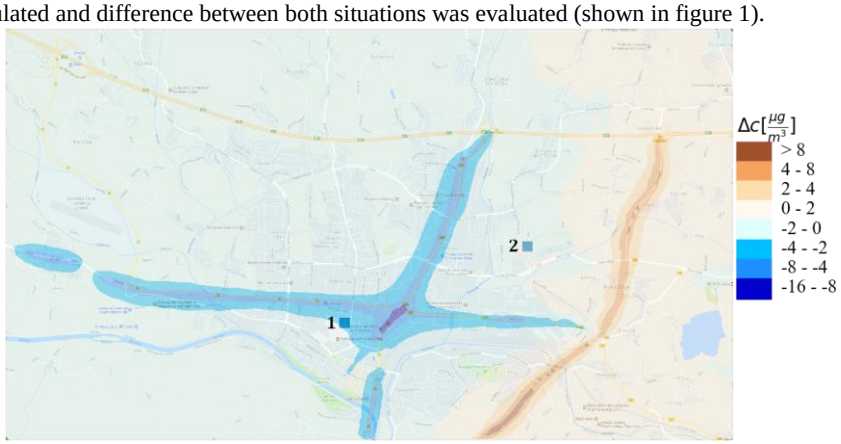

Fig.1 Difference in highest daily concentration after setting the bypass road (right third of the figure)

Tab.1 Numerical values of difference in concentrations after setting the bypass road

Time frame	Point of highest value [µg/m^3]	Measurement location 1 [µg/m^3]	Measurement location 2 [µg/m^3]
Year	-3	-0,4	0
Day	-6	-2	-1

Table 1 shows noticeable reduction in PM_{10} concentration with bypass road in point of highest value and on measurement location 1 that is close to the city centre. Measurement location 2 is situated on the edge of the city and due to the distance from main roads effects of the bypass road are not as pronounced.

Conclusions

Results show noticeable reduction in PM_{10} concentration especially on the main crossroads. CALPUFF modelling system in combination with COPERT software and traffic counting proved to be an efficient, low cost and fast means of evaluating effects of possible measures in initial stages. This enables selection of the best option between a vary possibilities.

Acknowledgement

This work was supported by the city council of Celje. We would like to thank environmental secretary Nina Mašat Strle for supporting this research.

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CFD MODELING OF VEGETATION BARRIERS TO IMPROVE AIR QUALITY

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Summary
This study aims to design effective vegetation barriers, including hedges and trees, to improve air quality behind them. To achieve this objective, Computational Fluid Dynamic (CFD) modelling is applied to an avenue with hedges and trees in one sidewalk located in Pamplona (Northern Spain). Firstly, model results are evaluated by means of an experimental campaign carried out in this zone. Then, several scenarios are simulated changing the vegetation configuration in order to analyse its influence on concentration distribution behind the barrier.

Introduction
Hedgerows and trees are usually employed to mitigate air pollution within and close to roads. The potential effect of roadside vegetation depends on several factors such as location, size, shape, Leaf Area Density (LAD) or local meteorology, therefore the appropriate selection of vegetation and its design along the streets is crucial for optimizing the beneficial impacts on near-road air quality. Within this context, we focus on an avenue in Pamplona (Northern of Spain) with hedgerows and trees in one sidewalk (see Fig. 1) and we simulate several types of barriers using CFD modelling in order to find the most effective designs to reduce pollutant concentration near the road.

Methodology and Results
Three experimental campaigns were carried out in the selected zone. Black Carbon (BC) concentrations were measured at three different points at about 0.3 m-height (red, green and blue in Fig. 1) in order to evaluate the concentration reduction due to a hedgerow. Taking as reference the BC concentration measured at the red point, it was found the concentration reduction at green and blue points are around 44% and 20%, respectively for SW wind direction (perpendicular to the hedgerow). This configuration was simulated by a CFD model. Dynamical effects of vegetation are modelled including a sink term in momentum equations and sink/source terms in turbulence equations. Deposition is considered as a sink term in the pollutant transport equation. This model has been previously validated by Santiago et al. (2017a, 2017b). Plan view of the numerical domain is shown in Fig. 2. Simulated BC concentration reductions were quite well predicted respect to real case and are 38% and 27% at green and blue point respectively. In addition, different vegetation configurations changing dimensions and location of vegetation are simulated. As an example, Fig. 3 shows the vertical profiles at different locations of BC concentration normalized with the concentration at red point for two cases: 1) Hedgerow of 1 m (real case) and 2) hedgerow of 2 m.

Fig.1 Experimental configuration

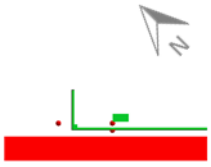

Fig.2 Plan view of numerical domain. Red: emissions; green: vegetation

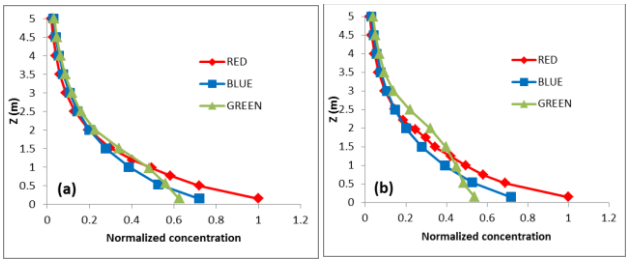

Fig.3 Vertical profiles at different locations of BC concentration normalized with the concentration at red point. (a) Hedgerow of 1 m (real case). (b) Hedgerow of 2 m.

Conclusions
The beneficial effects on air quality of vegetation barriers are restricted to certain zones and heights depending on the vegetation design (e.g. hedgerow size and location, trees behind hedgerow, etc.). This study shows the effectiveness of using vegetation barriers for mitigation of air pollution.

Acknowledgement
This study has been supported by the project LIFE+ RESPIRA (LIFE13 ENV/ES/000417) funded by EU and by the TECNAIRE-CM research project (S2013/MAE-2972) funded by The Regional Government of Madrid. Authors thank to CETA-CIEMAT by helping in using its computing facilities for simulations. CETA-CIEMAT belongs to CIEMAT and the Government of Spain and is funded by European Regional Development Fund (ERDF).

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MULTISCALE AIR QUALITY IMPACT FROM POWER PLANTS IN CITIES

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Summary
The use of cleaner fuels rather than coal, which is a main fuel source in China, for highly efficient power production is considered as one of the action for emission control. Within this project, the focus is on the use of a natural-gas-fired "combined cooling, heat and power" (CCHP) power plant. Such an installation is already in service since the opening of the Disney Shanghai in order to provide full electricity and hot water needs to the resort. And if such a system works efficiently for Disney resort, it can be imagined that in a near future CCHP can be used for residential areas, and thus reducing the operation of coal power plants.

Introduction
The purpose of this study is to assess the impact of a replacement of the Shanghai coal power plant activity with several CCHP installations. Disney research indicates that the optimal physical size for the efficient operation of urban infrastructure systems is on a scale similar to that of Disney's resorts. In this sense, a few CCHP installations could supply energy to the whole Shanghai region. Within this ascertainment 2 scenarios have been tested to answer these questions: what would be the gain in term of air quality if a CCHP supplied energy to a district? And what if all Shanghai agglomeration was fed only by CCHPs, suppressing the activity of the coal power plant?

Methodology and Results
The 2 scales approach allows us giving a complete estimate of the benefits of substitution of actual coal-fired power plant by several CCHP installations on air quality. The Eulerian photochemical transport model CHIMERE is used for the regional study, while a micro-scale Lagrangian particle dispersion model PMSS is used for the local scale study. Two simulations have been performed at the regional scale, based on different emission scenarios.

- Scenario1: one CCHP installation supplies the electricity needs of Xuhui district. At the same time, we reduce by 5% the emissions from the Waigaoqiao coal power plant.
- Scenario 2: all Shanghai is supplied by CCHP installations. We have estimated that 22 CCHP installations are needed to supply the electricity of Shanghai. Meanwhile, the coal power plant emissions are totally removed.

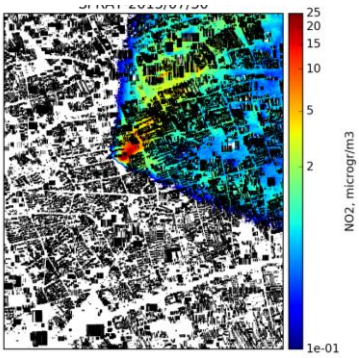

Fig.2 Impact of CCHP emissions on the Xujiahui district

The NOx emissions decrease from 276099 t/year in the reference case to 274930 t/year in the Scenario 1 (-0.4%), and to 255851 t/year in Scenario 2 (-7.3%). The dispersion modelling result shows that the 2 scenarios imply a reduction of NO_2 concentrations at the ground level due to the coal power plant emission reduction. The reduction is significant for scenario 2 (10 µg/m^3 at the ground level and even 30 µg/m^3 in altitude). The introduction of CCHP installations in Shanghai downtown doesn't affect much the air quality at the regional level as the concentration increase by less than 1µg/m^3.
The SPRAY model ran in order to evaluate the impacts of CCHP installations at the street scale level. Its associated NOx emissions reach 0.38 T/day. In comparison, the traffic emissions contribute for 4.2 T/day. Simulation results for a polluted day in January 2015 show that CCHP installations do have an impact at street scale. Average concentrations in the CCHP plume are quite low (up to 10µg/m3), but higher concentrations (25µg/m3) are simulated very locally downwind the installation.

Conclusions
In conclusion, CCHP process is a real efficient technology to provide electricity, heating and cooling with a low emission budget. However, the main question raised here is the displacement of the impacts: if NOx concentrations have been substantially reduced over the region, the CCHP plume impacts residential areas as they are necessarily installed within the districts.

Acknowledgement
This work was supported by Disney Research China.

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Poster Sessions

PART TWO

DYNAMICAL EMISSION MODELLING AND ITS EFFECT OF AIR POLLUTION SIMULATIONS WITH LOTOS-EUROS

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Summary
In this study the sensitivity of the model performance of the chemistry transport model (CTM) LOTOS-EUROS to the description of the temporal variability of emissions was investigated. A dynamic emission model is developed to construct improved time profiles taking into account dependency of the emissions on e.g. meteorology and activity patterns. The dynamic emission model leads to increases in temporal correlation for NO2, SO2, NH3 and PM10. The largest improvement is seen for the emissions from combustion in energy and transformation industries.

Introduction
Currently the temporal release of anthropogenic emissions is described by European average diurnal, weekly and seasonal time profiles per sector. These default time profiles largely neglect the variation of emission strength with activity patterns, region, species, emission process and meteorology. Therefore a dynamic emission model is developed to construct improved time profiles.

Methodology and Results
The sources dealt with in this study are combustion in energy and transformation industries (SNAP1), non-industrial combustion (SNAP2), road transport (SNAP7) and agriculture (SNAP10). For energy use, hourly data from dedicated heat plants were used to construct a country and year dependent time profile. For residential combustion, a method based on heating demand of houses was used to get a better day to day variability (Mues et al., 2014). Figure 1, nicely shows the agreement between the improved temporal description in the model, and the temporal variation based on real data from the electricity network use. For road transport, the profiles are based on traffic statistics for passenger cars and heavy duty vehicles. Also a split in fuel type is taken in this improved profile. For agricultural processes, the method of Skjoth et al. (2011), was extended with meteorological impacts and local regulations. A systematic increase of the correlation coefficient for NO2, SO2, NH3 and PM10 is found when using the new time profiles. The size of the increase depends on the source category, the component and station. The largest impact of the SNAP1 profile was found for SO2, while the largest impact for SNAP 10 was found for NH3. The daily average correlation coefficient increased by 0.04 at rural stations in Belgium. For SNAP 2 and 7 the largest impacts were found for NO2 and PM10. The hourly average correlation coefficient increased by 0.05.

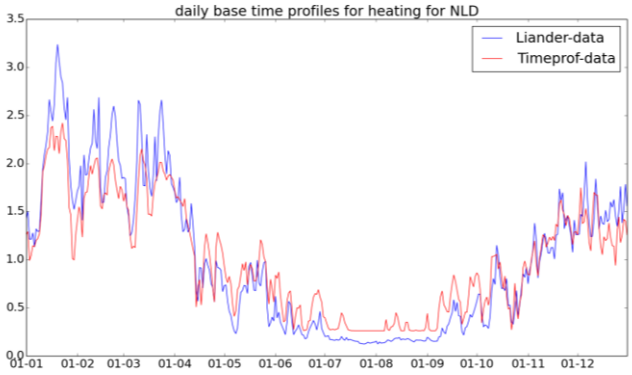

Fig.1 Temporal profile from dynamic emission model for heating emissions, compared to observed data from electricity company

Conclusions Taking into account dynamical variations in emissions is an important step forward in improving the representing of temporal variability in modelled air pollutant concentrations. Development on other sources sectors and dependencies will be pursued to further improve the air quality forecasts and analyses.

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FOSSIL FREE VEHICLE FLEET IN STOCKHOLM – IMPORTANCE OF AIR QUALITY AND HEALTH

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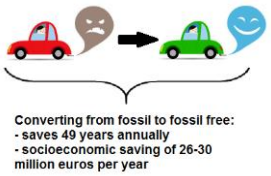
Summary
This study aims to quantify the effects on emissions and air pollution levels of emission particles and nitrogen oxides (NO_X) due to different fuel mixes in a fossil free vehicle fleet in Stockholm. The project also quantifies the health effect related to changes in vehicle fleet composition and an analysis of the socio-economic consequences. Transformation from today's fossil fuel fleet to a future fossil free fleet would lead to decreased particle emission regardless of the choice of fuel. NO_X would decrease for all scenarios which do not include a high share of rape-methyl-ester (RME) biodiesel. A future vehicle fleet mainly containing electrical and biogas vehicles was considered most favorably due to improvements in air quality and gained health benefits. Compared to a reference scenario, a transformation to only electrical and biogas vehicles would lead to 4.5 fewer premature deaths per year. The study demonstrates the importance of also considering air quality as a factor when evaluating future fuels.



Introduction
Long-term sustainable transportation has for a long time mainly been focused on reducing carbon dioxide emissions while emissions of hazardous substances have been less prioritized. Still, the national limit protecting human health is exceeded for nitrogen dioxide (NO_2) in Sweden and traffic is a large contributor to the outdoor ambient levels of NO_2. Air pollution has been well documented to cause or worsen respiratory problems, cardiovascular disease, cancer, and shorter life-spans (e.g. Hoek et al., 2013). Pollution is the largest environmental cause of disease and premature death in the world today (Landrigan, P. J. et al., 2017), highlighting the need for studies that contributes to improved air quality and sustainability.

Methodology and Results
A reference Business as usual scenario for the years 2015 and 2035 were compared to 5 different fossil free scenarios for the vehicle fleet in Stockholm in 2035. The project was divided into three parts; emission calculations using emission factors in HBEFA 3.2, dispersion and exposure modelling using a Gaussian dispersion model, and health related socioeconomic calculations using risk factors from the European ESCAPE study (Beelen et al., 2013). The traffic volume where held constant between the different scenarios but the fleet composition varied. The study found a 41-62 % decrease in particle concentration in ambient air converting to a fossil free vehicle fleet in 2035. NO_X were found to decrease with 33-47 % for scenarios not containing a high share of RME biodiesel. A high share of RME can result in an increase in ambient air concentrations of 5-13%. Using NO_X as health indicator, a vehicle fleet containing only electrical and biogas vehicles would result in 4.5 fewer premature deaths per year compared to a fossil vehicle fleet in 2035. Comparing the reference scenarios of 2015 and 2035 with NO_X as indicator showed 49 fewer premature deaths per year, showing a huge gain in health due to technology development, control means and stricter emission requirements. Socioeconomically, this corresponds to a reduction in costs of 26-30 million euros per year, taking only premature deaths into account.

Conclusions
While the vehicle fleet composition and selection of fuel is of importance for the emissions and air pollution levels of hazardous substances to human health, it is mainly technology development, control means, and stricter emission requirements that will drive decreasing ambient air levels of traffic related air pollution. However, the right choice of fossil free fuel can further reduce these levels. The development of electrical vehicles is of great importance for the reduction of traffic emissions and human exposure of hazardous pollution levels. Hence, there is need to introduce suitable legislation to accelerate the phasing out of fossil fuels in favour of green renewable fuels with both high climate and health benefits.

Acknowledgement
This work was supported by Stockholm County Council (Stockholms läns landsting, SLL). We acknowledge Karolina Ekman, Jonas Ericson, Eva Sunnerstedt (Environment and Health Administration, Miljöbilar), Martin Juneholm, Håkan Johansson (Swedish Transport Administration), Thomas Åkerblom, Krister Thulin (Scania), Mohammad-Reza Yahya (Swedish Environment Institute, IVL) and Gunnar Söderholm (Environment and Health Administration).

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Ahoj sousede. Hallo Nachbar. Interreg V A / 2014 – 2020

ODCOM Sachsen – Tschechien | Sasko – Česko

DETERMINATION OF VOCS IN AIR FOR ASSESEMENT OF ODOUR EPISODES IN THE CZECH-SAXON BORDER REGION – PROJECT ODCOM

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Introduction

Odour episodes and environmental air quality are topics of worldwide concern, mainly due to the fact that industrial facilities are often located very close to inhabited areas. Several atmospheric pollutants, mainly volatile organic compounds (VOCs), are responsible for odour episodes of varying degrees of annoyance. There are many possible sources of odorous compounds resulting from human activities that may cause adverse effects on citizens such as sewage treatment plants, petroleum refineries, chemical and food industries, diesel exhaust (Aatamila et al. 2011, Gostelow et al. 2001). The OdCom project is supported by the European Union – the European Regional Development Fund and is based on cooperation of 3 project partners from Czechia and 4 from Germany. The project was initiated in the year 2016 by repeated complaints on irritating odours in the Czech-Saxon border and will continue in 2018 a 2019 and then will be evaluated. The aim of the project is to identify main odour sources in the Czech-Saxon border. The procedure combines an analytical approach based on acquisition of samples to evacuated canisters with subsequent GC-MS chemical analyses on one hand, and a modelling approach on the other hand. Selected volunteers living in the border region are used for the sampling of polluted air to the evacuated canisters. Passive sampling of VOCs and carbonyls using Radiello cartridges is also used at both sides of the border.

Methodology and Results

Analytical method, based on concentration of VOCs sampled in Silco Can canisters with subsequent thermal desorption (TD) coupled with gas chromatography (GC) and mass spectrometry (MS) was used. HPLC-UV was used for the determination of carbonyl 2,4-dinitrophenylhydrazones from C4 to C10. Back-trajectory modelling (NOAH Hysplit modell) was used to track the origin of the air mass responsible for the discomfort backwards in time, mainly to find possible VOC sources outside the urban area. The analytical concentrations of measured substances (c_i in *ppb*) where compared with their odour thresholds (c_{OT} in *ppb*) and the odour where counted as odour units (*ou*) using the equation $C_{ODi}=C_i/C_{Oti}$. The total odour value of the sample were counted as $C_{OD}= \sum C_{Odi}$ (*ou*). The results were compared with the samples collected close to sources of VOCs (highway D8 near to Ústí nad Labem, gas exchange station, chemical factory in Ústí nad Labem). These sources will be used for determination of main sources of odorous compounds.

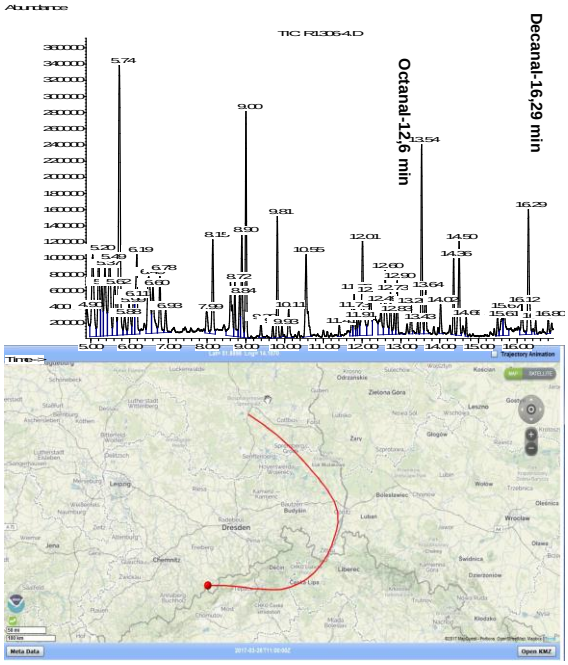

Fig.1 Sample from Seiffen. Chromatogram and Back trajectory

Conclusions

15 canisters and more than 50 stationary samples of aldehydes on two different locations in Czechia and Saxony were measured during the winter 2017. As shown on fig.1, the chromatograms from canisters are very extensive. Plenty of analytes were identified but only few of them are relevant as odour pollutants. Odour pollutants above the odour thresholds were identified as aldehydes (C4-C10) and phenols.

Acknowledgement

We would like to express our acknowledgement to all volunteers-sniffers for their help during sampling.

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CHARACTERIZATION OF THE NO_X DEPOLLUTING EFFECT OF PHOTOCATALYTIC MATERIALS IN A MEDIUM-SCALE TUNNEL REACTOR

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Summary
In the framework of the LIFE MINOx-STREET European project ("Monitoring and modelling of the NO_x removal efficiency of photocatalytic materials: a strategy for urban air quality management") an experimental method was designed and developed to characterize the behaviour of photocatalytic materials as NO_x sink under semi-controlled conditions. The experimental system consists of a photocatalytic tunnel that allows the material under study to be exposed to sunlight while controlling the flow rate and composition of the incoming air. NO_x concentration gradients are measured throughout this device and the mass removed from NO in the tunnel can be determined.

Introduction
Although laboratory tests under standard are being used to evaluate and quantify the efficiency of photocatalytic materials in the reduction of NO_x, the study of their use as part of urban air quality improvement strategies requires the development of techniques and tests that allow the evaluation of the environmental effect of the use of these materials at real scale. Given the difficulty of observing the weak macroscopic effect (NO_x elimination) due to the implementation of photocatalytic materials outdoors a system consisting of a medium-scale tunnel reactor to study these effects in semi-controlled conditions has been developed and tested.

Methodology and Results
In order to evaluate the efficiency of photocatalytic materials under semi-controlled conditions CIEMAT has developed an experimental system less dependent on meteorological conditions than others working under outdoor conditions (Palacios et al., 2015). This consists of a kind of wind tunnel (10 m L, 0.4 m W, 0.4 m H) transparent to solar radiation and allows regulating the air flow and the initial concentration of the target gas under study. It has a device that cleans the incoming air (ambient air), leaving it free of gases and polluting particles. This "zero air" is aspirated by a variable power fan and mixed with target gas (NO) from a gas cylinder of known concentration to generate an air mixture with the inlet initial concentration chosen. Subsequently, this air passes through a mechanism that ensures the homogenization of the flow and is conducted along the tunnel where the photocatalytic surface (10 m L, 0.4 m W) has been arranged. The tunnel has probes connected to an analyser that allow measuring the NOx concentration in the incoming and outgoing air. It also has flow, temperature and radiation sensors to measure the air flow inside the tunnel, its temperature and the radiation received by the photocatalytic material. Finally, the exhaust air flow is evacuated and the polluting gases are eliminated before being discharged into the external environment.
The NO concentration at the exit of the tunnel depends basically on the initial concentration, residence time of the air mass in the tunnel, solar radiation, humidity and the photocatalytic efficiency of the material.
Removal of NO mass from the incoming air is due to the sink effect induced by the photocatalytic material tested so that it is possible to calculate its efficiency through the NO horizontal concentration gradient observed in the air passing through the tunnel between the inlet and output, following a similar scheme of calculation to that employed by the ISO or UNI standards.
Having done previous tests of flow stability in the tunnel (0.33 ± 0.06 ms^{-1} average wind speed), experiments of NO purifying efficiency were carried out at around noon (UVA solar irradiance >40 Wm^{-2} and relative humidity <30%). The results obtained have shown an average yield of NO remediation of 15±4%. This photocatalytic efficiency value of NO is notably higher than those found in other experiments developed in real ambient air. On the one hand, the air volume/photocatalytic surface ratio in this experimental system has been much lower than in outdoor assays and, on the other hand, the dynamic and environmental conditions in which the experiment was carried out were semi-controlled and favorable so that the macroscopic photocatalytic effect could be easily observed.

Conclusions
The use of a medium-scale photocatalytic tunnel has been useful to observe the depolluting effect of NO in semi- controlled conditions so it would be strongly recommend to encourage the investigation of solutions aimed at exploring new engineering designs and applications, based on the use of photoactive building materials, to obtain a real effectiveness of urban air pollution mitigation measures.

Acknowledgement
This work has been partially funded with the contribution of the LIFE financial instrument of the European Union (LIFE12/ENV/ES/000280).

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STUDY OF THE EFFECTS ON AIRBORNE AND LIXIVIATES DUE TO THE WEAR OF A PHOTOCATALYTIC PRODUCT APPLIED OUTDOORS

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Summary

In the framework of the LIFE MINOx-STREET European project ("Monitoring and modelling of the NO_x removal efficiency of photocatalytic materials: a strategy for urban air quality management") one photoactive product was selected and applied in a real outdoor scenario (bituminous pavement). The depolluting capability, operation-induced changes and durability as well as the generation of by-products (resuspended and particle matter and titanium, Ti, into lixiviates) have been analysed.

Introduction

Besides the potential reduction of NO_x and other primary pollutants in real ambient air through the use of photocatalytic products, there are other controversial issues that need to be deeper investigated as the wearing associated to their use, the possible loss of depolluting activity and the generation of potential harmful products.

Methodology and Results

The selected photocatalytic coating, mainly composed of TiO_2-anatase, was implemented on an area of 1000 m^2 of bituminous pavement of a street in the municipality of Alcobendas (Madrid) on 25th September, 2015. Samples were obtained several days later (5, 12, 18, 25, 32 and 39) to quantify the removal capacity of nitric oxide (NO) by using the ISO 22197-1: 2007 assay. Additionally, the distribution of Ti on the surface during the wearing of the coating, due to road traffic, was investigated by means of scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (XEDS), and the Ti content and the presence of crystal structures were determined by wavelength dispersive X-ray fluorescence (XRF) and X-ray diffraction (XRD) measurements, respectively.

Results from the ISO assay reveal a decay tendency in the NO removal capability of the photocatalytic material under test, caused for the wearing and soiling, without a clear associated trend in the Ti content very probably due to the great variability among-samples originated by both the huge heterogeneity of the photocatalytic surface itself and the real ambient conditions of the road (soiling, driving conditions and variable traffic load). Nevertheless, in a previous study carried out at a test track, in which experiments were developed on a less heterogeneous substrate and in semi-controlled conditions, the substantial lessening in the amount of Ti distributed at the surface of the samples, in the course of accumulated cycles of wearing, correlated quite well with a decrease in the photocatalytic activity (Palacios et al., 2015).

Moreover, an air quality monitoring program was carried out from September to November 2015. A micro-orifice uniform deposit impactor (MOUDI M110R) was placed to collect size resolved atmospheric aerosol samples (eleven stages with 50% cut-off diameters from 18 to 0.056 µm and a backup stage <0.056 µm). Deposited particles on the road were sucked on several areas with a sampling device (cut-off diameter of 0.3 µm). Both types of samples were analysed for Ti content by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and for determination of the crystal structures by X-ray Diffraction (XRD). Measurements were done before the coating was applied and also several days later (4, 12, 21 and 27).

Airborne Ti was only found in the filters of the backup stage of the MOUDI and their XRD analysis could not detect crystalline phases, not being attributable to the wearing of the photocatalytic pavement. The presence of ultrafine Ti particles in ambient air could be attributed to wearing of car brakes. Regarding the deposited particles, TiO_2 in anatase phase has only been detected in the sample obtained after 4 days of wearing although the rest of the samples reflect Ti content from probable crustal origin.

The impact on lixiviates was studied by washing a test area to eliminate deposited dust and the material eroded from the photocatalytic surface. This was performed during several intensive campaigns developed before and after (7, 14 and 28 days) the implementation of the photocatalytic coating. For that, Ti, nitrite, nitrate and ammonium content was quantified by ICP-MS. No significant difference among the samples could be detected.

Conclusions

The employed methodology, based on different techniques and assays, has allowed detect a lessening in the photoactivity but the general results point out that another methodology, based on in-situ measurements, must be set-up to address the evaluation the causes of the loss of activity with the time. No impact in the generation of by-products could be observed due to the use of the selected photocatalytic product.

Acknowledgement

With the contribution of the LIFE financial instrument of the European Union (LIFE12/ENV/ES/000280).

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MULTISCALE AIR QUALITY IMPACT FROM POWER PLANTS IN CITIES

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Summary
The use of cleaner fuels rather than coal, which is a main fuel source in China, for highly efficient power production is considered as one of the action for emission control. Within this project, the focus is on the use of a natural-gas-fired "combined cooling, heat and power" (CCHP) power plant. Such an installation is already in service since the opening of the Disney Shanghai in order to provide full electricity and hot water needs to the resort. And if such a system works efficiently for Disney resort, it can be imagined that in a near future CCHP can be used for residential areas, and thus reducing the operation of coal power plants.

Introduction
The purpose of this study is to assess the impact of a replacement of the Shanghai coal power plant activity with several CCHP installations. Disney research indicates that the optimal physical size for the efficient operation of urban infrastructure systems is on a scale similar to that of Disney's resorts. In this sense, a few CCHP installations could supply energy to the whole Shanghai region. Within this ascertainment 2 scenarios have been tested to answer these questions: what would be the gain in term of air quality if a CCHP supplied energy to a district? And what if all Shanghai agglomeration was fed only by CCHPs, suppressing the activity of the coal power plant?

Methodology and Results
The 2 scales approach allows us giving a complete estimate of the benefits of substitution of actual coal-fired power plant by several CCHP installations on air quality. The Eulerian photochemical transport model CHIMERE is used for the regional study, while a micro-scale Lagrangian particle dispersion model PMSS is used for the local scale study. Two simulations have been performed at the regional scale, based on different emission scenarios.

- Scenario1: one CCHP installation supplies the electricity needs of Xuhui district. At the same time, we reduce by 5% the emissions from the Waigaoqiao coal power plant.
- Scenario 2: all Shanghai is supplied by CCHP installations. We have estimated that 22 CCHP installations are needed to supply the electricity of Shanghai. Meanwhile, the coal power plant emissions are totally removed.

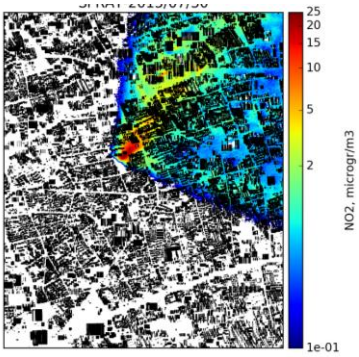

Fig.2 Impact of CCHP emissions on the Xujiahui district

The NOx emissions decrease from 276099 t/year in the reference case to 274930 t/year in the Scenario 1 (-0.4%), and to 255851 t/year in Scenario 2 (-7.3%). The dispersion modelling result shows that the 2 scenarios imply a reduction of NO_2 concentrations at the ground level due to the coal power plant emission reduction. The reduction is significant for scenario 2 (10 µg/m^3 at the ground level and even 30 µg/m^3 in altitude). The introduction of CCHP installations in Shanghai downtown doesn't affect much the air quality at the regional level as the concentration increase by less than 1µg/m^3.
The SPRAY model ran in order to evaluate the impacts of CCHP installations at the street scale level. Its associated NOx emissions reach 0.38 T/day. In comparison, the traffic emissions contribute for 4.2 T/day. Simulation results for a polluted day in January 2015 show that CCHP installations do have an impact at street scale. Average concentrations in the CCHP plume are quite low (up to 10µg/m3), but higher concentrations (25µg/m3) are simulated very locally downwind the installation.

Conclusions
In conclusion, CCHP process is a real efficient technology to provide electricity, heating and cooling with a low emission budget. However, the main question raised here is the displacement of the impacts: if NOx concentrations have been substantially reduced over the region, the CCHP plume impacts residential areas as they are necessarily installed within the districts.

Acknowledgement
This work was supported by Disney Research China.

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AIR QUALITY TRENDS IN A COASTAL CITY, SANTA CRUZ DE TENERIFE

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Summary
Concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and PM_{10} (particles with aerodynamic diameter < 10 μm) have been assessed for a coastal city (Santa Cruz de Tenerife, Spain) for a 17-year period (2000-2016). The air quality of the city is affected by a mix of local anthropogenic emissions and longer-range natural emissions such as Saharan dust intrusions. The decrease in SO_2 concentrations since 2014 when the oil refinery ceased operation is clearly shown. The measurement and assessment of ambient air concentrations over long time scales constitutes a necessary tool to monitor emission changes and identify improvements in ambient air quality.

Introduction
The coastal city of Santa Cruz de Tenerife is the capital of Tenerife (Canary Islands) and has 204,000 inhabitants. Santa Cruz de Tenerife has a complex mixture of anthropogenic sources (on-road and maritime traffic and an oil refinery) and being close to the African continent (~300 km) it is subject to Saharan dust intrusion events which increase the particulate concentrations. Santa Cruz de Tenerife has experienced various changes to the drivers of its air quality in recent years, such as the refinery ceasing crude oil refining operations in 2013, a marked dieselisation of the on-road vehicle fleet in the last two decades and implementation of International Maritime Organization (IMO) regulations for the sulphur limit for fuel oil used by ships, both at sea and at berth. Consequently, a study was undertaken to assess the air quality trends in Santa Cruz de Tenerife for the years 2000-2016 and to characterise the response of air quality in this city to these real-life emission changes.

Methodology and Results
Concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and PM_{10} were assessed for various measurement stations of the Air Quality Network of Santa Cruz de Tenerife. SO_2 daily mean concentrations for the period 2000-2016 for one of the measurement stations (Tome Cano) are shown in Fig. 1. The EU air quality standards for daily averages of SO_2 concentrations set a limit concentration value of 125 μg m^{-3} not to be exceeded more than three times per year (EC, 2008). It can be seen that this limit was exceeded in various years, up to and including 2011, but has not been exceeded since this date. In July 2013, the Santa Cruz de Tenerife refinery ceased crude oil refining operations, although it resumed operation for a short time in December 2013. Since this date, the refinery has not returned to activity. The improvement in SO_2 concentrations and the subsequent air quality can be clearly seen since 2014 and the significantly stricter World Health Organisation (WHO) Air Quality Guideline (20 μg m^{-3} daily mean) has only been exceeded on two occasions since 2014.

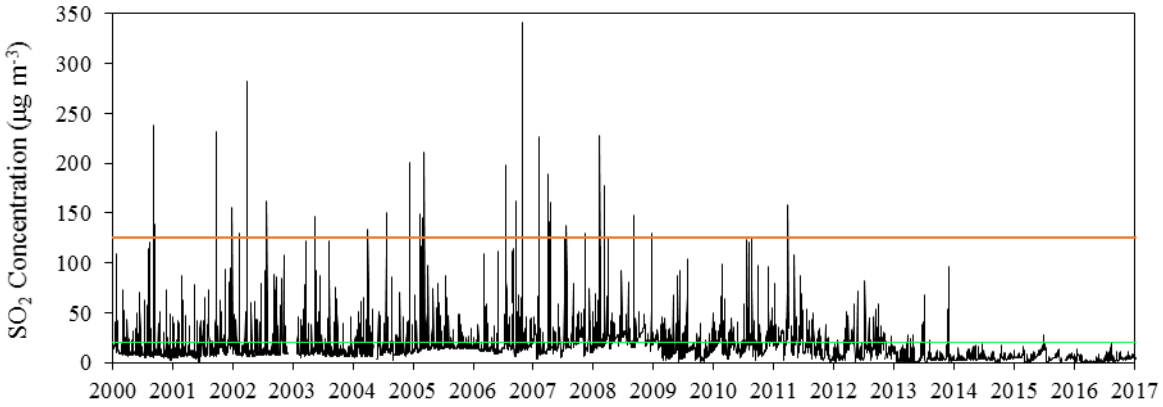

Fig.1 SO_2 daily mean concentrations at Tome Cano, Santa Cruz de Tenerife, 2000-2016. Also shown are the daily mean EU Air Quality Standard and daily mean WHO Air Quality Guideline for SO_2 concentrations.

Conclusions
The improvement in SO_2 concentrations and in the subsequent air quality of the coastal city of Santa Cruz de Tenerife can be clearly seen since 2014. The measurement and assessment of ambient air concentrations over long time scales constitutes a necessary tool to monitor the effect of real-life emission changes and the consequent improvement in ambient air quality.

Acknowledgement
The authors would like to thank the Canary Government for data from their Air Quality Monitoring Network. This activity has been undertaken in the framework of the World Meteorological Organisation Global Atmosphere Watch Urban Research Meteorology and Environment (GUERME) project.

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A NEW SAMPLER FOR EVALUATING THE SPATIAL VARIABILITY OF PM COMPONENTS: VALIDATION AND FIELD APPLICATION

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Summary
A new very-low volume sampler has been developed with the purpose of allowing spatially-resolved determination of atmospheric particulate matter (PM) and of its chemical components. The low-cost, automatic and self-powered device assures long-term (1-2 months) collection of PM on membrane filters, suitable for subsequent chemical analyses. The device has been validated during a 1-year study focused on the concentration of PM_{10} mass, ions, levoglucosane, polycyclic aromatic hydrocarbons (PAH) and elements. It showed very good performance in terms of repeatability of the samplings, which is the essential characteristic to build a reliable network.
The samplers have been employed, for the first time, to evaluate the spatial variability of PM_{10} mass concentration and its main chemical components in the area of Terni, a urban/industrial hot-spot sited in an intramountain depression of Central Italy. The meteorological conditions of Terni basin, which limit the dispersion and enhance the accumulation of atmospheric pollutants, are ideal to test and validate the new experimental method for the acquisition of spatially-resolved data.

Introduction
The study of the spatial distribution of atmospheric PM and of its components is essential for a reliable identification of emission sources, the evaluation of particle dispersion over the territory and the assessment of personal exposure. However, the very high cost of a network based on traditional PM samplers generally prevents the achievement of these goals.
A low-cost, self-powered and automatic device for PM sampling on membrane filters has been recently become available (SMART SAMPLER, FAI Instruments, Fonte Nuova, Rome, Italy). The sampler constitute a promising possibility to build low-cost networks for atmospheric PM.

Methodology
The SMART SAMLER (Figure 1) operates at the flow rate of 0.5 l min^{-1}. It is equipped with a small solar panel and a rechargeable battery. For the validation step, three PM_{10} samplers were operated side-by-side for 1 year (30- or 45-day samplings). The samples were analysed for PM mass by gravimetry, ions by IC, levoglucosan by HPAEC-PAD, PAH by HRGC-MS and elements by ICP-MS. The results were evaluated in terms of relative standard deviation of the replicates and compared with the average values obtained from daily samplings carried out by a reference sampler operating at the flow rate of 2.3 m^3 h^{-1}.
In the field, 23 SMART SAMPLER were located at different sampling sites to design an inexpensive, extended and extensive (about 1 km between the samplers) monitoring network across Terni. Localizations of the samplers were chosen in order to evaluate the impact of different local PM_{10} emission sources (such as power plant, steel plant and vehicular traffic). Chemical analysis of the samples was focused on the elemental content, using a chemical fractioning procedure that allowed us to discriminate water-soluble and residual fractions of analyzed elements. This approach proved to be valuable for increasing selectivity of elements as source tracers.

Fig.1 Picture of the SMART SAMPLER

Results
The repeatability of the samplings carried out by the SMART SAMPLER was about 5%. The comparison with the reference sampler was very good for stable, fine components (e.g.: sulphate, potassium, levoglucosan, elements) and satisfactory for stable coarse components (e.g.: sodium, magnesium, calcium).
Spatially resolved data, obtained by monthly sampling in parallel at 23 monitoring sites of Terni, permitted to properly evaluate the spatial variability of PM_{10} and elemental mass concentrations. Source tracers of the main PM_{10} local emission sources were identified. Chemical fractionation improved the selectivity of element as source tracers. Spatial variability of Ni, Cr, Mn (insoluble fraction) and Mo (water-soluble fraction) concentrations showed the steel plant role in the emission of PM_{10}. Spatial variability of Fe (insoluble fraction) resulted to be correlated not only with the steel plant emission but also with vehicular traffic. The role of this emission source was also confirmed by the spatial variability of elements such as Sb and Cu. Rb (soluble fraction) was confirmed to be a good tracer of biomass combustion processes.

Conclusions
The obtained results proved the efficiency of the new experimental procedure for the evaluation of the spatial variability of PM_{10} and its main chemical components through the acquisition of spatially resolved data. In particular, the innovative SMART SAMPLER, used for the first time in this monitoring campaign, allowed to build an extended and extensive monitoring network, with low associated costs, which was able to represent the different emission source contributes to the total PM_{10} in the monitored area. This experimental approach promises to be effective for the validation of dispersion models without the high costs associated to an air quality monitoring network.

RETRIEVAL OF AEROSOL VERTICAL PROFILES OVER ATHENS USING MAX-DOAS MEASUREMENTS

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Summary

This work presents four selected cases during which aerosol extinction vertical profiles were calculated from MAX-DOAS measurements over Athens, using the BOREAS retrieval algorithm developed by the Institute of Environmental Physics and Remote Sensing, University of Bremen. The retrievals are compared to ground-based lidar measurements and to the Aerosol Optical Depth (AOD) derived from sun-photometric (CIMEL/AERONET) measurements. Overall, the MAX-DOAS aerosol profiles are in good agreement with those retrieved by lidar (r^2 varying from 0.56-0.88). In two out of the four cases, MAX-DOAS underestimates the AOD when compared to CIMEL, however the diurnal variation is in good agreement in most of the cases.

Introduction

Air quality in Athens is often affected by increased levels of aerosol load. Dust transport from Sahara under specific meteorological conditions, along with anthropogenic sources (e.g. biomass and fossil fuel combustion), are the main sources of aerosols in the city. Although aerosol extinction profiles are systematically monitored in Athens using lidar measurements (e.g. Papayannis et al., 2008), there are no published profiles retrieved by MAX-DOAS measurements. MAX-DOAS, unlike Lidar, provides less expensive and continuous measurements during daytime. Thus, it is important to compare cases of aerosol vertical distributions and AODs retrieved by both instruments and evaluate, for the first time, the MAX-DOAS' related quality in vertical profiling over Athens.

Methodology and Results

Measurements were performed by a MAX-DOAS instrument, part of the BREDOM network (http://www.iup.uni-bremen.de/doas/groundbased_data.htm), operating at the premises of the National Observatory of Athens (500 m.a.s.l). Calculations of the aerosol extinction profiles over Athens were conducted using the BOREAS profile retrieval algorithm (Bösch et al., 2017). Four selected cases are studied: (i) 05 Feb 2015: intense dust event, (ii) 09 Jul 2015: low levels of pollution (i.e. NO_2) (iii) 10 Jul 2015: same as previous case and (iv) 04 Apr 2016: elevated pollution levels (high levels of NO_2) - (Fig.1). In all cases the MAX-DOAS aerosol extinction vertical profiles, calculated for 457.5 nm, show a reasonable agreement with the corresponding lidar profiles (e.g. case i, Fig.2). In cases (ii) and (iii) the calculated AOD is in very good agreement with the AOD from CIMEL measurements (in case (ii) the mean daily value is the same for both instruments and in case (iii) the difference is 0.04 or 13%), while in cases (i) and (iv) MAX-DOAS seems to underestimate the AOD, by 0.10 (24%) and 0.14 (48%) respectively when compared to CIMEL. It is important, though, that the two instruments present a notable agreement in the AOD diurnal variation (e.g. case (i), r^2=0.86).

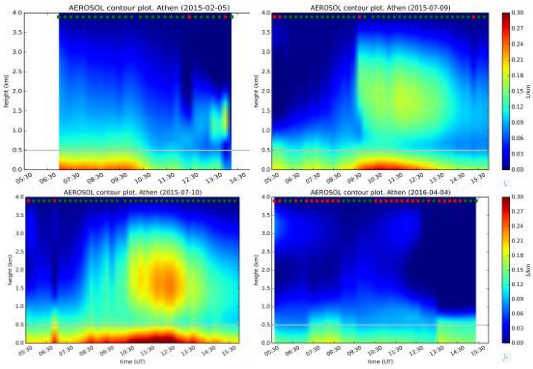

Fig.1 Contour plot of aerosol extinction, all cases

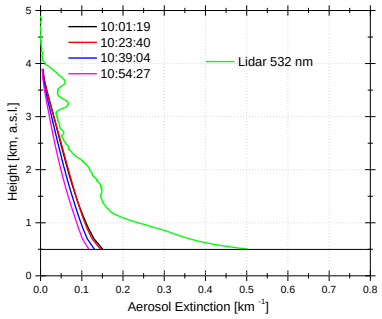

Fig.2 Lidar aerosol extinction mean profile 10:00-11:00 UTC (green curve) compared to MAX-DOAS results, case (i)

Conclusions

The retrieval of aerosol vertical profiles from MAX-DOAS measurements is of great importance as it can provide long term, uninterrupted data series. However, further research is needed to improve these retrievals and understand all constraints that may introduce uncertainties to the retrieved profiles.

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IMPACT OF SOLAR RADIATION AND EXISTING AEROSOL ON THE FORMATION OF SECONDARY PARTICLES IN A LARGE CITY.

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Summary
The size distribution of particle matter has been examined in several sites and years (2007 – 2013) in order to study the factors that influence secondary particle formation. During winter, little formation of secondary particles is seen and in summer the highest number of secondary particles was observed. There is a high correlation between the number secondary particles and the solar ultraviolet energy. Inhibition of secondary particle formation was also observed in heavily polluted streets.

Introduction
Most of the aerosol in the city of Santiago de Chile is composed by fine particles ($PM_{2.5}$), as opposed to what happened more than 25 years ago, when PM_{10} was dominant. The Ministry of the Environment has been working for more than 15 years to improve the air quality of the city. Consequently, there has been a steady decline in the PM_{10} and $PM_{2.5}$ since 1998. However, in the last few years there has been a leveling off and even a slight increase in of $PM_{2.5}$[1]. This increase seems not to be due to primary emissions; but to formation of secondary fine particles. This finding points out the need of a more thorough study of the sources of this contamination[2].

Methodology and Results
Non-continuous measurements of particle number distribution were performed from year 2006 until 2013 in several sites in the city of Santiago and its surroundings. Measurements were performed years 2006, 2007 and 2009 with a Differential Mobility Particle Sizer (DMPS) to measure particles with diameters in the range 10-700 nm in 25 channels. An electrical low pressure impactor (ELPI Dekati, Tampere, Finland) was used in the year 2013 to measure particle number with diameter in range from 10 nm to 8 μm in 14 channels. Ultraviolet radiation was measured continuously with a Solar Light UV-B sensor PMA1101. The number of ultrafine particles was extracted from the data between 12:00 and 5:00 pm, which corresponds to the hours of highest solar intensity. The net number of particles between 10 and 20 nm was calculated as shown in Figure 1. The background (**B**) is subtracted from the total between 12:00 and 5:00 pm, to obtain the net amount (**N**).

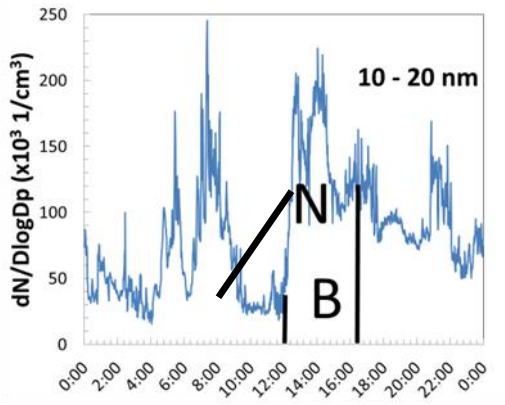

Fig.1.Calculation of the net amount of particles with diameters between 10 and 20 nm.

The net number of particles is shown in Figure 2 along with the total UV-B incident energy. The UV data was measured during 2013 but the net number of particles was measured in different years. It can be seen that in periods with high UV energy the net number of particles is higher. A detailed calculation of the net number of particles versus the energy for that day gives a correlation of $R^2 = 0.55$, indicating that UV energy is an important variable in the formation of secondary particles. Simultaneous measurements in the curbside of a busy street and at the roof of a nearby building show particle formation in the roof site but not on the curbside. This is a direct indication that a high number of existing particles prevents formation of secondary's.

Conclusions
A high correlation was found between solar UV energy and formation of secondary particles indicating the importance of this factor on secondary particle formation.

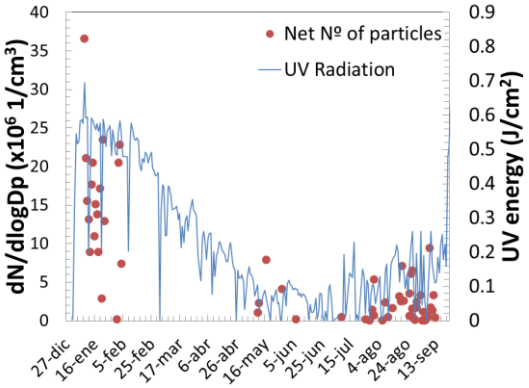

Fig.2. Net number of secondary particles (10 – 20) nm in several sites in Santiago. UV radiation is for year 2013.

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CONTINUOUS ATMOSPHERIC FORMALDEHYDE MEASUREMENT IN A RURAL BACKGOUND AREA IN NORTHERN IBERIAN PENINSULA

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Summary

Atmospheric formaldehyde (HCHO) was continuously measured during the summer of 2016 in a rural forested area: The Valderejo Natural Park (VNP), Northern Spain. The HCHO database obtained is, to our knowledge, the first high time resolution one in Southern Europe, which will help to characterize O_3 episodes in the area. This database is also of interest due to the toxicity and carcinogenicity of HCHO. Other 66 non-oxygenated C_2-C_{10} volatile organic compounds (VOCs) were hourly measured, as well as O_3 and meteorological parameters every 15 minutes. HCHO mixing ratios (average: 1.42 ppbv; standard deviation: 1.16 ppbv) were highly correlated with O_3 concentrations (population information threshold was once exceeded: 1 h average concentration of 188 $\mu g \cdot m^{-3}$) and radiation, being temperature a key factor in the formation of HCHO and O_3 peaks at VNP.

Introduction

VOCs play a key role in the atmospheric chemistry as O_3 precursors. In rural and forested areas, biogenic VOCs (BVOCs) may be more important than anthropogenic ones. Increased emissions of BVOCs in the warm season, higher solar radiation, and temperature may result in O_3 episodes, with HCHO directly involved in such photochemical process. HCHO is directly emitted by anthropogenic and natural sources, but is also the main oxidation product of BVOCs. Apart from being a potential O_3 precursor, HCHO causes irritation and it is carcinogenic to humans. Hence, the HCHO may be a key VOC in the characterization of O_3 episodes.

Monitoring and methodology

Monitoring site is located at VNP, a rural forested area in a nearly inhabited valley, more than 50 km away from urban and industrial areas. Main VOC sources are the surrounding forested mountains and meadows, though polluted air masses regularly reach the site in summertime (Navazo et al., 2008). HCHO was continuously monitored with an automatic analyzer (AL4021, Aero Laser), based on the Hantzsch reaction and a fluorescence spectroscopy detector. The response is linear up to 3 ppmv, with a detection limit, LD = 0.1 ppbv. The analyser was set up in a 5 min basis, but HCHO mixing ratios were 15 min-averaged. The Air Quality Monitoring and Control Network of the Basque Government supplied data of conventional pollutants (including O_3), and meteorological parameters on a 15-min basis.

Results

HCHO was monitored from July 11th to September 30th (81 days, number of valid data N=6722, average mixing ratio: 1.42 ppbv; SD: 1.16; median: 1.09 ppbv, minimum: < DL; and maximum 9.82 ppbv, recorded on 18th July at 17:45 UTC). Fig. 1 shows the HCHO and O_3 time series. Monthly average HCHO mixing ratio was higher in Aug. (1.52 ppbv) than in Jul. (1.48 ppbv) or Sep. (1.27 ppbv), in agreement with the average temperature (Aug.: 18.0 ºC, Jul.: 16.8 ºC, and Sep.: 15.8 ºC). Although the O_3 concentration also followed the same trend, its maximum (202 $\mu g \cdot m^{-3}$) was recorded on Sep. 7th at 16:45 UTC (Fig. 1).

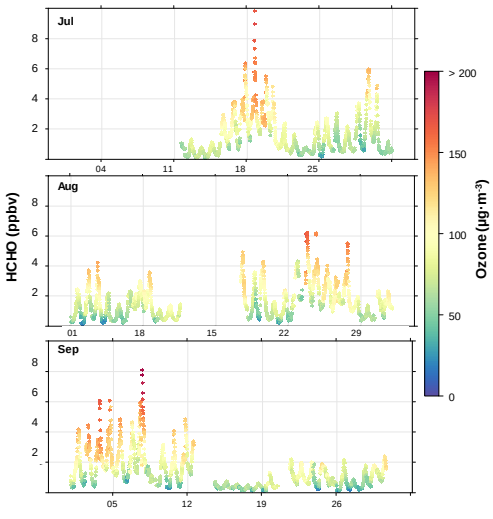

Figure 1. HCHO and O_3 15 min-averaged mixing ratios time series. X-axis indicate day of the month weekly separated by vertical lin

Conclusions

HCHO mixing ratios were measured in a rural forested area in Northern Spain between July and September 2016： HCHO mixing ratios were highly correlated with O_3 concentrations and temperature, which confirms the relevance of the HCHO measurement in the characterization of O_3 episodes and their forming mechanisms.

Acknowledgement

We wish to thank for their financial aid to the Spanish Ministry of Science and Innovation (MICINN) for the PRORAT project (Ref.: CTM2013-45223-P), and to University of the Basque Country UPV/EHU (Ref.: GIU 16/03, GIU 13/25, EHU 13/47, UFI 11/47). We also acknowledge the Basque Government for providing data, and the VNP staff for their help and support.

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EXPOSURE TO PARTICLES AND THEIR ELEMENTAL COMPOSITION DURING COMMUTE IN CURITIBA, BRAZIL

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Summary
The target of this work was to evaluate the short-term personal exposure to particles and their elemental composition, in routes of public transportation buses mode of Curitiba city, Brazil. The fine particulate matter ($PM_{2.5}$) and Particles Number Concentrations (PNC) data were systematically collected through five routes with higher flux in the city. The $PM_{2.5}$ ranged from <9.9 μg m^{-3} to <23.7 μg m^{-3} and the PNC from 200 to 330 cm^{-3}. The elemental composition of PM was performed through X-ray fluorescence spectroscopy (EDX-RX) and Black Carbon (BC) in reflectance mode. As a main result, this work shows that the principal chemical composts that constitute the $PM_{2.5}$ come from vehicular combustion, and the $PM_{2.5}$ and PNC are higher in peak periods.

Introduction
Recently, several studies have been performed focusing in measurements of personal exposure to particulate matter (PM) originated from different modes of public transportation (KUMAR, 2014; KUMAR, 2016; RIVAS, 2017). However, only scarce studies dealing to personal exposure and combined with their elemental composition analysis, as well as measurements of Particles Number Concentrations (PNC) in similar conditions of the diary-routine-transportation displacements. Specifically, in Brazil there are still no studies dealing these issues. In this way, the target of this work is to evaluate the short-term personal exposure to particles and their elemental composition in buses routes of public transportation system of Curitiba city, Brazil. It is worthy to say that Curitiba is considered a worldly environmental-reference, and in public transportation. (RAEMAEKERS, 1998; PARRA, 2006)

Methodology and Results
$PM_{2.5}$ was sampled and measured through a personal equipment (DataRAM™ pDR-1500) using filters of PTFE at flux of 3 L min^{-1}). The equipment travelled in geo-referenced routes in same diary displacements done by the local population through local bus lines. The PNC were measured by a particle's count equipment (MetOne, cutoff of 0.3 μm). Five bus routes (pertained to public transportation) of higher costumers-demanded were chosen and three samples were collected in peak periods (17:00 – 19:30) and in not-peak periods (09:00 – 17:00) for each route. The PM elemental compositions were done through X-ray fluorescence spectroscopy (EDX-RX) and Black Carbon (BC) in reflectance mode. The average values of $PM_{2.5}$ changed in the range of 23.7 to 14.3 μg m^{-3}. Figure 1 shows the chosen bus routes and the respective values of $PM_{2.5}$ concentrations for peak periods (Fig. 1A) and not peak periods (Fig. 1B). In the peak period the PM concentrations (in μg m^{-3}) fall in the range of 23.7 to 18.4 while in not-peak period the PM concentration was in 9.9 to 14.2 range. The PNC 0.3 (the concentration of particles sized below 0.3 μm, in particles cm^{-3}) were the range of 200 to 300 and 240 to 330 for the peak and not-peak period, respectively. It can be noted that in the R4, the route that travels the whole city with stops, in average, at every 3 km, presented the higher concentration of $PM_{2.5}$ as well an elevated PNC 0.3 index. This may be due to the fact of such route connects the almost of totality of other routes in the city. Three major chemical elements were identified in the investigated environment: sulphur (S), concentrations (μg m^{-3}) in the range of de 36.64 to 55 for not peak period and 39.31 to 45 for peak period; sodium (Na) presented the same parameters as 76.25 to 84 and 91 to 93. Similarly, for iron (Fe) it were found 27 to 39.53.and 30 to 33. The Black Carbon data (in μg m^{-3}) were 7.43 to 16.19 for not peak period and 11.05 to 20 for peak period.

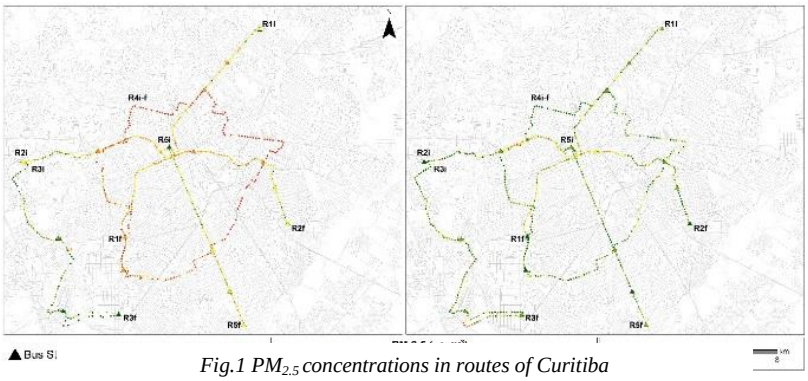

Fig.1 $PM_{2.5}$ concentrations in routes of Curitiba

Conclusions
The highest $PM_{2.5}$ concentrations were found in the peak periods and were strongly connected to the vehicular emissions. In addition, the concentrations were relatively higher in long routes and with several stops.

Acknowledgement
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ATMOSPHERIC DEPOSITION OF TRACE ELEMENTS BIOMONITORING STUDY AT THE TERRITORY OF THE REPUBLIC OF BELARUS

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Summary

In 2015 for the third time in the Republic of Belarus the moss biomonitoring technique was used to study atmospheric deposition of heavy metals and other trace elements. Samples of moss species of *Hylocomium splendens* and *Pleurozium schreberi* were collected at 86 sites over the Gomel, Vitebsk and Minsk Regions. Collection was carried out according to the sampling strategy adopted by the UNECE ICP Vegetation program on long-range atmospheric transport in Europe based on moss analysis (ICPVEGETATION, 2015). The moss samples were subject to instrumental neutron activation analysis (INAA) at the IBR-2 reactor of FLNP JINR in Dubna. A total of 36 elements were determined (Na, Mg, Al, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Mo, Sb, I, Cs, Ba, La, Ce, Sm, Tb, Yb, Hf, Ta, W, Hg, Th, U). Additionally, Cd, Cu and Pb were determined by atomic absorption spectrometry (AAS). The principal component analysis allowed distinguishing soil, plant, and anthropogenic components in the moss, and apportioning the main pollution sources.

Introduction

The moss biomonitoring technique is widely used all over the Europe as a method to evaluate atmospheric deposition of metals more than 50 years (Frontasyeva, Steinnes, Harmens, 2016), but in Belarus it was applied for the first time at 2005. Every five years moss survey (see Fig.1) was conducted to see the difference between pollution levels in the country.

Methodology and Results

Samples of the two moss species *Pleurozium schreberi* (more than 85% of all collected samples) and *Hylocomium splendens* were collected during 2005-2015 years in all country regions. Sampling sites were located at least 300 m from main roads and populated areas and at least 100 m from smaller roads. From each sampling site, 5 to 10 sub-samples were taken within a 50 × 50 m area and mixed in the field. Sampling and sample handling was performed using polyethylene gloves and collected material was stored in paper bags (Harmens H., Frontasyeva M.V. 2014). Then in the Frank Laboratory of Neutron Physics (Dubna, Russia) was performed epithermal neutron activation analysis (ENAA). The samples were carefully cleaned from needles, leaves, soil particles and only the green, green-brown shoots representing the last three years growth were analysed, after being air-dried to constant weight at 30–40°C for 48 hours. The samples were neither washed nor homogenized.

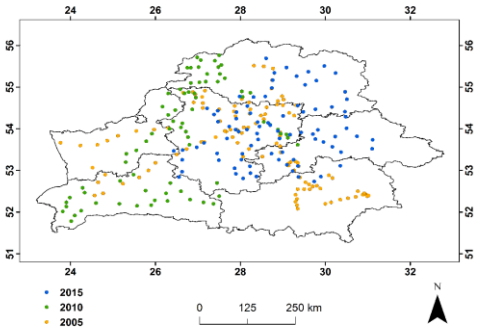

Fig. 1. Distribution of the sampling sites

Comparison of the median values for V, Cr, Fe, Ni, Zn, As, Al, Sb from the three surveys in Belarus (in 2005/6, 2010/11 and 2015/16), showed a decrease of the content of V and As in the mosses and increase of Cr in 2010. Other elements are mostly at the same levels (Fig. 2). Although we noticed the increase of metal concentration at some sampling sites, the comparison of the results for Belarus with the analogous data for the other European countries showed relatively low contamination levels for the most of heavy and toxic elements.

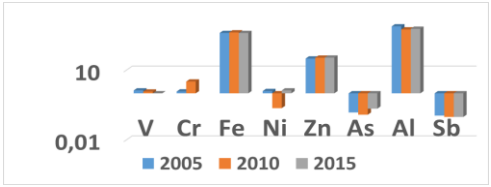

Fig. 2. Comparison of the median values for selected elements determined in 2005, 2010 and 2015 (log scale)

Conclusions

During this ten-year research, we study all Belarusian regions and see that in comparison with other European countries, median concentrations of elements in Belarus are low. It could be explained by not so developed heavy industry as in nearby countries, and absence of extractive and processing industry. Deposition levels for some elements in Belarus are comparable with Norwegian data (which are used as a background) but we reveal some polluted areas. In thus areas, the main pollution sources could be tractor plant in Minsk, engineering plant in Zhodino, farming, paintworks plants, iron and steel plant. Also we didn't see any influence of the transboundary pollution from neighboring countries. But still it is important to continue monitoring heavy metal deposition in order to see long-term trends.

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TEST RESULTS OF LOW COST SENSORS FOR PARTICULATE MATTER AND GASES FOR THE USE IN OUTDOOR AIR QUALITY

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Summary
In air quality there is a trend to use low cost sensors instead of expensive measurement instruments. Uncertainty of the sensors can be reduced and determined with different quality assurance measures, by comparing the results of the sensors to reference instruments. Tests of low cost sensors for PM as well as gaseous compounds were performed in laboratory as well as outdoor in the ambient air. Results will be presented as well as the limitation of the use of sensors will be shown.

Introduction
In the field of air pollution control, sensors have been increasingly used for emission measurements for a long time, in addition to the usual emission measuring devices. One should think of the millions of lambda sensors installed in vehicles with regulated catalysts. Sensors are also used for other applications. For studies in the ambient air, for a long time sensors were not sensitive enough to detect the usually very low concentrations of airborne contaminants in the outside air. In recent years, however, there has been a huge development in various sensors, which also makes them suitable for use in outdoor air.
Interesting are the low-cost sensors for different reasons: First, they are very inexpensive to purchase. The price is between 0.1 and a few percent of the cost of a commercially available professional measurement instrument, e.g an aerosol spectrometer for measuring PM. In addition, the sensors are small, light, require little power and can often be powered by batteries or accumulators. Due to the low price, larger networks can be built by installing sensors at many points in a city or area. This gives a very good overview of the spatial and temporal distribution of air pollution in an investigation area. The other advantages mentioned, such as the low weight and the battery operation, make it interesting for mobile measurements as performed by the authors. As mobile measuring platforms bicycles, tethered balloons, possibly drones and public transport such as buses, trams and rack railways are planned. Currently in many cities, sensor networks spring up (e.g. http://luftdaten.info), some of them with several hundred sensors to determine the air quality, mainly the PM10 and PM2.5 components. The network operators generally do not put much effort into quality assurance, either because of a lack of awareness of the need for quality assurance or due to the lack of the required sensor matching technology. Another reason is the notion that when using as many sensors as possible, the individual sensors do not necessarily deliver "accurate" results, but the uncertainties rebalance.

Methodology and Results
The authors have acquired different low-cost sensors from different manufacturers for both particulate matter (PM10, PM2.5, PM1, particle count) and different gases (NO, NO_2, O_3 and CO). Comparative measurements for PM with profession aerosol spectrometer were performed both, in the laboratory as well as in the ambient air. On the one hand, the determination of the measurement uncertainty of the sensors are subject. On the other hand, a concept was developed and comparison measurements were done, where low-cost sensors of the sensor networks were compared with professional aerosol spectrometers to reduce the uncertainty of the sensor results and increase the data quality. First simple correction approaches have shown that this can improve the deviation of the measurement results of the sensors with each other and in comparison to the aerosol spectrometers. An important influencing factor on the quality of the results of the particle sensors is the humidity. This influence must be considered in the evaluation.
The concluded results of comparison measurements of low cost sensors of different companies with professional aerosol spectrometers are shown in Table 1. All sensors need a calibration with a reliable PM standard. After calibration, sensor no.1 delivered satisfying results for small particles in the range of 0.3 to 2µm (PM2.5 signal). For coarser particle in the range of 2 to 10 µm (PM10 signal) this sensor did not deliver satisfying results. Sensor no.2 did not deliver satisfying results, neither for PM2.5 nor for PM10 signal. Sensor no. 3 delivered satisfying results for all PM channels, PM10, PM2.5 and PM1. Even more this sensor delivers reliable results for 16 channels between 0.38 and 17 µm for the particle number concentration.

Tab.1 Results of different sensors in comparison to reference instruments

No.	Sensor: model, manufacturer	Behavior for fine particulate matter 0,3 – 2 µm	Behavior for coarser particulate matter 2 – 10 µm
1	SDS011, Nova Fitness		
2	PMS5003, Plantower		
3	OPC-N2, Alphasense		

Reference aerosol spectrometers were model Fidas 200 from PALAS company and model 1.108 handheld instrument from GRIMM company

For gaseous compounds results of calibrations with calibration gases as well as comparative measurements between different electrochemical sensors and reference instruments (chemiluminescence, NDIR, UV absorption) will be presented.

Conclusions
Low cost sensors can be used after the application of quality assurance measures prior to the measurements instead of expensive measurement instruments. But not all sensors deliver the same quality of data. Some are even inappropriate for usage in the ambient air.

IMPLEMENTATION OF LOW-COST, SMALL SENSORS FOR URBAN AIR POLLUTION MEASUREMENTS ON STATIONARY AND MOBILE PLATFORMS

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Air pollution is linked to about nine million premature deaths worldwide in 2015 according to the last Lancet commission report. The classical view of urban air pollution monitoring is based on well-established and expensive reference methods installed in scarce and static monitoring stations. The use of small sensors as a complementary tool for air quality monitoring could give us high spatial density and temporal resolution relevant for city scale measurements and more information related to air pollution exposure of the population. This potential is however associated with challenges, such as interferences and the impact of environmental influences that require significant evaluation and calibration of the sensors to ensure data quality.

In summer 2017, in the framework of the project "Urban Climate Under Change", a field campaign was carried out in Berlin, Germany where NO_2, O_3 and particulate matter were measured using low-cost, small air quality sensors (Earthsense Zephyrs). The sensors were implemented over the course of a number of months to measure the vertical distribution of pollutants in a street canyon, as well as more limited implementation for mobile measurements. The results of these deployments, as well as the calibration and performance of these sensors will be discussed.

THE UNIVERSAL CLOUD AND AEROSOL SOUNDING SYSTEM (UCASS): AN OPEN PATH PARTICLE COUNTER FOR MULTI-PLATFORM MONITORING OF PARTICULATE MATTER

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Summary
This presentation discusses a new optical particle counter design, developed at the Centre for Atmospheric and Climate Physics (CACP), at the University of Hertfordshire. The Universal Cloud and Aerosol Sounding System (UCASS) is an open geometry instrument, which uses wide-angle elastic light scattering for the high precision sizing of particles from 0.3µm to 40µm. The instrument design and preliminary field results are discussed.

Introduction
Routine meteorological data are obtained in the atmosphere using disposable radiosondes, giving temperature, pressure, humidity and wind speed. Additional measurements are obtained from dropsondes, released from research aircraft. However, a crucial property not yet measured during these soundings is the size and concentration of atmospheric particulates, including dust. Instead, indirect measurements are employed, relying on remote sensing, to meet the demands from areas such as climate research, air quality monitoring and civil emergencies. In addition, research aircraft can be used in situ, but airborne measurements are expensive, and aircraft use is restricted to near-horizontal profiling, which can be a limitation, as phenomena such as long-range transport depend on the vertical distribution of aerosol. To take such measurements, the Centre for Atmospheric and Climate Physics has recently developed a range of low-cost, miniature particle counter for use with disposable radiosondes, dropsondes, UAVs or in dense ground-based sensor networks.

Methodology and Results
The UCASS sizes particles based on elastic light scattering. Particles passing through an optically defined sensing zone are counted, and the magnitude of the optical response is used to calculate the size. Modelled results using T-Matrix and Lorenz-Mie theory show that, for the optical set up utilized in the UCASS, the instrument response is largely independent of particle shape and optical absorption. Therefore, the system is suitable for the measurement of both spherical and none-spherical particles, and particles with unknown optical properties. Earlier versions of the UCASS have been used for the vertical profiling of mineral dust (Nicoll et al. 2011, Ulanowski et al. 2010) and volcanic ash (Harrison et al. 2010, Ulanowski et al. 2010a). The more recent, open geometry system has been used for ground based air-quality monitoring (Kaye et al. 2014) and most recently as a balloon borne sounding system during the Ice in Clouds Experiment –Dust (ICE-D) campaign, located in Cape Verde, August 2015. During ICE-D, the UCASS was launched coincident to a SAVEX flight, and comparisons between the UCASS and various aircraft instrumentation show good agreement for the sizing and counting of aerosol particles in the Saharan air layer.

Conclusions
Comparisons with aircraft mounted instrumentation show good agreement in the counting and sizing capabilities of the UCASS. These devices offer alternative sampling techniques to in-situ aircraft studies and can be used for deep vertical profiles with no restrictions on light levels. Therefore, these instruments can offer valuable information in addition to, or in lieu of aircraft measurements, thus aiding the measurement of the vertical distribution of cloud and aerosol particles.

Acknowledgement
This work was supported by a NERC (capital grant CC0030) and a small research grant (SRG) from the Aerosol Society.

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URBAN MOBILE INSTRUMENTS FOR ENVIRONMENTAL MONITORING URBMOBI 3.0

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Summary

Urban climate research is primarily based on point or location-based measurements of climate and air quality data. With the development and implementation of the third generation of an urban mobile measurement device, abbreviated as URBMOBI 3.0, we aim to amend this scenario. The URBMOBI 3.0 is a relatively small sensor unit equipped with micro-sensors for measuring the following meteorological parameters: temperature, relative humidity, and solar radiation. Additionally it measures ambient air pollutant concentrations of particulate matter (PM) from 0.30 to 17 µm with a typical flow rate of 1.2L/min, nitrogen dioxide (NO_2), nitrogen oxide (NO), and ozone (O_3) up to 20 ppm. Geo tagging of the measured data is enabled via a Global Positioning system (GPS) device and the acquired data is stored in a built in SD card. It is expected that by 2018 vehicles such as trams, buses or other vehicles will be mounted with URBMOBI 3.0 prototype devices in order to measure climate and air quality data at high spatial and temporal resolutions (2 sec) within the city of Berlin. These measurements can then take place on a regular basis, where conventional measurements systems are not built up or cannot be set up. Urban climate models and simulation tools will be fed with the acquired data, which in turn may provide a better understanding of the status and reasons of existing urban climate conditions. This will provide an opportunity to improve the urban climate by providing tools for enhanced city planning and air quality management. A high temporally and spatially resolved data set over a longer period will be of major importance for validation, testing and usage when microscale climate models and other simulation tools come into place. This study outlines the design of the device and the first results of the associated calibration tests.

Introduction

Climate change and air pollution are classified as the 5th and 7th top global issues respectively of 2016 (Nathe 2016). Although a number of sources and factors have been identified as a cause of air pollution it is difficult to pinpoint a particular source and manage it due to the variability of the pollutants in space, time, and the socio-economic factors involved (Deguen and Zmirou-Navier 2010, Krupnick 2007). The evolving land use pattern and urban heat island effect within growing metropolitan areas coupled with the population projections, calls for new observational data sets and atmospheric models for projection and planning of development projects which will help in combating the adverse effects of urban climate. The measurement of air pollutant is currently restricted to fixed monitoring sites due to cost, man power and safety issues. A surge of low cost electrochemical sensors in the recent years can reform this situation. However these sensors trigger questions regarding their credibility due to their instability under various ambient temperature and humidity conditions. This study aims to design and develop a new measurement device which can provide a credible data set over high spatial and temporal resolution at reasonable cost and effort.

Methodology

URBMOBI 3.0 is an integrated device with a solar radiation sensor (ML-01 Si-Pyranometer) at the top, a PM sensor (OPC-N2) based on Mie scattering theory from Alphasense Ltd., NO_X (NO2-A43F and NO-A4) and O_3 (OX-A431) electrochemical sensors also from Alphasense Ltd. and Temperature and humidity sensors (Sensiron- SHT35-DIS) enclosed by housing fitted with radiation shields. The entire device is mounted on a vacuum suction cup which facilitates easy mounting and dismounting of the device. The inlet to the sensors starts after the second radiation plate from the base in order to avoid interference from the body of the vehicle. A GPS system is included to enable geolocation and time tagging The device is calibrated with a combination of field and laboratorial tests. Although the factory set calibration factors are sufficient for laboratorial tests, outdoor conditions at ppb conditions require more complex approaches (Mead et.al, 2013). This study uses multiple linear regressions to optimise the algorithm used and employs field validation according to the Joint Research Centre (JRC) protocol of evaluation and calibration of low-cost sensors for monitoring of air pollution (Spinelle Laurent; Aleixandre Manuel; Gerboles Michel 2013).

Acknowledgements

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SUBMICRON AEROSOL SPECIATION IN SANTIAGO, CHILE

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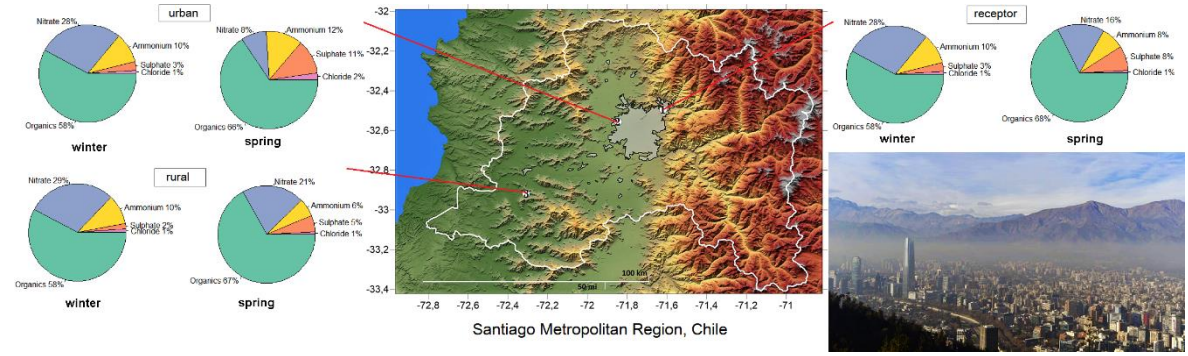
Summary
Concentrations of non-refractory $PM_{1.0}$ (organics, nitrate (NO_3), sulfate (SO_4), ammonium (NH_4) and chloride (Cl)), are described for Santiago de Chile, 2016. A high-resolution Aerosol Chemical Speciation Monitor (ACSM) was used to characterize $PM_{1.0}$ in winter and spring. Measurements were obtained for approximately 2 months at a rural, urban and urban-receptor sites. The organic aerosol was the species observed in higher concentration, followed by nitrate and ammonium. In the urban-receptor site, the greater chemical activity that results in particulate matter formation was observed.

Introduction
Santiago (Metropolitan Region), Chile, is an urban center of 7.1 million people, about 40% of the country's total population. The geographic and climatic characteristics prevailing in the area have been largely associated with unfavourable conditions for the air pollutants dispersion. Near 75% of the surface is mountainous terrain, which blocks the air circulation in the lower atmospheric layers. The aerosol mixing layer reaches altitudes near 400 meters in colder months and rise above the 800 meters in spring and summer (Muñoz et al., 2012). Elevated temperatures and solar radiation promote secondary aerosol formation and stronger photochemical reactions during daytime. Pollutants are transported and accumulated in eastern high-altitude sites, with the consequent increase in photochemical products (Rappenglück et al., 2000).

Methodology and Results
The study was conducted in Santiago, valley surrounded by the Coastal and Andes mountain ranges (Figure 1). A winter and a spring campaign was carried out in a rural (Melipilla), urban (Pudahuel) and urban-receptor sites (Las Condes) on 2016. $PM_{1.0}$ (aerodynamic diameter < 1.0 µm) non-refractory species, were monitored using the Aerosol Chemical Speciation Monitor (ACSM, Aerodyne Research Inc, USA). Wind-related parameters were obtained from the public meteorological network.



Graphical Abstract

Chloride concentration was negligible at all station. Sulfate was the only that increased its concentration during the spring, in all monitoring stations (0.59 µg/m^3 average). Ammonium was observed in greater concentration in the urban-receptor and urban site in winter (4.48 and 3.10 µg/m^3 respectively). Nitrate was also recorded in greater concentration during winter in the urban-receptor and urban site (12.32 and 6.42 µg/m^3 respectively). The organic aerosol was the predominant fraction in the submicron particle following the order: urban (32.16 µg/m^3) > urban-receptor sites (20.15) during winter. The highest average submicron particle concentration was observed in Pudahuel (urban) and Las Condes (urban-receptor site) during the winter. Several pollution episodes (concentration above 100 µg/m^3) were observed particularly the urban site. Meteorology data revealed that the region is characterized a reduced dispersion conditions in winter. Both the urban and rural sites recorded low-speed winds, while slightly higher at the urban-receptor site. Predominant winds follow a mountain-valley direction in winter, and change to a valley-mountain pattern during the spring.

Conclusions
The study concludes that the atmosphere in Santiago contains a high load of organics, nitrate and ammonium species, which are more concentrated during the winter. It can be deduced that the atmosphere is also rich in nitric acid, which accumulates to the east near the mountains.

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URBAN NANOPARTICLES SIZE DISTRIBUTIONS IN THE METROPOLITAN REGION OF PORTO ALEGRE, BRAZIL

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Summary

This study aims to understand the sources and mechanisms influencing nanoparticle number concentrations. Measurements of particle size distribution were made in urban area, in the period of 2014-2015 (Nov/2014-Set /2015) using a Scanning Mobility Particle Sizer Spectrometer-SMPS. Characteristics of each clusters and the associated sources were identified at the site: Vehicle exhaust- traffic (rush-hour), regional background particles, nucleated particles, vehicle exhaust (morning), nucleated fresh particles, regional nucleation event, urban traffic and urban background. Particle size distribution spectra was dominated by nucleation mode particles, identified in the majority of clusters

Introduction

Atmospheric nanoparticles can affect climate, urban visibility, atmospheric chemistry and subsequently human health. Morawska et al. (2008) studied the characteristics of PSDs of six different types of aerosol in terms of their modal characteristics and concluded, that despite the common peak in the ultrafine size range <100 nm (UFP), each size distribution incorporated unique modal parameters. This addresses the question whether it is feasible to extract characteristic and distinctive information from a large data set in terms of cluster analysis, a method to classify groups of homogeneous data (clusters) within large data sets. (Wegner et al., 2012). Thus, the aim of this study was to identify possible sources and processes related with the formation and size number nanoparticles.

Table 1. Characteristics of clusters

Cluster number	Contribution	Source
1	16.8%	Vehicle exhaust
2	11.3%	Regional background particles – biomass and soot
3	14%	Nucleated aged nocturnal particles
4	13.7%	Vehicle exhaust – morning
5	3.9%	Photochemically induced nucleated fresh particles
6	18%	Regional nucleation event
7	11.9%	Urban traffic – petrol and diesel
8	10.4%	Urban background aerosols in cold days

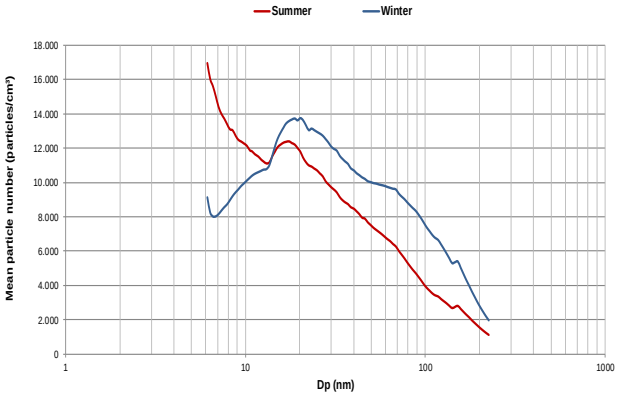

Figure 11. C. Average PNCs for each range size mode for warmer and colds days

Methodology and Results

The equipment used in the study for nanoparticle measurement was Scanning Mobility Particle Sizer Spectrometer 3936NL88 (SMPSS 3936NL88) of the mark TSI incorporated. Analysis of the potential health risk associated with the inhalation of nanoparticles was carried out considering the estimated respiratory deposition dose rates. Total dose received by an individual was measured considering the breathing rate, the period of exposure, and the difference between the inhaled and exhaled particle numbers during each breath (Azarmi et al., 2014). Measurements of particle size distribution were made in urban area, MAPA-Brazil, in the period of Nov. 2014- Sep.2015, employing a SMPS. K-means clustering analysis was performed on the data collected, resulting in eight size distributions that described aerosols population. Eight clusters and the associated sources were identified in the urban area (Table 1). This study clearly showed that the traffic conditions influenced the measurement and identified sources. Moreover, some identified sources included background clusters. Average PNC show that particles of the nucleation mode (<10 nm) had a maximum in warm days, being the highest mean PNC for summer; while mean PNC for cold day started to increase up to 20 nm, in the Aitken mode.

Conclusions

Nanoparticles concentration was affected by environmental conditions and depend on emission type and meteorological conditions, showing seasonal variation.

Acknowledgement

CAPES, FAPERGS and CNPq for the financial support.

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SPATIAL CHEMICHAL CHARACTERIZARION OF PM2,5 AND PM10 AT SEVEN CHILEAN SITES

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Summary
Mass and elemental concentrations of PM_{10} and $PM_{2.5}$ were measured in three of major Chilean regions: Metropolitan, V and VIII regions. An exploratory spatial analysis and a receptor model analysis has been implemented to all measurements in order to identify both natural and anthropogenic sources at all sites. Industries, biomass burning and vehicular transport were the most important anthropogenic sources of PM_{10} and $PM_{2.5}$. Vanadium is the clearest tracer of industrial emission and shown a very clear variation among the sites, due mainly to the use of petrol fuels.

Introduction
Chile is a fast-growing economic country with important industrial activities near large urban areas. Most of the economic development is concentrated at the three largest regions: Metropolitan Region (MR), V and VIII Regions. MR is the largest urban without a developed industrial area, while V and VIII Regions has a mix of industrial-urban areas. Large industries include Cu smelters, oil refinery, coal power plants, and steel production. Besides, V and VIII regions are growing from the shore of the Pacific to inner land, while MR has always been a Mediterranean area. These Regions has PM_{10} and $PM_{2,5}$ concentration that exceeds the annual USEPA standards. The economic growth in Chile and the improvement in air quality show that both could go together[1].

Methodology and Results
PM_{10} and $PM_{2.5}$samples were collected at 3 sites in MR: Las Condes and Pudahuel (Urban sites) and Melipilla (Rural site); 3 sites in VIII Region: Hualqui (Rural), UDT and Kingston College (Urban sites); and one site was selected at V Region: La Greda (Industrial site). Summer campaigns (~35 samples/site) runs at all sites, and a winter campaign was carried out in all MR sites. Gravimetric and XRF analysis were performed for all samples at Harvard University. Only concentration samples above the detection limit were include in data analysis. Receptor Model (PMF5.0) were used to each site to identify and quantify the sources of PM_{10} and $PM_{2.5}$. A spatial distribution analysis is presented (fig. 1) to illustrate the variation among the sites.
On summer, all rural samples have shown values almost half to 0.7 times of the urban and industrial sites. $PM_{2,5}/PM_{10}$ ratios indicate a growing gradient from MR<V<VIII, ranging from 0.34 to 0.45 on average, indicating that $PM_{2,5}$ contribution increase to the south and to the coast. $PM_{2,5}$ and PM_{10} winter concentration in Las Condes and Pudahuel showed 1.5 and 3 times higher than the rest of the sites, showing important seasonal effect due mainly to increase of $PM_{2,5}$.

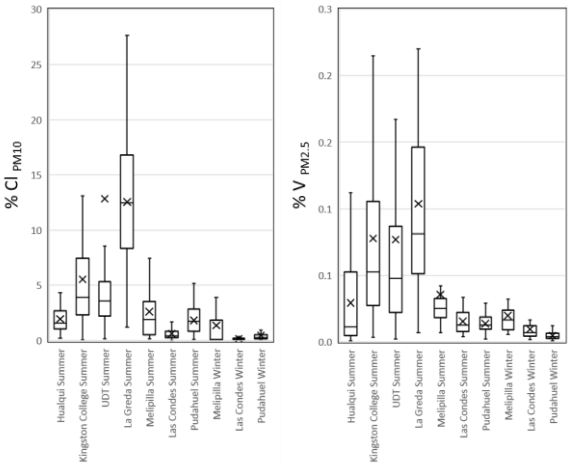

Figure 12: Xelement/$PM_{2.5 or}PM_{10}$ ratio of each

Box plot of elemental/PMx ratio is a very good exploratory analysis to characterize each measurement site. For example, as shown in Figure 12, Vanadium is a tracer for petrol fuel used mainly by industries[2], has more impact on industrial site, and at the urban sites of VIII region, while at MR the contribution is quite low. Similarly, Chlorine can be used as tracer of marine aerosol and at the coast sites, this element shown a higher contribution.
PMF analysis indicates that industrial, biomass burning and vehicular transport's emission are the most important anthropogenic sources, while marine aerosol is the most important natural source. The agreement between calculated and measured mass and elemental concentrations was excellent in most of the sites.

Conclusions
A spatial study was carry out to illustrate the major emissions sources of $PM_{2,5}$ and PM_{10}. Seven Chilean sites. Industrial, biomass burning and vehicular transport's emission are the most important anthropogenic sources, while marine aerosol is the most important natural source. The agreement between calculated and measured mass and elemental concentrations was excellent in most of the sites.

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FEASIBILITY STUDY OF PHOTOCATALYTIC MATERIALS TO IMPROVE URBAN AIR QUALITY

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Summary

During the European "LIFE MINOx-STREET" project ("Monitoring and modelling of the NO_x removal efficiency of photocatalytic materials: a strategy for urban air quality management"), a selection of several promising commercial photocatalytic products was done based on rigorous assays. After that, three of these photoactive products were applied on different building materials at distinct urban settings of Alcobendas (Madrid, Spain) and their effect on the NO_x ambient concentrations were evaluated both experimentally and through a validated numerical prototype. Finally, the generation of possible by-products present both in lixiviates and in deposited and resuspended particulate matter were investigated.

Introduction

The concentrations of NO_x continue to be a matter of concern in European cities, with NO_2 levels frequently higher than the European threshold limits. Although some photocatalytic products of the market have proved reasonably high photoactive activity in laboratory studies, doubts remain concerning their use in urban environments.

Methodology and Results

Tested photoactive products have showed NO_x removal efficiencies from non-active up to 56% under ISO 22197-1:2007, with NO dry deposition rates in the range of 0.3-10 10^{-3} ms^{-1} (Palacios et al., 2015).

The mechanical and superficial properties of photoactive concrete sidewalks and bituminous pavements have been evaluated, being affected some of them such as freeze-thaw and deicing salt resistance and slid resistance. Low durability of the photocatalytic material has also been detected. However, the pavement temperature has been affected positively.

Based on these tests, three different photocatalytic products were chosen and applied in three distinct urban scenarios: (1) bituminous pavement; (2) sidewalk pavement; (3) facade, to assess the NO_x remediation. The NO removal effect of photocatalytic materials has only been documented in the case of the facade scenario, very close the wall surface (20% as an upper limit at 5 cm) (Pujadas et al., 2017). The modelling results of the three urban scenarios were in good agreement with the registered measurements. Moreover, the photocatalytic activity measured on these implemented materials over time has shown an unambiguous decrease. Finally, on bituminous case, the analysis of lixiviates and size resolved atmospheric aerosol and deposited dust samples have revealed no significant difference between photoactive and non-photoactive scenarios.

Conclusions

The following are the main one: (1) enormous variability among the air purification efficiencies of the different commercial photocatalytic products; (2) performance on air purification depends on several factors (photocatalytic product itself, implementation procedure, substrate, ambient conditions, wear, soiling, conservation); (3) low deposition velocities and the high air volume/photoactive surface ratio make the induced photocatalytic macroscopic effect very weak; (4) great difficulty to establish the possible cause-effect relationship between any observed ambient NO_x reduction and the presence of photocatalytic surfaces; (5) low NO_x concentration reduction, only produced very close to the photoactive surfaces with poor global incidence on ambient air; (6) before implementing any photocatalytic material at real scale it should be assayed in laboratory on the real surface/substrate where it will be applied on to characterize its performance; (7) further research in photocatalytic materials is needed to achieve a general improvement of their performance as well as to explore new engineering designs and applications; (8) a microscale model to simulate the dispersion of pollutants at urban scale has been set-up at the mentioned real urban scenarios and the prototype is ready to simulate the impact of the individual and combined use of these photocatalytic materials on the pollutants gradient at district level (see poster B. S. Sánchez); (9) "in-situ" monitoring of the photocatalytic activity is highly recommended in view of the wearing and soiling of the photocatalytic surfaces; (10) no evidence of local effects via ambient air or lixiviates due to the photoactive products use.

Acknowledgement

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OXIDATIVE POTENTIAL IN PM FIELD SAMPLES

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Summary
In this work were selected three most important oxidative potential (OP) assays reported in the literature: the dithiothreitol (DTT), the acid ascorbic (AA) and the 2′,7′-dichlorofluorescin (DCFH) assays (Fang et al. 2016, Huang et al. (2016). These assays were applied to different field samples in order to identify the relations between OP values and chemical and dimensional characteristics of particles. The analysis of the soluble and insoluble fractions of dusts deriving from specific emission sources evidenced a very different behaviour of the three assays. Furthermore, the study showed that the insoluble fraction is able to generate OP values similar or even higher than the soluble (and bio-accessible) fraction.
The application of the three OP assay to $PM_{2.5,}$ PM_{10} and size-segregated samples (10-stage impactor) collected in the cities of Ferrara and Rome allowed us to confirm the non-inter-changeability of the three methods and the importance of combining the different assays, in order to successfully predict the overall capacity of PM of causing oxidative stress. Furthermore, the relations between chemical composition and OP results were studied by the application of multivariate statistical computations to the experimental data set.

Introduction
In the last years, several studies highlighted the important role of the urban airborne particulate matter (PM) in the increase of morbidity and mortality due to cardiopulmonary diseases, related to inflammatory processes and genotoxic effects (Dockery et al., 1993; Pope et al., 2002). Different a-cellular assays are currently used in literature for the determination of the PM oxidative potential (OP), which is considered as a predictive index of PM capacity to generate ROS in biological organisms. Oxidative stress occurs when there is an imbalance between the level of reactive oxygen species (ROS) or free radicals and the natural antioxidant defence of the biological system. ROSs class include families of free radicals, ions and other oxygenated molecules (such as organic and inorganic peroxides) and their formation in cells occurs through the reduction of oxygen from biological reducing agents such as NADH and NADPH. It is important to emphasize that the scientific world is still questioning the possible causes that link the air pollution with the effects on health and different study approaches have been evaluated in order to gain more information about it.

Methodology and Results
Samples were extracted by mechanical agitation (20 min) in Milli-Q water and subsequently divided in different aliquots in order to analyse the oxidative potential and have a complete chemical characterization (anion, cation, traces elements, WSOC, EC/OC) of each samples. The results obtained by the analysis of the soluble and insoluble fractions of some kinds of dust that make significant environmental contributions to PM (i.e. NIST1648a, brake dust, coke, road dust, Saharan dust, soil, ash pellet) showed different OP results depending on chemical components present in each dust. Moreover, the oxidative potential measured in the insoluble fraction of the dusts is comparable to (or even higher than) that measured in the soluble fraction, showing an important results not widespread in literature. The OP values obtained for the field samples ($PM_{2.5}$, PM_{10} and size-segregated) collected in Ferrara and Rome depended less on the sampling site than on the particle size. PM chemical composition also influenced the OP values, even though each assay showed a different sensitivity towards the oxidant species. The application of the three methods confirmed that the DTT method was more sensitive to organic substances, but also to metals components present in PM samples, while the AA method is more sensitive towards dusts rich in metals and metalloids. It is also important to highlighting that these two methods would seem to respond to similar chemicals components but with different affinities. This result was also confirmed by the results obtained by the analysis of samples collected by 10-stage impactor; DTT assay evidenced a greater affinity to particles in the fine mode, while AA responds mainly to particles present in the *course* fraction. The interpretation of the results obtained by the DCFH assay has been particularly difficult, as DCFH results appear to be driven by a competition between several factors, some of which increase the response while others suppress it.

Conclusions
In this work, it was possible to confirm the non-interchangeability of the three methods of analysis of the OP, and thanks to different types of approach, it was possible to study the relationships that bind the oxidative potential to specific emission sources and to the size of the particles present in the PM.

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THE SATELLITE-BASED MONITORING INITIATIVE FOR REGIONAL AIR QUALITY (SAMIRA)

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Summary
We present an overview and first results of the ESA-funded 3-year project *Satellite based Monitoring Initiative for Regional Air quality* (SAMIRA), which aims at improving regional and local air quality monitoring through synergetic use of data from present and upcoming satellite instruments, traditionally used in situ air quality monitoring networks and output from chemical transport models.

Introduction
While there is a vast amount of satellite-based Earth Observation (EO) data available that has the potential to be useful for air quality applications, the exploitation of such data at regional and local scales is currently quite limited. In order to address this, the SAMIRA project aims at demonstrating the usefulness of existing and future satellite products of air quality for improving monitoring and mapping of air pollution at the regional scale.

Methodology and Results
Six core activities are being carried out in order to achieve this goal: Firstly, the project is developing and optimizing algorithms for the retrieval of hourly aerosol optical depth (AOD) maps from the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) onboard of Meteosat Second Generation. As a second activity, SAMIRA aims to derive particulate matter ($PM_{2.5}$) estimates from AOD data by developing robust algorithms for AOD-to-PM conversion with the support from model- and Lidar data. In a third activity, we evaluate the added value of satellite products of atmospheric composition for operational European-scale air quality mapping using geostatistics and auxiliary datasets. The additional benefit of satellite-based monitoring over existing monitoring techniques (in situ, models) is tested by combining these datasets using geostatistical methods and demonstrated for nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and aerosol optical depth/particulate matter. As a fourth activity, the project is developing novel algorithms for downscaling coarse-resolution satellite products of air quality with the help of high-resolution model information. This will add value to existing earth observation products of air quality by bringing them to spatial scales that are more in line with what is generally required for studying urban and regional scale air quality (see Fig. 1). In a fifth activity, we implement robust and independent validation schemes for evaluating the quality of the generated products. Finally, in a sixth activity the consortium is working towards a pre-operational system for improved PM forecasts using observational (in situ and satellite) data assimilation.

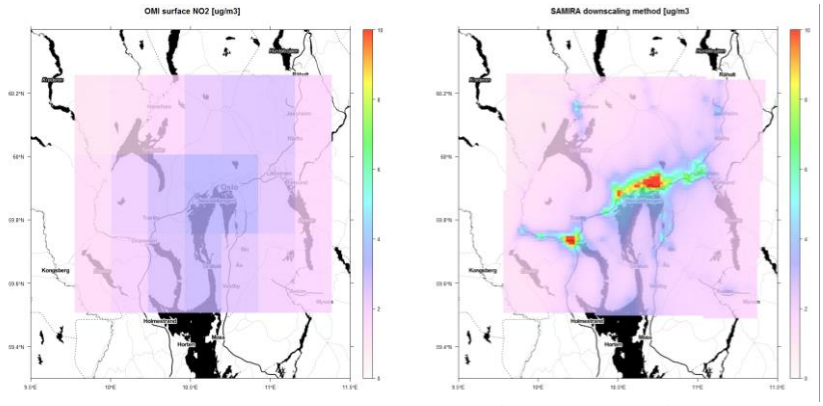

Fig 1. The SAMIRA downscaling methodology shown for the example of NO_2 over Oslo, Norway. The left panel shows a satellite-based surface NO_2 field derived from data of the Ozone Monitoring Instrument (OMI), whereas the right-hand panel shows the downscaled result at a spatial resolution of 1 km by 1 km.

Conclusions
The SAMIRA project works towards a better exploitation of existing and future satellite data products for applications related to regional and local air quality. Using a combination of satellite data, model information, and ground-based observations, the project develops method for deriving value-added products of regional air quality.

Acknowledgement
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UNCONVENTIONAL CARRIERS TO CONDUCT AIR QUALITY MEASUREMENTS

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Summary
This study aims to use unconventional carriers to conduct air quality measurements. Applications and experiments from the use of low-cost sensors for measuring particulate matters and other substances with drones, balloons and sea ships are presented. The use of portable, lightweight devices makes it possible to carry out measurements in areas where conventional measurement systems are not feasible.

Introduction
In the last period can be seen dynamic development of real-time systems with large spatio-temporal resolution based on low-cost sensors, since such information cannot provide conventional measurement systems due to limited data availability and scalability problems. Current research and direction for development focus on the concept of a next-generation air pollution monitoring systems that use new measurement technologies and techniques for communicating and delivering data (Rogulski, 2017). These systems can be complementary to traditional air quality monitoring systems.
Low cost, small dimensions and low energy requirements make it possible to build mobile measuring devices equipped with such sensors. Drones, hot air balloons and sea ships were used to test the quality of the air in places that were not available yet with classic measurements equipment.

Fig.1 Measuring device with drone

Fig.2 Measuring device with balloon

Methodology and Results
The purpose of the drone measurements was to create a mobile system that would contain sensors being able to detect the presence of certain substances emitted from combustion of various materials. The measuring device is equipped with particulate matter, formaldehyde and hydrogen cyanide sensors. In the next variant, the possibility of using a balloon as a carrier was investigated. The balloon does not give the ability to place in a precise location like a drone, but by this carrier it is possible to test the air quality much higher above the ground surface than is allowed with the drone. Locations not yet available for large stationary measurement devices include also sea areas, and in particular areas of coastal zones, so in the third variant mobile measurement device was installed on sea ship during a cruise on the North Sea and the Baltic.
All analyzed cases showed the usefulness of using unconventional carriers for measuring devices. The use of drone allowed identification of selected substances emitted, for example, from chimneys (eg. formaldehyde). With the use of balloon was possible to measure pollutions higher above the ground, as well as identify the height to which the pollution comes from the so-called low emission. The sea ship, in turn, allows for exploration the scope of pollutions at sea, as well as emissions from marine sources (other sea ships, drilling platforms).

Conclusions
Small, low-cost sensors allow you to build measuring devices for specific needs and integrate with the objects by which they are moved. It makes possible to conduct research in places where access has so far been very difficult.

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EXPOSURE TO PARTICLES AND THEIR ELEMENTAL COMPOSITION DURING COMMUTE IN CURITIBA, BRAZIL

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Summary
The target of this work was to evaluate the short-term personal exposure to particles and their elemental composition, in routes of public transportation buses mode of Curitiba city, Brazil. The fine particulate matter ($PM_{2.5}$) and Particles Number Concentrations (PNC) data were systematically collected through five routes with higher flux in the city. The $PM_{2.5}$ ranged from <9.9 μg m^{-3} to <23.7 μg m^{-3} and the PNC from 200 to 330 cm^{-3}. The elemental composition of PM was performed through X-ray fluorescence spectroscopy (EDX-RX) and Black Carbon (BC) in reflectance mode. As a main result, this work shows that the principal chemical composts that constitute the $PM_{2.5}$ come from vehicular combustion, and the $PM_{2.5}$ and PNC are higher in peak periods.

Introduction
Recently, several studies have been performed focusing in measurements of personal exposure to particulate matter (PM) originated from different modes of public transportation (KUMAR, 2014; KUMAR, 2016; RIVAS, 2017). However, only scarce studies dealing to personal exposure and combined with their elemental composition analysis, as well as measurements of Particles Number Concentrations (PNC) in similar conditions of the diary-routine-transportation displacements. Specifically, in Brazil there are still no studies dealing these issues. In this way, the target of this work is to evaluate the short-term personal exposure to particles and their elemental composition in buses routes of public transportation system of Curitiba city, Brazil. It is worthy to say that Curitiba is considered a worldly environmental-reference, and in public transportation. (RAEMAEKERS, 1998; PARRA, 2006)

Methodology and Results
$PM_{2.5}$ was sampled and measured through a personal equipment (DataRAM™ pDR-1500) using filters of PTFE at flux of 3 L min^{-1}). The equipment travelled in geo-referenced routes in same diary displacements done by the local population through local bus lines. The PNC were measured by a particle's count equipment (MetOne, cutoff of 0.3 μm). Five bus routes (pertained to public transportation) of higher costumers-demanded were chosen and three samples were collected in peak periods (17:00 – 19:30) and in not-peak periods (09:00 – 17:00) for each route. The PM elemental compositions were done through X-ray fluorescence spectroscopy (EDX-RX) and Black Carbon (BC) in reflectance mode. The average values of $PM_{2.5}$ changed in the range of 23.7 to 14.3 μg m^{-3}. Figure 1 shows the chosen bus routes and the respective values of $PM_{2.5}$ concentrations for peak periods (Fig. 1A) and not peak periods (Fig. 1B). In the peak period the PM concentrations (in μg m^{-3}) fall in the range of 23.7 to 18.4 while in not-peak period the PM concentration was in 9.9 to 14.2 range. The PNC 0.3 (the concentration of particles sized below 0.3 μm, in particles cm^{-3}) were the range of 200 to 300 and 240 to 330 for the peak and not-peak period, respectively. It can be noted that in the R4, the route that travels the whole city with stops, in average, at every 3 km, presented the higher concentration of $PM_{2.5}$ as well an elevated PNC 0.3 index. This may be due to the fact of such route connects the almost of totality of other routes in the city. Three major chemical elements were identified in the investigated environment: sulphur (S), concentrations (μg m^{-3}) in the range of de 36.64 to 55 for not peak period and 39.31 to 45 for peak period; sodium (Na) presented the same parameters as 76.25 to 84 and 91 to 93. Similarly, for iron (Fe) it were found 27 to 39.53.and 30 to 33. The Black Carbon data (in μg m^{-3}) were 7.43 to 16.19 for not peak period and 11.05 to 20 for peak period.

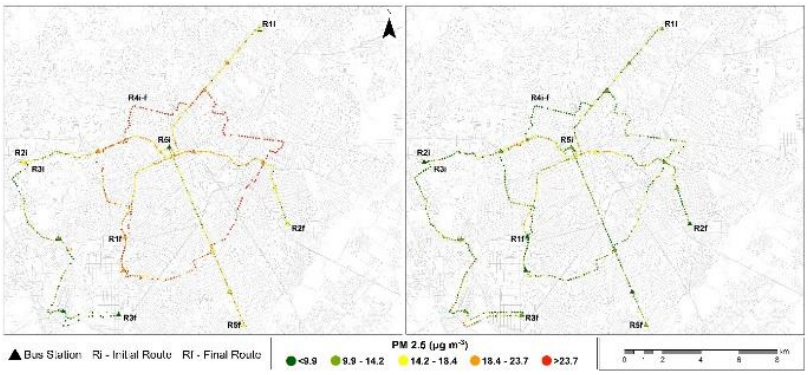

Fig.1 $PM_{2.5}$ concentrations in routes of Curitiba

Conclusions
The highest $PM_{2.5}$ concentrations were found in the peak periods and were strongly connected to the vehicular emissions. In addition, the concentrations were relatively higher in long routes and with several stops.

Acknowledgement
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SENSORS IN AIR QUALITY MONITORING IN HELSINKI – FIELD TEST RESULTS AND UTILIZATION OF COMPLEMENTARY SENSOR NETWORKS

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Summary

The aim of this work is 1) to evaluate the performance of two air quality sensor types (AQT420, Vaisala Oyj; AQ Urban, Pegasor Oy) in urban field conditions in the Helsinki metropolitan area, and 2) to demonstrate the benefits gained by complementary sensor networks. Five AQT420 instruments were compared with reference-level monitors at a traffic site in summer 2017 and relatively high correlations were observed for gaseous pollutants (NO_2, O_3, CO). The correlations for PM_{10} were lower during the clean summer period but very high correlations were observed during the spring-time street dust period. AQ Urban instruments were used for the long-term monitoring of particle lung-deposited surface area (LDSA) concentrations at four sites (traffic, background, two detached house areas). The correlations between LDSA and BC and NO_x were high due to emissions from local traffic and wood combustion. In the Helsinki region, sensors are already utilized in air quality research projects (e.g. air quality gradients in a street canyon) and a large complementary sensor network is now under construction.

Introduction

Air quality sensors can be utilized in complementary urban air quality networks and various research projects where easy deployment of compact instruments opens new possibilities. However, the quality of sensor measurement results may vary significantly in field conditions, depending on sensor type, pollutant levels and sources as well as meteorological conditions. The aim of the present work is 1) to evaluate the performance of two different air quality sensor types in field conditions, and 2) to demonstrate the utilization of these sensors in air quality monitoring and research.

Methodology and Results

The NO_2, O_3, CO and PM_{10} concentration results of five AQT420 instruments were compared with reference-level measurements at an urban traffic supersite station during a five-week period in summer 2017. The correlations (R^2) between AQT420 and reference results were quite high for gaseous pollutants; 0.79-0.89 (range of five instruments) for NO_2, 0.71-0.78 for O_3 and 0.58-0.85 for CO (Table 1). The correlations for PM_{10} were lower (0.50-0.53) during the clean summer period (PM_{10} mean concentration 12 µg/m^3). However, high correlation (R^2=0.87) for PM_{10} was observed during the one-month test period in spring when street dust elevated PM_{10} concentrations (monthly mean 31 µg/m^3). After the test period in summer, the AQT420 sensors were installed in a street canyon to evaluate long-term pollutant gradients and these results will also be shown at the conference. AQ Urban sensor measures the lung-deposited surface area (LDSA) concentration of particles that is usually dominated by very small particle sizes (~10-500 nm; Kuuluvainen et al., 2016). Four AQ Urban instruments were installed at different sites to test their performance in the long-term monitoring of local particle emissions from vehicle exhausts and residential wood combustion. High correlations (R^2) between LDSA and other combustion-related parameters were observed both at a traffic site (e.g. 0.80 for BC, 0.76 for NOx and 0.63 for particle number concentration) and at a suburban detached house area (e.g. 0.72 for BC and 0.47 for NOx). The hourly variation of LDSA concentrations clearly indicated the impacts of local traffic and wood combustion emissions at the different sites (Fig. 1).

Table 1. Correlations (R^2) between AQT420 and reference results at the traffic site. Mean concentrations (Conc.) during the 5-week period are also shown.

Device No	NO_2	O_3	CO
AQT 1	0.83	0.71	0.71
AQT 2	0.79	0.71	0.81
AQT 3	0.88	0.78	0.61
AQT 4	0.89	0.78	0.58
AQT 5	0.85	0.74	0.85
Conc. µg/m^3	30	39	182

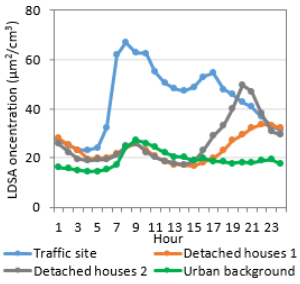

Fig. 1 Hourly variation of LDSA concentrations at different sites between February and May 2017.

A large complementary air quality sensor network, using AQT420 and AQ Urban devices, will be established in the Helsinki metropolitan area at the end of year 2017. All data from 15 new sensor sites and 11 existing official monitoring stations will be used as input to the FMI-ENFUSER model that generates online air quality now-casts and forecasts with high spatial resolution. The description of the sensor network will be presented at the conference.

Conclusions

The current work indicates that AQT420 and AQ Urban sensors provide valuable complementary information that can be utilized in air quality research projects and long-term monitoring as well as in real-time communication and air quality forecasts.

Acknowledgement

This work was supported by the Finnish Funding Agency for Innovation (CITYZER project), the Helsinki-Uusimaa Regional Council (HAQT project, national AIKO funding) and the City of Helsinki (KAILA project).

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SAMPLE PREPARATION AFFECTS METAL DISTRIBUTION IN A BIOMONITOR AFTER EXPOSURE TO SIMULATED ATMOSPHERIC NANO-POLLUTION: CELL MEMBRANE INTEGRITY ASSESSMENT

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Summary
This study aims to determine the sample preparation factors affecting metal distribution in moss biomonitor *Pleurozium schreberi* (Brid.) Mitt. as well as the factors altering the membrane integrity following a simulated atmospheric nano-pollution. The moss samples were exposed to a suspension of nano-ZnO after various pre-treatments, dried in an oven or ambient air and subjected to sequential elution followed by ICP-AES analysis in order to determine the amount of accumulated zinc in the surface, extracellular, intracellular and residual fractions. Simultaneously, potassium concentrations in the fractions were determined to assess the integrity of the membranes. Washing and continuous irrigation affected the Zn distribution the most, the potassium extra/intracellular ratio was affected strongly by the pre-exposure drying and post-exposure oven drying – as evaluated by ANOVA. If the monitoring survey strategy is to determine the distribution of the pollutant in the moss biomonitor, it is, hence, recommended not to subject the samples to water prior to the exposure and not to dry them in the oven afterwards.

Introduction
Nanomaterial production is continuously increasing and the need for the nanoparticle (whether engineered or secondary) monitoring in the atmosphere is imperative. Moss biomonitoring is a common tool in atmospheric pollution research, however, only few studies so far assessed the application of mosses in the monitoring of nanoparticle pollution.(e.g. Canivet et al., 2015). No attention was paid to the distribution of the nanoparticles in the biomonitoring plant which can reveal further information on the temporal and chemical patterns of the pollution. For the best applicability of mosses in the nanoparticle pollution assessment, proper sample preparation and handling procedures have to be also established. When the temporal patterns (evaluated by the determination of distribution of the pollutant in the moss) are the study subject, the study of the cell membranes integrity is crucial since it may disrupt the in-plant distribution to the fractions. In this study, factors of sample treatment affecting the metal distribution in moss and integrity of the cell walls following a simulated nano-pollution exposure were determined.

Methodology and Results
Moss samples of *Pleurozium schreberi* (2–4 cm long apical segments) were collected in NE Czechia far from the pollution sources. In the laboratory, samples were divided to sixteen groups of treatments, four replications each. The treatment of the samples consisted of either washing or not washing, irrigation or no irrigation one week prior to the exposure, exposure to nano-ZnO or control and drying in the oven (50 °C) or at the ambient temperature after the exposure and prior to the analysis. The exposed samples were subjected to 2.5 ml of 0.1 $g.l^{-1}$ nano-ZnO suspension twice a week for 5 weeks. Sequential elution following the procedure of Pérez-Llamazares et al. (2010) was applied. After drying, all filtrates and residual matter were decomposed using $HF+HNO_3+H_2O_2$ mixture and analysed for Zn and K content using ICP-AES. All the pre-exposure treatments had significant effect on the Zn content in all the assessed fractions. Washing the samples significantly altered the Zn content in all the fractions (ANOVA, $p < 0.05$). Irrigation and the method of post-exposure exsiccation were also found to be important factors. Intra/extracellular ratio of potassium content, indicator of cell membrane integrity, was significantly lowered mostly by pre-exposure drying and post-exposure oven-drying. Nano-ZnO exposure had paradoxical positive effect on membrane integrity ($p < 0.05$).

Fig.1 Intracellular Zn concentration

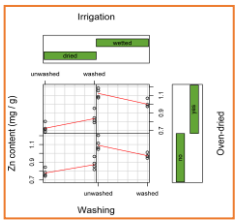
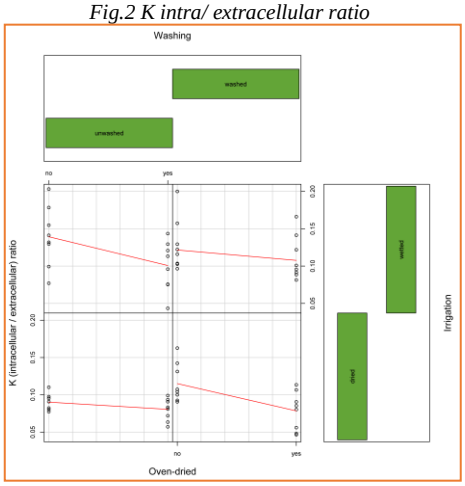


Fig.2 K intra/ extracellular ratio



Conclusions
Nano-ZnO exposure leads to differing Zn content in cellular fractions in *Pleurozium schreberi*. In future, post-exposure oven drying and pre-exposure irrigation are to be avoided. Nano-ZnO exposure was less harmful to the moss than distilled water– use of it for control samples is, thus, not recommended.

Acknowledgement
This research was realized in the frame of the SP 2017/71 project, financially supported by the Ministry of Sport and Education of the Czech Republic.

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HOTSPOT MONITORING OF BTEX CONCENTRATIONS AT AN INTERNATIONAL AIRPORT IN SOUTH AFRICA

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Summary

Airports are known air pollution hotspots due to the variety of fuel driven activities that take place within the confines of them. As such, people working within airports are particularly vulnerable to exposure of hazardous air pollutants, including a group of compounds known as BTEX (viz. benzene, toluene, ethyl-benzene and xylenes). These compounds have been identified as being harmful to human and environmental health. Through the use of passive and active sampling methods the spatial and temporal variability of benzene, toluene, ethyl-benzene and xylene concentrations within the international airport was investigated, and hotspot modelling conducted. The spatial investigation revealed that the BTEX hotspot was located in the vicinity of the main apron of the airport where fuel driven activities are heightened.

Introduction

Air travel has experienced proliferative growth in the past few decades. The average annual growth rate is predicted to increase by 4.6 percent from 2010 to 2030 (Vennam et al., 2015). Aviation's impact on the environment is heavily debated, particularly in relation to climate forcing attributed to emissions at cruising altitudes and the noise and the deterioration of air quality at ground-level due to airport operations. Among pollution issues, poor air quality attracts a high level of interest within the scientific community and engages public opinion because of the known relationship between exposure to many air pollutants and increased adverse short- and long-term effects on human health. This specific study focussed on a class of volatile organic carbons (VOCs) known as BTEX (benzene, toluene, ethylbenzene, xylene). BTEX are referred to as the most important type of VOCs due to their carcinogenic effects as well as their relatively high abundance in the atmosphere (Miri et al., 2016).

Methodology and Results

Two sampling campaigns were conducted. In order to quantify the temporal variability of concentrations within the airport, an active sampling strategy using the Synspec Spectras Gas Chromatography 955 instrument was used. While a passive sampling campaign, using Radiello Passive Samplers was used to quantify the spatial variability of these compounds.

The passive sampling campaign revealed that BTEX concentrations ranged from 12.95 to 124.04 $\mu g.m^{-3}$.

The spatial investigation revealed that the BTEX hotspot was located in the vicinity of the main apron of the airport where fuel driven activities are heightened (see Fig. 1). However, when the individual BTEX compounds were analysed they displayed spatial variations that were dependent on their source areas such as motor vehicle and aircraft movement.

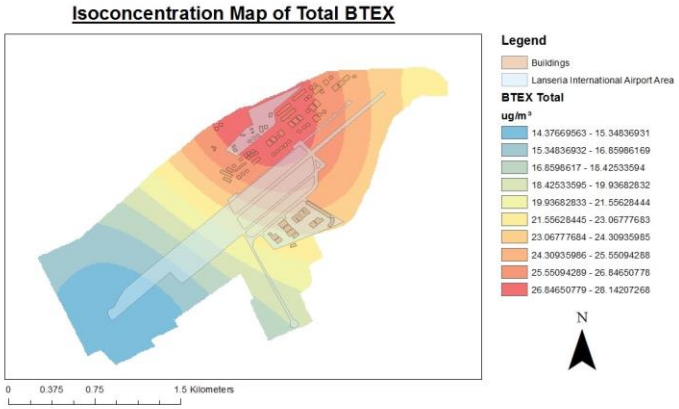

Fig.1 Iso-concentration map indicating time weighted average of total BTEX

Conclusions

It can therefore be concluded that the spatial variation of BTEX within the airport is mainly influenced by their main source contributor while the daily temporal variations is dependent on multiple factors including the type of BTEX compound being examined, the source of that specific BTEX compound, the location of the sampler, the surrounding terrain and lastly the effect of meteorological factors on the dispersion of that specific BTEX compound.

Acknowledgement

This work was financially supported by the National Research Foundation of South Africa (Grant number: 99303).

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PILOT STUDY OF THE IMPACT ON ENERGY EFFICIENCY AND EMISSIONS OF APPLYING GREEN PLUS CATALYSIS TECHNOLOGY TO DIESEL VEHICLES IN THE ABURRÁ VALLEY-COLOMBIA

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Summary
The metropolitan area of the Aburrá Valley. AMVA, have been presenting emergencies for PM2.5 in recent years and that indicates the need of strategies of intervention to ensure cleaner air. It has been proposed to add the catalyst agent *Green Plus* (GP) to diesel fuel, which, according to previous experiences in several countries reduces the specific fuel consumption and lowers pollution emissions. To demonstrate this at the local level, a pilot project was undertaken between December 2016 and April 2017, subjecting 25 diesel operated vehicles to continuous work during three months with fuel enhanced with GP under carefully monitored conditions, including determination of fuel mileage and static test emissions at 30, 60 and 90 days, comparing the results to a baseline initial month in which normal fuel (LB) was used. Significant reductions in specific emissions of CO, particulate matter (PM), EC and OC were obtained, as well as increases in fuel efficiency, which leads to economic attractiveness and avoided CO2 emissions.

Introduction
There has been a continuous effort to regulate the pollution emission coming from mobile sources, of which PM is an important component. In the case of the Aburrá Valley it has been determined that these sources generate more than 70 % of the PM emissions, being the diesel operated vehicles a significant contributor. There is a need to improve on the situation by all means, due to the continuous population and vehicle use growth in the region, which is causing environmental crisis associated to high PM2.5 concentrations during certain months in the year, where poor atmospheric conditions can affect the health of the population (Clean Air Institute, 2013). Under this context, the Mexican company Horeb proposed the use of the GP catalyst as a proven and certified fuel enhancer which could contribute to diminish emissions, including PM. To demonstrate its possibilities and advantages in the region, Horeb approached Politecnico Colombiano Jaime Isaza Cadavid (PCJIC), to develop a pilot plant study.

Methodology and Results
During 4 months, one with base line (LB) and three using enhanced fuel (GP), information was collected associated with 25 diesel vehicles. This included determination of mileage and fuel use, to determine specific fuel consumptions and monthly tests under normalized static conditions (low, idling, and high speed, cruising, motor rotation speeds). In these test determinations were carried (including exhaust flow conditions, CO and PM concentrations). The PM samples were studied to find elemental, (EC) and (OC), by the SEM-EDS and Thermal Optic methods in the DRI (Nevada) and the gas concentrations were found following the current normalized Colombian testing norms for vehicle emissions, in a certified testing center. The diesel fuel was analyzed, using ASTM methods and results showed that the fuel catalyzed with GP at 20 ppm, did not change the properties in a significant way and the pertinent fuel norms are fulfilled. The pilot study showed an average increase in fuel yield of 6.8% (which is associated with less CO2 emissions) and average reductions in specific emission at idle conditions of CO of 36 % and particulate matter emissions of 47.1 %, which are associated to similar decreases in $PM_{2.5,}$ and EC reduction up to 52%.%.

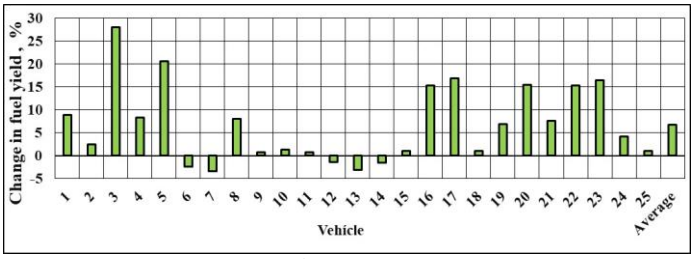

Figure 1. Change in fuel yield with GP catalyser

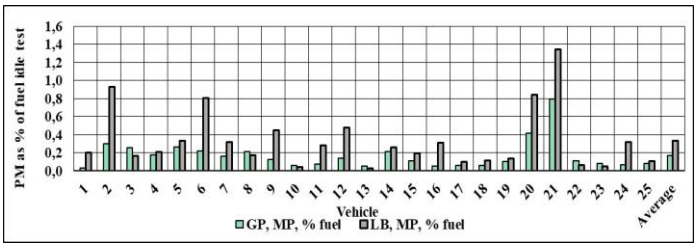

Fig.2 MP emission reduction with GP vs LB

Conclusions
Significant reductions in CO, PM, EC and CO2 emissions and increases in fuel yield are to be expected using GP technology. This should be the basis for introducing GP as a useful means to alleviate the PM2.5 and EC pollution problem in the region.

Acknowledgement
Thanks are given to local environmental authority, Área Metropolitana del Valle de Aburrá (AMVA) and to the four local transporting companies that allow for the study to be done in their vehicles.

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EXTENDED CYCLING OPERATION OF A COPPER-BASED TYPE SO_X ADSORBENT

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Summary
This study aims to relate the activity of a regenerable copper-based SOx adsorbent using SBA-15 as an inert silica mesoporous support able to catalyse the SO_2 oxidation into SO_3 and reversibly chemisorb SO_3 as $CuSO_4$. A focus has been done on the regeneration phase of the adsorbent in order to avoid the sintering of the copper-based active phase, which drastically reduces the performances of the material. It has been shown that a thermal regeneration under inert atmosphere induces a significant increase in adsorption performances after one cycle, but leads to the sintering of copper species into bulky copper oxide which are not active enough, along subsequent cycles. Conversely, regenerations under reductive atmosphere and at moderate temperature allowed a high dispersion degree of copper species in the mesoporous support SBA-15 and consequently the conservation of the SOx adsorption capacity over several sulphation and regeneration cycles.

Introduction
Sulphur oxides SO_x (SO_2 + SO_3) are key gaseous pollutants that are strictly regulated through the European directives (e.g. Industrial Emissions Directive). While the current abatement technologies allowed a large reduction of SOx emissions in the last decades, both the use of high-carbon footprint compounds (e.g. lime, caustic soda) and the prohibitive reprocessing costs of the generated solid wastes, have made these processes unsustainable. The use of regenerable SOx adsorbents has been therefore considered as an alternative solution. In this work, the SBA-15 Organised Mesoporous Silica functionalised with CuO was selected as a regenerable adsorbent (Gaudin et al., 2016). The performances of this material in SOx trapping were evaluated along cycling experiments (adsorption and regeneration cycles), correlated to an extensive characterisation of the material using XRD, TEM/EDX, N_2 physisorption and XPS analyses. The objective was to determine the optimal regeneration phase parameters (to ensure the best efficiency of the adsorbent along cycling experiments.

Results
A thermal regeneration of the sulphated adsorbent at 600°C under pure N_2 leads to a strong increase in the performances of the CuO/SBA-15 adsorbent during the next adsorption step, due to the autoreduction of copper Cu^{2+} species into more active Cu^{+}-based ones. These species are probably more efficient in the catalytic oxidation of SO_2 into SO_3, which is a preliminary step before the SO_3 chemisorption. For instance, a CuO/SBA-15 material containing 15 wt.% of active phase exhibits an increase in SO_x adsorption capacity of more than 70% before and after such a thermal regeneration, to reach a SOx storage capacity of 64 mg_{SO2}/g_{ads} (capacity for a SO_2 concentration in the exhaust of 75 ppm) during cycle #2. Nevertheless, this efficiency gradually decreases over subsequent cycles, due to a partial active phase agglomeration into bulky copper (II) oxide particles. Regenerations under reductive atmosphere (H_2 0.5% vol. in N_2) were also investigated in order to decrease the regeneration temperature with the aim of limiting copper agglomeration phenomenon. It was found that this regenerative treatment can be performed starting from 280°C (minimal temperature for $CuSO_4$ decomposition under H_2 0.5 vol.%) (Berger et al., 2017). Under these conditions, the SO_2 adsorption capacities of the CuO/SBA-15 material were maintained over several cycles and the characterisation of the regenerated sample clearly shows that no sintering of the active phase occurs. However, the decomposition kinetic of $CuSO_4$ was too low. Regeneration experiments performed at 600°C under similar reductive conditions avoid such a phenomenon, but the adsorption capacities decrease with the increase of the adsorption and regeneration cycles.

Conclusions
The stability of the adsorbent was highly impacted by the regeneration conditions to which it has been subjected. A mild regenerative treatment under H_2 0.5 vol.% performed at 280°C was used to stabilise the adsorbent capacity over several adsorption and regeneration cycles, without any substantial loss of performances.

Acknowledgement
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ASSESSMENT OF THE METHANE PRODUCING AND EMISSION IN THE DOMINANT LANDSCAPES OF TYPICAL TUNDRA OF THE WESTERN YAMAL

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Summary
In this presentation, we report the main results of our estimation of methane formation and emission in dominant landscapes of typical tundra. The study area is located in Western Yamal. The landscape structure of the representative area of typical tundra was studied, and landscape map was compiled. Soils of the active layer and upper permafrost were sampled within all dominant landscapes. Methane concentration was measured for every sample, and total methane content in the active layer and upper permafrost was evaluated. The highest methane content was observed in mires and ravines. Peatlands, well-drained tundra, wet tundra, and sand fields were characterized by the lowest methane content. Thus, mires and ravines are the main sources of methane emission in typical tundra. Daily methane flux in these landscapes reaches 10 to 20 mg/m^2.

Introduction
Permafrost plays an important role in global climate change and affects biological, hydrological, and human activities in the Arctic. In this study, we ~~try to~~ estimate methane content and its emission to atmosphere in dominant landscapes of typical tundra of Western Yamal based on the field investigations.

Methodology and Results
Prior to measurements of methane emissions, we had developed a landscape map of the representative area 1 x 1 km based on satellite imagery and field observations, and determined its landscape structure (Fig. 1). It is known that emissions of methane generally peak between July and early August, with smaller emissions observed during late spring, early summer, and fall (Euskirchen et al., 2017). Samples for evaluation of methane concentration were obtained from cores of boreholes drilled in late July 2016 within every dominant landscape. Soil samples were degassed, and the gas was collected using a "head space" method. Methane content was measured using a gas chromatograph XPM.4 with plasma ionization detector in the Institute of Physical, Chemical, and Biological Problems in Soil Science RAS. Distribution of methane concentration with depth is shown in Fig. 2. The highest values are related to permafrost samples. High methane concentrations were detected only within the two landscapes – mires and ravines – while there is almost no methane in the active layer of all other landscapes. Methane fluxes were measured in 200-mm-diameter plastic pipes installed within each dominant landscape. Gas samples were collected every hour during three to four hours. Field measurements showed that the highest methane emissions to the atmosphere were typical of the same two landscapes. Surface temperatures during the field experiment varied from 4 to 8 °C. Daily methane flux in these landscapes reached 10 to 20 mg/m^2 (late July 2016), while in all other landscapes it did not exceed 2 to 5 mg/m^2.

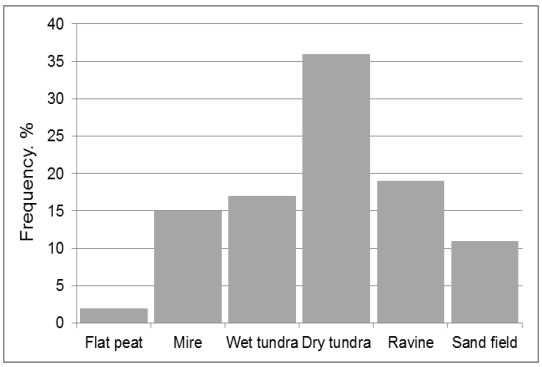

Fig.1 Landscape structure of typical tundra of Western Yamal

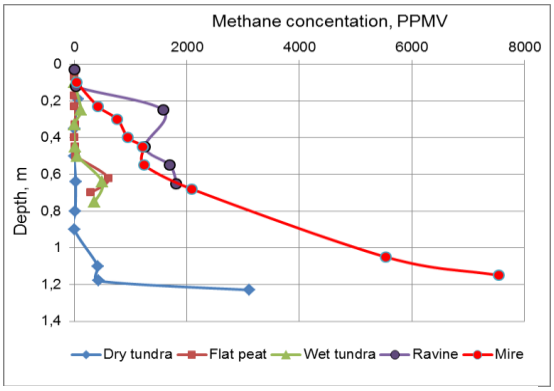

Fig.2 Methane concentration in active layer of dominant landscapes

Conclusions
Based on our studies, the highest methane emission occurs only within the two landscapes: mires and gullies, which occupy approximately 30% of typical tundra. During the peak emission, daily methane flux in these landscapes can reach 10 to 20 mg/m^2.

Acknowledgement
This work was supported by RSF, grant №16-17-00102. Study of methane content in frozen Quaternary sediments was supported by RFBR grant № 16-05-00612. We acknowledge Liza Rivkina for the help with lab analysis.

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COASTAL RETREAT AND METHANE EMISSION IN THE WESTERN YAMAL

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Summary
This study proves that permafrost degradation of coastal and marine sediments of the Arctic Seas can result in large amount of methane emitted to the atmosphere. The quantitative assessment of such emissions requires data on methane content in permafrost sediments and ground ice. The samples were analyzed to determine composition, salinity, and organic carbon content. Gas was present in pores of sediments and in bubbles within the ice. The methane content is characterized by high variability. The value of methane emissions in the destruction of frozen sea shore with underground ice is high enough and comparable to the emission of methane from wetland ecosystems.

Introduction
Methane is emitted in the atmosphere during the permafrost degradation on the Arctic shelf, the continent and the melting of the subsurface ice. Methane is the second greenhouse gas after the carbon dioxide, its increase in the atmosphere has a significant impact on the climate as a whole. Since the second half of the XX century, the concentration of methane in the atmosphere has been increasing annually by 1%.

Methodology and Results
Long-term regular observations near the polar station Marre-Sale, Western Yamal ($69^0$43'N/$66^0$49'E) of the sea coast retreat since 1978 showed a speed of about 1.7 meters per year. The profile of the coastal cliff near the station is a complex of quaternary deposits that contains an uneven-aged syngenetic ice wedges and two types of tabular massive ground ice. Methane contained in the air bubbles in the underground ice and permafrost sediments. More than 400 samples of gas from permafrost and ice were selected. CH_4 concentration was measured by headspace-equilibration, using KhPM-4 (Russia) gas chromatograph with flame ionization detector and hydrogen used as a carrier gas (Pushchino, Russia). It was found out that there is abnormally high value of methane concentration in tabular massive ground ice. The methane content in it reaches 21.5 ml kg^{-1} . Methane is practically absent in the Holocene sands with syngenetic ice-wedges. Epigenetic types of freezing explain high levels of methane in marine sediments. Syngenetic freezing does not contribute to the accumulation of methane while the epigenetic freezing is favorable for its conservation (Vasiliev et al., 2015). Theamount of methane released from permafrost due to erosion was estimated for 100 m of the coast and for the full length of 4.5 km long coastal section was estimated. It was found, that each year the destruction of 100 m of the sea coast in the research area causes 10300 g of methane to be released into the atmosphere and around 463500 g is released around a 4.5 km-long coastline. The amount of methane released into the atmosphere every year by the destruction of a 100 meter and 4.5 km long coast was calculated. It was found, that each year the destruction of 100 m of the sea coast in the research area causes 10.3 kg of methane to be released into the atmosphere and around 463.5 kg is released around a 4.5 km-long coastline. Marine clay and loam contribute most of all to methane emission that happens due to the destruction of the sea coast near the polar station Marre-Sale contribute (Fig.).

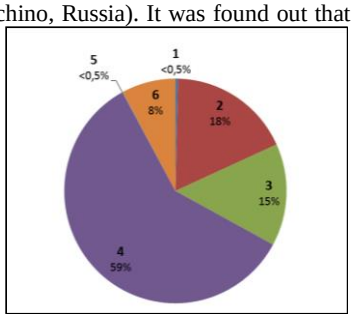

Fig. The contribution of methane from sediments and ice in the total emission of methane in the destruction of a 100 m coast segment in one year. 1 – alluvial sand; 2 – lacustrine silt and sand; 3 – lacustrine silt and sand; 4 – marine clay and loam; 5 – ice wedges; 6 – tabular massive ground ice.

Conclusions
The comparison between the amount of methane released into the atmosphere from the surface of tundra wetland ecosystems of the north of Western Siberia and the amount of methane released into the atmosphere as a result of the destruction of the sea coast near the polar station Marre-Sale showed, that the amount of methane coming from the 100 m^2 section of the coast amounted to 0.501 kg / year. On average tundra wetland ecosystems emit 0.117 kg / year of methane from a 100 m^2 segment (Kazantsev, 2013). The value of methane emissions in the destruction of frozen sea shore with underground ice is high enough and comparable to the emission of methane from wetland ecosystems.

Acknowledgement
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PAHS EMISSIONS FROM BIOMASS FUELS BURNING IN IGP PLAIN INDIA

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Summary

In this study, the experimentally determined emission factors of PAH emitted from biomass fuels (dung cake, fuelwood and crop residue) from rural household of five (Delhi, Uttar Pradesh, Punjab, Haryana and Uttarakhand) over Indo-gangetic (IGP) plain of India, are presented. The gaseous phase and particulate phase PAHs emissions are simultaneously determined from various biomass fuels. The average emission factors of total polycyclic aromatic hydrocarbons (PAHs) from dung cakes, fuelwood and crop residue over the Northern India are estimated as60.6mg/kg, 52.3 mg/kg and 42.1mg/kg respectively. The emission factor of particulate phase PAHs (46.1 mg/kg, 44.5mg/kg and 37.2 mg/kg) was found higher as compared to gaseous phase PAHs (2.3 mg/kg, 7.8 mg/kg and 4.9 mg/kg) from dung cakes, fuel-wood and crop residue, respectively.

Introduction

In rural India, nearly 94% of primary energy use is accounted for by biomass (TEDDY, 2007).In India especially in rural areas, fuelwood, crop residue and dung cake are burnt in traditional domestic stoves (chulha) with low combustion efficiency for space heating and food preparation. PAHs are semi-volatile compounds containing 2 or more aromatic rings. The present study has been carried out across the IGP part of India as this part is a major source of pollutants over India due to the usage of biomass fuels as energy.

Methodology and Results

Samples of domestic biomass fuels have been collected at district level in rural areas of IGP India. A dilution sampler was designed and installed in laboratory to meet the considerations needed for accurate aerosol measurements based on those identified for organic aerosols (Venkataraman et al., 2005).Low volume sampler (LVS) with a flow rate of 46.7 L/min was used to collect particulate and gaseous PAHs. Particulate PAHs were collected on quartz microfiber filters, and gaseous PAHs were obtained on PUF plugs in a glass filter holders. Analysis of PAHs is done using GC-MS. The average emissions (Table 1) of gaseous phase PAHs are highest from fuelwood, while crop residue and dungcake show lower emissions. Naph (2.33 mg/kg), Acy (1.78 mg/kg), and Flu (1.36 mg/kg) are major gaseous phase PAHs found from fuelwood while Naph (1.57 mg/kg), Ace (1.29 mg/kg), and Phen (1.10 mg/kg) are predominant gaseous phase PAHs from crop residue. The average emissions of particulate phase PAHs are found higher from dung cake (60.6 mg/kg), than fuelwood (52.3 mg/kg), and crop residue (42.1 mg/kg). 4 to 6 rings PAHs emissions are found higher in dung cake, whereas 3 to 4 ring PAHs are predominant in fuelwood and crop residue.

Table 1 Emission factors of PAHs (mg/kg) for biomass fuels used in IGP India

States	**Dung cake**			**Fuelwood**			**Crop residue**		
	Gas	Part	Total	Gas	Part	Total	Gas	Part	Total
Delhi (n_{FW} = 101, n_{CR}= 20, n_{DC}= 95)	2.2	47.5	49.7	4.2	42.4	46.6	2.6	36.9	39.5
Uttarakhand[a] (n_{FW} = 181)	-			11.6	53.7	65.3	-		
Haryana (n_{FW} = 92, n_{CR}= 35, n_{DC}= 38)	3.7	62.7	66.4	7.2	38.7	45.9	5.5	39.6	45.1
Punjab (n_{FW} = 139, n_{CR}= 40, n_{DC}= 48)	3.3	66.6	69.9	7.5	39.3	46.8	6.4	37.4	43.8
Uttar Pradesh (n_{FW} = 149, n_{CR}= 35, n_{DC}= 38)	2.5	53.9	56.4	8.4	48.3	56.7	5.2	34.8	40
Northern India Average	***2.3***	***46.1***	***60.6***	***7.8***	***44.5***	***52.3***	***4.9***	***37.2***	***42.1***
[a]Note: Dung cake and agricultural residue are not used in domestic sector; (n_{FW} = No. of fuelwood samples, ,n_{CR}= No. of agricultural residue samples, n_{DC}= No. of dungcake samples)									

Conclusions

The emission factor of gaseous phase and particulate phase PAHs obtained is higher from fuelwood and dung cakes respectively. Hot flames generally produce a higher amount of gaseous PAHs. Dung cake, with a lower burn temperature, was more polluting than fuelwood and crop residue, in terms of particulate PAHs emissions with predominance of 4 to 5 rings PAH compounds. The PAH profiles showed a predominance of Chr, B[k]F, B[b]F, B[a]F, B[a]A, Flt and Pyr from all biomass fuels.

Acknowledgement

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EVALUATION OF TRAFFIC EMISSION MODELS COUPLED WITH A MICROSCOPIC TRAFFIC SIMULATOR WITH ON-ROAD MEASURES

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Summary
This study aims to compare and contrast the emission results of two traffic emission models coupled with a microscopic traffic simulator and the observed results of on-road measurements done by RSD (Remote Sensing Device) on real driving vehicles in Barcelona. This is done by the comparison of the traffic emission model Panis 2006 which is already integrated into the traffic simulator AIMSUN, and the coupling of AIMSUN to an up to date vehicle emission model as PHEMlight is. The study's goal is to assess the divergence between the observed results of the RSD measurements performed at street level, and the modelled emission results in order to evaluate the representativeness of the emission factors applied.

Introduction
Air pollution is an important issue for public health, economy and environment. Barcelona is one of the more polluted European cities, and this is directly related with the urban traffic. According to that, air quality measures are everyday more connected with mobility measures (e.g. vehicle restriction, car lanes reduction, increment of parking fees) that aims the reduction of moving vehicles within the city and the pollution associated to them. To further evaluate and assess the utility of these measures, emission models coupled with traffic simulators must be as realistic as possible and calibrated to the city and conditions where they are applied. Considering this, the study compares the results of an already coupled but out-of-date traffic emission model and an updated one with the observed results of on-road measurements performed with RSD technology on a recent study in Barcelona.

Methodology and Results
The traffic simulator AIMSUN (TSS, 2014) was used to obtain the representative driving cycles (speed-time data) for each class of vehicle. The vehicle fleet data was obtained from the recent RSD study performed by the Àrea Metropolitana de Barcelona (AMB, 2017) and the different origin-destination demand matrices were provided by inLab FIB research centre (J. Barceló & L. Montero 2015). The driving cycles of each vehicle were introduced into PHEMlight vehicle emission model (TUG, 2017), to obtain traffic emissions for each vehicle type. These are the emissions for each vehicle at each second of its drive cycle (e.g. µg NOx/sec) which were initially compared to the already coupled but outdated emission model within AIMSUN: Panis et al. 2006 (See Fig.1) to be then contrasted with the emission results per each type of vehicle obtained from the RSD (Remote Sensing Device) on-road study performed by AMB. Between the two different traffic emission models, primary results show large discrepancy in NOx emissions, probable due to the difference between the old emission factors and the proven real ones after the dieselgate scandal. Discrepancies were also found with the PM, attributed to the new particle filters that new cars have and that none of the two models considers non-exhaust emissions or resuspension.

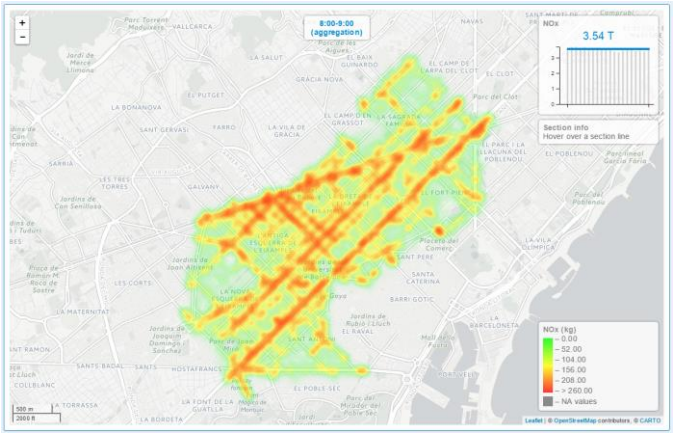

Fig.1 Vehicle emissions over Eixample using Aimsun's emission model.

Conclusions
Air pollution causes severe health effects on population, and the high traffic density within urban sites leads the total emissions registered. Precise vehicle emission factors are needed to take action against this problem and improve the air quality by mobility policies selected under realistic traffic emission results.

Acknowledgement
This work was supported BSC-CNS Earth Science department and the inLab FIB (Universitat Politècnica de Catalunya).

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BIG DATA IN ENVIRONMENTAL AND OCCUPATIONAL EPIDEMIOLOGY: THE BEEP PROJECT

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Summary
The analysis of big data is an emerging topic in environmental health that may help scientists to get insights from a large amount of structured and unstructured information. The ongoing BEEP (Big data in Environmental and occupational Epidemiology) project is presented. BEEP aims to collect, link and analyse a large amount of data coming from different sources to support exposure assessment and epidemiology studies. The health effects of environmental factors in the general population and workers will be investigated at different levels ranging from the national to the urban scale.

Introduction
One of the big challenges of the modern environmental epidemiology is to collect and link a huge amount of heterogeneous geographic, environmental and health data to get ensemble information otherwise not available. The general objective of the BEEP project is to estimate, using Big Data, the health effects of air pollution, noise and meteorological parameters on the Italian general population, and to evaluate the risk of occupational injuries in sub-populations of workers. The Project started on June 2017 and will last two years. It is structured in Specific Objectives focused on different spatial domains, from the whole national territory to the urban micro-scale. A special focus will be devoted to the risk of hospitalizations and mortality at the national level and within the major metropolitan areas, the risk of occupational injuries and road accidents related to environmental factors, population mobility and extreme meteorological conditions.

General and specific objectives
General Objective:
1. To estimate the health effects of several environment risk factors (air pollution, noise, meteorological conditions) on the Italian population;
2. To evaluate the risk of injuries in sub-populations of workers in relation to environmental exposures

Specific Objectives
1. To estimate the exposure of the Italian population to different environmental risk factors and their health effects, in terms of hospitalizations or occupational accidents on a national scale, using the municipality as the spatial unit;
2. To evaluate the risk of non-accidental and cardio-respiratory mortality induced by different environmental exposures among the residents of five Italian regions, at the municipality level;
3. To evaluate the adverse effects of air pollution and extreme temperatures on mortality and occupational accidents within six urban metropolitan areas, at the census block spatial resolution;
4. To evaluate the joint short-term and long-term health effects of environmental exposures at the individual level in the longitudinal Studies of Rome and Pisa-Cascina.

Expected data to be used and/or produced:
- Satellite data at high spatiotemporal resolution
- Environmental monitoring data
- Land use data
- Dynamic population distribution derived from mobile phone traffic data
- Modelling of environmental parameters at national, regional, urban and address levels
- Mortality and hospitalizations data
- Follow-up of cohorts of resident population
- Data on occupational injuries and road accidents while commuting
- Data on road accidents with injuries

Expected results
- National level relational database containing information on geographic, meteorological, demographic, air pollution and noise exposures at high spatiotemporal resolution;
- High-resolution daily maps of air pollutants concentration at national level;
- High-resolution daily maps of air temperature at national level;
- Effects of air pollution and extreme temperatures on hospitalizations and cause-specific mortality at national and municipality levels;
- Acute effects of environmental exposures on occupational accidents;
- Estimation of urban population mobility based on mobile phone traffic data;
- Effects of mobile phone use on the risk of road accidents;
- Short-term and long-term health effects of environmental exposure in five metropolitan areas at census-block level;
- Effects of heavy rain and extreme temperatures on the risk of road accidents and injuries in Rome

Conclusions
Results provided by the BEEP project, in addition to address new directions in the scientific research, will provide relevant indications to decision makers in the fields of air quality, urban planning and public health.

Acknowledgement: This work was supported by INAIL Bando Ricerche in Collaborazione (BRiC) 2017 . More info on the BEEP project can be found in the project website: www.progettobeep.it

AEROBIC EXERCISE BENEFITS ON OXIDATIVE STRESS IN RATS EXPOSED TO AIR POLLUTION

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Summary

The aim of this study was to investigate the effects of aerobic exercise on measures of oxidative stress in rats exposed to air pollution. Male Wistar rats were instilled with a residual oil fly ash (ROFA) suspension and underwent to a treadmill running protocol for 90 days. Body mass, exercise tolerance test (ETT) and oxidative stress analyses were performed. Trained groups demonstrated a lower gain of body mass and increased distance, time and velocity in ETT. Oxidative stress analyses in lungs and heart showed no differences among groups. In gastrocnemius, trained groups demonstrated an increased superoxide dismutase (SOD) activity and decrease concentration of malondialdehyde (MDA). Air pollution exposure could lead to an oxidative adaptation in lungs and heart in a healthy sample, while exercise training is responsible for an improvement in antioxidant defense decreasing oxidative stress of gastrocnemius.

Introduction

Air pollution exposure is the largest environmental risk for health, it is closely related to premature mortality and development for a range of diseases (Pope et al. 2016). Physical activity demonstrates well-established health benefits, acting as important mediators of physiologic signaling and cellular adaptations. Although, during exercise the respiratory system undergoes adaptations that result in an increase in the volume of air inhaled. Consequently, exercising outdoor in polluted environment could lead to adverse effects caused by a higher exposure to air pollutants (Lovinsky-Desir et al. 2016). The majority of studies investigating air pollution with exercise demonstrate controversial findings. Therefore, the aim of the present study was to evaluate the effects of aerobic exercise in subchronic air pollution exposure on adaptation of aerobic exercise and measures of oxidative stress.

Methodology and Results

Male Wistar rats (n=32) were randomly distributed into four experimental groups: ROFA-SED, instilled with ROFA and sedentary rats (n=8); ROFA-AT, instilled with ROFA and trained rats (n=8); Sal-SED, instilled with saline and sedentary rats (n=8); Sal-AT, instilled with saline and trained rats (n=8); Rats exposed to air pollution received for 90 days 50µg of ROFA via intranasal instillation, which was applied as a recognized particulate matter (PM). This dose represents the concentration of 29µg/m³ of PM2.5, which is the value found in a polluted city. ETT was performed in all groups before and after exercise protocol. Trained animals underwent aerobic exercise training sessions for 50 min/day with 70% of ETT intensity, 5 times/week, during 12 weeks. Animals were euthanized after 12 weeks of treatment and training. Oxidative stress analyses of SOD and catalase (CAT) activity and MDA concentration were analyzed in lung, heart and gastrocnemius. Trained groups demonstrated a lower gain of body mass ($p<0.0001$), increased distance, time and velocity of the running when compared to sedentary groups ($p<0.0001$). Oxidative stress analyses in lungs and heart showed no differences ($p>0.05$). In gastrocnemius, trained groups demonstrated an increased SOD activity ($p=0.0002$) and decreased concentration of MDA compared to sedentary groups ($p=0.0030$), although CAT activity demonstrate no differences among groups.

Conclusions

Exercise training could decrease body mass gain and increase exercise tolerance, as well as lead to beneficial adaptation in oxidative stress through increasing antioxidant SOD enzyme activity and decreasing MDA concentration, indicating reduced lipid peroxidation in skeletal muscle in rats exposed to air pollution. Air pollution, in dose used in our study, could lead to an adaptation response in lungs and heart, however, the emission of pollutants is rising and, if any measured was made to control it, the new and increased rate of emissions may cause more damage.

Acknowledgement

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HARMFUL EFFECTS OF OCCUPATIONAL EXPOSURE TO TRAFFIC-RELATED AIR POLLUTION ON OXIDATIVE AND GENETIC OUTCOMES IN PROFESSIONAL MOTORCYCLISTS

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Summary
This study aims to quantify air pollutants gaseous, metals and metalloids related to traffic-related air pollution and harmful outcomes associated with oxidative and genetic damage in professional motorcyclists. Passive monitoring was used to quantify nitrogen dioxide (NO_2) and ozone (O_3) and trace elements were determined by ICP-MS. Oxidative stress profile was accessed spectrophotometrically and genotoxicity was evaluated by micronuclei assay. Individual exposure to air pollutants, trace elements content (Sb, Pt, As, Cd, V, Mn and Co), oxidative and genetic damage were higher in the exposed group. Additionally, a very strong correlation was observed between pollutants gaseous and lipid peroxidation, as a strong positive correlation between pollutants gaseous and micronuclei frequency. Results suggest that professional motorcyclists belong to a high-risk group due to long-term atmospheric pollution exposure, which can imply in the onset of a large range of harmful effects and worsening of pre-existent diseases.

Introduction
Vehicles play an important role in modern life. However, road vehicle emissions became one of the most important sources of human exposure to air pollution, mainly because vehicles world fleet increased drastically in last two decades (Davis et al. 2014). The damage caused in occupationally exposed subjects, as professional motorcyclists, is mostly caused by harmful products derived from engine combusting exhaust (Estévez-García et al. 2013). Although several epidemiologic evidence shows that exposure to traffic-related air pollutants plays a central role in pulmonary and cardiovascular dysfunctions, there is a lack of studies attempt to investigate the personal concentration of these pollutants in occupationally exposed subjects, as well the first genotoxic and oxidative stress biomarkers changes. Considering this, we determined air pollutants levels, genotoxic rate and biomarkers of oxidative stress in professional motorcyclists, in addition to the quantification of traffic-related chemical elements levels.

Methodology and Results
A cross-sectional study was performed among professional motorcyclists and office workers from Porto Alegre, Brazil, between January and December 2016. Individual exposure to air pollutants was assessed by passive monitoring. Fingernails trace elements were determined by ICP-MS. Oxidative stress biomarkers were quantified spectrophotometrically using plasma and genotoxicity was evaluated by micronuclei assay using exfoliated buccal cells. Individual exposure to NO_2 and O_3, trace elements content (Sb, Pt, As, Cd, V, Mn and Co), oxidative stress factors and genetic damage were statistically higher in professional motorcyclists than in office workers ($p < 0.05$). Moreover, NO_2 and O_3 levels showed a very strong positive correlation with plasmatic lipid peroxidation ($p < 0.001$ and $r = 0.8849$ and 0.8995) and a strong positive correlation with buccal micronuclei frequency ($p < 0.001$ and $r = 0.7683$ and 0.7280).

Conclusions
Professional motorcyclists are part of a more vulnerable group to the harmful effects derived from air pollution, as they are in continuous exposition to high levels of hazardous air pollutants and toxic chemical elements. Therewith, this specific group deserves more attention about researchers connect to the injurious effects related to air pollution exposure and the development of more sustainable transportation facilities.

Acknowledgement
This work was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

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REDUCING PERSONAL EXPOSURE TO FINE AND ULTRAFINE PARTICLE BY MEANS OF IMPROVED COOKSTOVES IN RURAL SENEGAL

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Summary
This study aims to assess the effectiveness of the Rocket cookstove, the most extended type of improved stove in sub-Saharan Africa, to reduce exposure to indoor atmospheric pollutants during cooking activities in rural Senegal. While cookstove studies are already available in the literature, this one is among the first to quantify exposures to ultrafine particles (UFP) and the first to quantify the benefits of improved cookstove programmes in Senegal. A total of 22 rural households was selected, using traditional and improved cookstoves. Results evidenced statistically significant reductions in exposure to the more conventional pollutants ($PM_{2.5}$, CO) as well as to the novel metrics (UFP, lung-deposited surface area or LDSA). However, black carbon (BC) emissions and impacts on exposure increased with the improved cookstoves. These results are thus conflicting from the point of view of human health (with reduced exposure to PM, UFP, CO) and climate (with increased BC emissions), and highlight the need for holistic approaches which are able to take into account health and climatic considerations, simultaneously.

Introduction
In Senegal, biomass accounts for 83% of the demand for domestic fuel use in rural areas (WB, 2013) and 6,300 people die every year because of indoor air pollution (WHO, 2009). However, very little effort has been made in this country to evaluate indoor air quality impacts from biomass combustion with traditional stoves and indoor air quality improvements derived from the use of improved cookstoves.

Methodology and Results
A cross-sectional study was conducted in a rural village of Senegal to determine indoor air pollution during cooking and non-cooking periods. Indoor concentrations of ultrafine particles (UFP), black carbon (BC), $PM_{2.5}$ and CO were determined, by means of portable monitors. To the authors' knowledge this is the first study to provide a comprehensive real-world assessment of household pollutant concentrations from the combustion of biomass fuels for cooking in Senegal, and one of the first worldwide to focus on ultrafine particles from cooking emissions. A total of 22 households was selected, 12 with using the traditional stove and 10 with using a locally produced rocket stove. Our results evidenced that the use of Rocket stoves contributed to a significant reduction of fine and ultrafine (UFP) particles and carbon monoxide (CO) (75%, 31% and 54%, respectively, $p<0.05$) with regard to traditional stoves. However, it increased BC concentrations (36%, $p<0.05$).

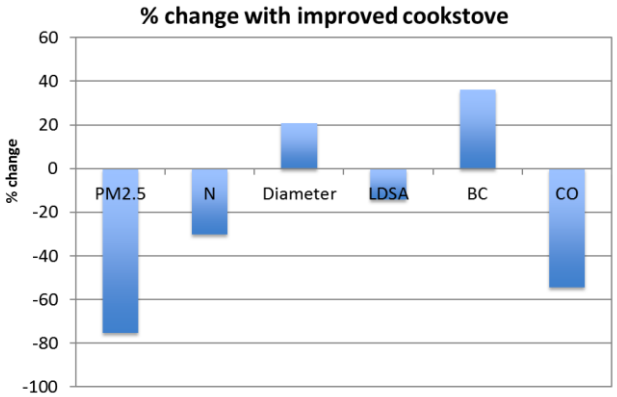

Fig.1 Relative change in exposure to the different parameters monitored (BC, UFP, PM, LDSA, CO) with improved with respect to traditional cookstoves.

Conclusions
The Rocket improved cookstoves tested in this work seem to have a positive impact with regard to health effects, even if not for all of the pollutants monitored (e.g., BC). This evidences that the climate and health-relevant properties of stoves do not always scale together and highlights that both dimensions should be considered simultaneously during the design of improved cookstove programmes. Alternative cookstoves focusing on the reduction of BC emissions should be considered to increase co-benefits on climate change mitigation. The adoption and sustained use of stoves by families is plausibly the most important and challenging consideration to implement improved cookstove projects. Thus, successful strategies focused on the improvement of household air quality in Senegal and other populations of sub-Saharan Africa should include information about better ventilation practices and an appropriate education on the cooking environment.

Acknowledgement
We would like to thank the families, especially women, of Bibane for their kindness. This work has been financially supported the Global Alliance for Clean Cookstoves (GACC, Enhancing Capacity of Regional Testing and Knowledge Centers, RTKC2), the Iberdrola Foundation (Grant for Research on Energy and the Environment), and the Spanish National Research Council (CSIC, I-COOP programme, COOPB20122). Support has also been granted by SGR33 AGAUR2014.

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SPATIAL DISTRIBUTION OF AIRBORNE POLLEN-INDUCED HEALTH SYMPTOMS IN BERLIN

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Summary
To gain information about spatial distribution of airborne pollen-induced health symptoms a network of pollen traps was established at 14 sites across Berlin. Birch, grass and mugwort pollen were measured from March till October 2014 using gravimetric traps of Durham type. Pollen-induced health symptom data were reported by sufferers using the online-based self-documentation tool "Patient´s Hay-fever Diary" (PHD). PHD data on eye, nose and/or airways symptoms were statistically correlated with pollen data measured at the closest site to residence. The results show remarkable spatial variations of pollen sedimentation across the town. Higher amounts of birch and grass pollen measured in the peripheral areas were reflected in stronger symptoms of users located within suburbs than those located in the city centre.

Introduction
Allergic diseases are widely spread in the German population. Medical diagnostic allergic rhinitis is stated for approximately 10.3% of children and adolescents and for around 14.8% of adults (Langen et al. 2013). Until today, airborne pollen is mainly monitored continuously at about 40 stations in Germany and about 400 stations in Europe by 7-day volumetric spore traps. However, there exist a few studies, considering the aspect of heterogeneity in cities by installing temporary operating networks with two, three or more traps as stated in Werchan et al. (2017). An approximate share of 15-18% of the Berlin population is affected by pollen allergy, corresponding to 525,000 to 630,000 inhabitants (Bergmann et al. 2012). Aim of the study was to measure spatial differences in distribution of three allergologically relevant pollen species (birch, grass, mugwort), which could cause allergenic pollen-induced health symptoms in different degrees within the city of Berlin.

Methodology and Results
Allergenic pollen of birch (*Betula*), grasses (*Poaceae*; including *Cerealia*) and mugwort (*Artemisia*) were monitored with gravimetric pollen traps located in about 2 m height above ground level at 14 different sites in Berlin city. Samples were changed weekly in the course of 33 weeks from March 2014 till end of October 2014 (Werchan et al. 2017a). Pollen-induced health symptom data were reported by using the online-based self-documentation tool "Patient´s Hay-fever Diary" (PHD). PHD enables hay fever sufferers anonymously reporting their daily eyes, nose and/or airways symptoms online or via apps ("Pollen" or "Husteblume") together with the geographical location where the symptoms occurred, characterized by region, postal codes or geographic coordinates. PHD user data were linked with the closest pollen trap, and statistically analyzed with pollen data of corresponding traps using Kendall´s Tau test.
During the birch pollen season (March to May) 163 PHD users reported for at least one week symptom data. During the grass pollen season (April to August) 149 PHD users and during the mugwort pollen season (June to September) 71 reported. Tentative results show higher amounts of monitored birch and grass pollen in the peripheral areas of Berlin were associated in stronger airway symptoms of users located within suburbs than those located in the city centre. No statistical relationship were identified between the varying presence of mugwort pollen and the severity of health symptoms.

Conclusions
The study shows spatial differences in the severity of health symptoms within the city going along with spatial differences in birch and grass pollen counts. Therefore, pollen data from a single trap may not serve appropriate explanations for differences in allergenic pollen-induced symptoms. More detailed and reliable information about the exposure to allergenic pollen can be addressed by the installation of further traps. Allergenic pollen should be accepted as an important factor for air quality assessments. From public health point of view an introduction of suitable legislation to regulate measurement of allergenic pollen should be considered in the future.

Acknowledgement
The study was supported by the German Environment Agency.

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MAIN SOURCES OF OXIDATIVE STRESS INDUCED BY AIRBORNE PARTICULATE MATTER

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Summary
Particulate Matter (PM) can generate reactive oxygen species (ROS) through two different mechanisms. Through the oxidative constituents absorbed onto their surface and can cause oxidation and through their ability to induce cellular generation of ROS in target cells, such as pulmonary epithelial cells and pulmonary macrophages. Chemical components of ambient PM, such as quinones and transition metals can initiate the catalysis of redox reactions in a biological system. Few studies so far have focused on the link between ROS generation with the respective aerosol sources. Identifying sources of redox-active PM_x is important for environmental health and industrial technology development. The present study aimed at investigating the most important sources that drive the redox activity of ambient PM_x (PM_1, $PM_{2.5}$, PM_{10}) in Thessaloniki, Greece. PM oxidative potential was not correlated to its mass concentration. On the contrary, a strong correlation between chemical composition and oxidation capacity of PM was observed.

Introduction
Chemical components of ambient PM, such as quinones and transition metals can initiate the catalysis of redox reactions in a biological system. Few studies so far have focused on the link between ROS generation with the respective aerosol sources. Identifying sources of redox-active PM_x is important for environmental health and industrial technology development. A variety of methods are available for measuring the capacity of PM_x to catalyse redox reactions. The dithiothreitol (DTT) assay is a commonly used acellular assay due to its ability to correlate well with biological markers. Several source apportionment techniques (e.g., positive matrix factorization and chemical mass balance) have been applied for the identification of the major emission sources associated with PM-catalyzed ROS generation.

Methodology and Results
An extensive campaign was carried out at two types of locations in the area of Thessaloniki to determine the chemical composition of urban aerosols and to correlate their toxicity with PM sources. From the chemical analysis of the PM_x sampled we found that oxidative potential of PM was not correlated to its mass concentration. On the contrary, a strong correlation between chemical composition and oxidation capacity of PM was observed. A rough estimation of ROS sources was obtained based on correlations between DTT activity and chemical species found in the respective PM samples and on connecting those species with sources. At the traffic site Cu and Zn were correlated with DTT activity, highlighting the presence of vehicular emissions while at the urban background site K, levoglucosan and PAHs were correlated with DTT activity of PM. However, the contribution of traffic to PM levels in urban air is reduced in the last five years in Greece. Also it was observed that the mean concentrations of PM_x at the urban background site were higher than at the traffic site. Similarly, the average total PAH concentrations were significantly higher at the urban background site. Black carbon (BC) levels (associated to internal combustion sources) did not differ significantly between the two sites. During the sampling period the contribution of biomass-fueled domestic heating to ambient air PM mass concentration was calculated to rise up to 34%. On a mass basis, ultrafine particles were more potent than either the fine or coarse particles. To identify the contribution of various sources to the oxidative properties of PM_1, $PM_{2.5}$ and PM_{10}, a PMF (positive matrix factorization) analysis was conducted using the DTT activity and measured chemical composition data at each sampling site. At background site 4 factors were determined by PMF. The first had high loadings of crustal elements (Al, Si, Ca, Ti, Mn, Fe) and it was attributed to soil resuspension. The second contained high loadings of BC, Ca, V, Ni, Cu, Zn and Pb and represented vehicular traffic. Transition metals such as Cu, Fe, Mn, and Zn, which have been related to adverse health outcomes, were associated to this factor by 91%, 12 %, 52 % and 64 %, respectively. As third factor, secondary aerosols were identified, characterized with high loadings of S, BC NO_3^-, benz[a]anthracene and chrysene. The fourth factor had a clear signature of biomass burning with very high concentrations of BC, K and PAHs. PAHs are important to the oxidative potential of PM due to their ability to be transformed into quinones through photochemical reactions with atmospheric oxidants. At the traffic site five factors were identified as important. The first factor contained high loadings of BC, Ca, V, Ni, Cu, Zn and Pb and it was attributed to vehicular emissions. Ni and V originate from oil combustion which is linked to diesel vehicles and shipping emissions. The second factor was biomass burning characterized by very high concentrations of BC, K and PAHs. Secondary aerosol was third with very high concentrations of S, BC. The fourth factor had high loading of crustal elements (Al, Si, Ca, Ti, Mn, Fe) while the fifth factor had high loadings of Mn, Cu, Zn, Ca and Fe.

Conclusions
Vehicle emissions and biomass burning were the two most important sources that drive DTT redox activity of ambient PM_x in Thessaloniki, Greece. Biomass burning was the largest contributor at the urban background site while vehicle emissions at the traffic site.

Acknowledgements
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MODELING OUTDOOR ULTRAFINE PARTICLES INFILTRATION INTO AN INDOOR ENVIRONMENT IN NATURAL AND MECHANICAL VENTILATION SYSTEMS

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Summary
This study aims to assess the ability of CONTAM multi zone model in reconstructing indoor concentrations of ultrafine particles (UFP) infiltrated from the outdoor environment. A modern office building was selected as test case. Building leakages, doors/windows opening as well as natural and mechanical air-conditioned ventilation regimes were taken into account for modelling the infiltration of outdoor UFP into indoor. Results shows overestimation of observed $PM_{0.7}$ concentrations in both ventilation regimes. Reconstruction of actual air exchange rate and uncertainties in the correct parameterization of leakages, of the actual frequency of opening of doors/windows, as well as an assessment of the actual contribution of particles depositions at different size fractions, are the key factors for the indoor UFP modelling.

Introduction
UFP exhibits different abilities in penetrating into indoor depending on the size fraction, building characteristics and its ventilation mechanisms. Infiltration factors based on contemporary I/O measurements can estimate the infiltration factors, but lack of information on key parameters such as air exchange rate, type and characteristic of air leakages of building indoor environment, do not allow understanding the related phenomena. Modelling is a possibility to simulate all the above aspects.

Methodology and Results
A field campaign to measure UFP number concentrations in both outdoor and indoor environments has been carried out in a modern office building located at INAIL research area, Italy. I/O UFP concentrations were measured both at size fractions between 10-700nm ($PM_{0.7}$) in open air and in a meeting room within the office building, by means of DISCMINI portable particle counters. In addition, outdoor UFP measurements at 32 size fractions from 5.6 to 560 nm were collected using a Fast Mobility Particle Sizer (FMPS). Complementary indoor and outdoor meteorology measurements were carried out. Both particles and meteorology data were collected at ten-minute time resolution from 10am to 6pm. Two different ventilation regimes were studied: natural, where building leakage, doors/windows opening and indoor thermal exchange are the main drivers; mechanical air-conditioned, where ventilation is mainly driven by a local HVAC system (four fans for a total of 1700 m^3/h of supply air and one fan with 1000 m^3/h of return air). The multi-zone air movement and contaminant transport program CONTAM (Walton and Dols, 2005) was used. It was setup to model indoor $PM_{0.7}$ and UFP at 32 size fractions starting from the corresponding outdoor measurements. The layout of the office building was model reconstructed. Literature derived leakage values for the various building components were used as model inputs. Mechanical ventilation was simulated using flow observations at fans apertures. Particle sized penetration and deposition were also simulated using literature decay rates. Figure 1 shows, as an example, a time series of observed and modelled indoor/outdoor $PM_{0.7}$ and UFP (from 5.6 to 560nm) concentrations under mechanical ventilation regime. Overestimation of observed indoor concentrations are detected. Similar results are obtained for the natural ventilation regime. Size resolved indoor particle distribution were estimated and compared with outdoor ones. Results were found to be strongly dependent on the correct parameterization of keys building characteristics such as air exchange rate, leakage parameters, aperture of doors/windows, thermal gradients.

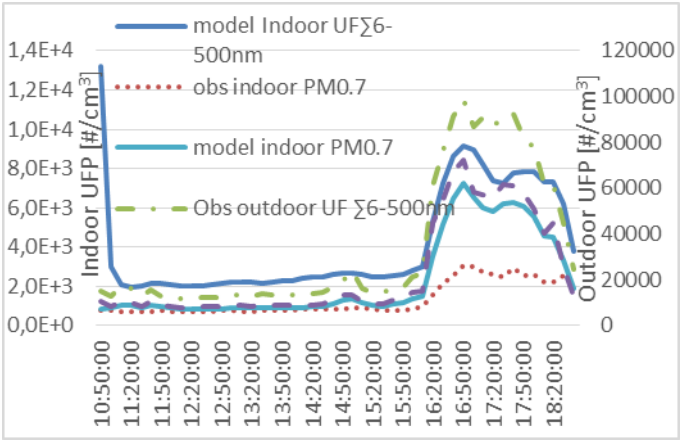

Fig.1 Time series of observed and modelled indoor and outdoor $PM_{0.7}$ and UFP (6-500nm) concentrations under mechanical ventilation.

Conclusions
CONTAM simulations and experimental studies were performed to estimate indoor UFP concentrations for an office test building. The results show overestimations of observed indoor UFP concentrations. The model correctly predict lower concentrations in mechanical ventilation regime than natural one. Results are strongly affected by the right parametrization of all keys process like penetration, filtration and deposition. Data about building leakages and actual air exchange rate are mandatory to increase accuracy of model results.

Acknowledgement
This work was supported by INAIL research funds, under the research plan of 2015-2018, Project VIEPI.

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INDOOR PM10 AND PM2.5 PARTICULATE MATTER POLLUTION ASSESSMENT ACCORDING AMBIENT AIR QUALITY AND USE OF AIR PURIFIERS

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Summary
The main aim of this study is to describe the direct impact of ambient air quality on concentrations of PM10 and PM2.5 inside the buildings. The new approach is based on modelling of the transfer function between indoor concentrations and condition of outside ambient air to estimate parameters describing reduction rate of aerosol concentration during ventilation process. Additionally model approach allows to describe the efficiency of indoor air cleaners irrespective of prevailing air pollution conditions.

Introduction
Particulate matter is one of the most important indoor and outdoor air quality pollutants (WHO, 2003). In Southern Poland, where the bad ambient air quality is a common and continuous problem, there is a dire need to describe the relation between ambient and indoor air quality. It is well known that ambient air pollutants are transported inside the buildings with the air flow forced by ventilation. The question that motivated the following research was how much of the particulate matter is deposited and reduced before it reaches building interior. Another question was how efficiently commercially available air purifiers can improve indoor air quality, depending on changing outdoor conditions.

Methodology and Results
In most of the previously published papers, indoor and outdoor suspended particulate matter concentration was analysed either from samples collection on filters, or from long term mean measurements performed using other methods (A. Eštoková, 2010; E. Diapouli, 2005). In this work, we present the analysis based on high frequency measurements of particulate matter (PM10, PM2.5), performed between December 2016 and April 2017 by optical dust monitors (TSI, Environmental DustTrak). Simultaneous measurements performed both inside and outside of the surveyed buildings (11 sites of different ventilation and construction characteristics) have allowed the modelling of the dynamics of indoor particulate matter concentration, which were mainly forced by changes of ambient aerosol concentrations.
Lumped parameter model was used as a base of calculations. RMSE cost function was calculated in order to compare in-situ observations against a range of predictions performed in appropriate ranges of model parameters (delay constant - τ and filtration coefficient - r_f), and thus to quantify the impact of external pollutants on indoor air.
The assessment of the efficiency of indoor air cleaners under varying air pollution conditions can be very ambiguous. The use of modelling allows to predict the level of indoor particulate matter concentrations without an air cleaner, and evaluate its impact.

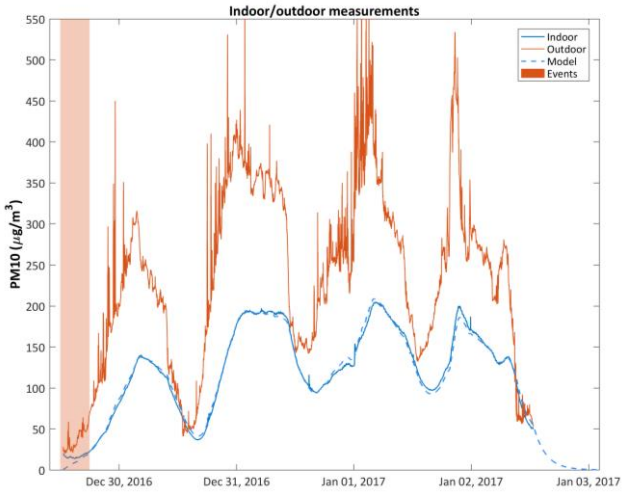

Fig.1 Exemplary concentrations of particulate matter PM10 observed inside and outside the building. Orange line – ambient air, blue line – internal, blue dashed line – model, orange solid - rejected data.

Conclusions
It was estimated, that between 30% and 70% of the external dust concentration is transferred through the ventilation to indoor volume, depending on the type of building, its construction, age and ventilation type.

Acknowledgement
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DISCUSSION ON THE REPRESENTATIVENESS OF CURRENT METHODOLOGIES TO ASSESS INDOOR AIR QUALITY

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Summary
In the Nordic countries, as well as in much of the industrialized world, mechanical heat-recovery ventilation is a common way to ventilate schools and office buildings. Demand Controlled Ventilation (DCV) is emerging as the dominating ventilation strategy in Norway, as well as in the rest of the Nordic countries, motivated by national requirements to reduce greenhouse gas (GHG) emissions as well as profitability, enabled by recent technological developments. In our study, we investigate the best strategy for DCV in terms of low energy consumption in combination with optimum indoor air quality. The main objective is to define robust strategies for demand-controlled ventilation of schools and office buildings to maximize air quality in occupied spaces and minimize energy use for ventilating empty spaces. In order to assess the objective, several methodologies have been applied and evaluated. The aim of this study is a discussion on the representativeness of the currently used methods of assessing indoor air quality and their reproducibility.

Methodologies
Different methodologies have been selected to address the target of energy-efficient ventilation for best indoor air quality. The methods consisted of air quality measurements at selected locations, in combination with perceived air quality assessments and performance tests.

- *Measurements* in schools and office buildings of indoor air quality parameters (Carbon dioxide, CO_2; Volatile Organic Compounds, VOCs; and Particulate Matter, PM) under certain ventilation conditions. In this study, the sampling location was a classroom in Fernanda Nissen elementary school (FNS, Oslo, Norway). FNS was built according to passive house standards in 2015, and established in autumn 2016. The building has L-shape and consists of three floors covering around 9 750-m^2 with capacity for 840 students. The measurement campaign was carried out in a classroom for one week. We continuously measured nitrogen oxides (NO_2 and NO), ozone (O_3), and particles number concentration between 10 nm and 32 µm indoors. The continuous measurements were complemented with sequential sampling of VOCs and aldehydes/ketones. We tested two ventilation strategies (VS1 and VS2) and the lack of ventilation. VS1 represents the strategy used by the Municipal Agency of Education in school buildings. VS1 is characterized by high CO_2 set point (1000 ppm) and air flow rates of around 432 m^3/h. The VS2 represents an alternative strategy with lower CO_2 set point (550 ppm) and 190 m^3/h air flow rate.
- *Perceived air quality.* Parallel to the measurement campaigns, a panel of young adult volunteers provided information about perceived air quality (PAQ). The information regarding indoor environmental perception was collected at 0 and 55 minutes after entry. All tests were self-administered with a tablet computer, and the panel was nonbiased regarding test variables (e.g. ventilation strategy).
- *Indoor Environmental quality.* Immediate perception of indoor related symptoms and environmental factors were reported by the volunteers at 0 and 50 minutes after entry using a continuous visual scale.
- *Performance Test:* A test of attention based on identifying characters in an nonsense text was performed 5 and 55 minutes after entry.

Results and Discussion
We will present the results obtained with the above mentioned methods, together with an assessment of the pollution levels for a given ventilation strategy. The preliminary results obtained in our study seem to be not conclusive, as for instance there is no clear correlation between ventilation rates and outdoor-generated pollutants (i.e. NO_2, NO and ozone). We will open up for a discussion on the representativeness of the used methods and their reproducibility based on the lessons learned from our study. The emphasis will be on challenges posed by swift changes in ventilation rate and occupancy and the time resolution needed to account for short-term sensory effects and moderate-term effects like skin, eye and respiratory symptoms.

Acknowledgement
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CONNECTION BETWEEN VENTILATION REGIMES, TKE AND PARTICULATE MATTER IN INDOOR AIR

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Summary
It is well known that dispersion of pollutants depends on characteristics of air turbulence. In fact, the pollutant dispersion is connected to the mechanical turbulence by means of eddy diffusion and Prandtl mixing theory (Degrazia et al., 2000). While the turbulence spectrum is relevant for air pollution dispersion in outdoor areas, in the indoor environment the turbulence energy is linked with the air change rate (AER) (Haghighat et al., 1991). The latter is connected with the infiltration factor which links indoor air quality with the outdoor one (Sajani, et al., 2015). Our study investigate the relationship between the ultrafine particles (UFPs) concentration and the turbulent kinetic energy (TKE) in an indoor work environment, in five different stationary ventilation regimes.

Introduction
INAIL being interested in health of workers, funded the project VIEPI ("Valutazione Integrata dell'Esposizione al Particolato Indoor") to study and evaluate indoor air quality and indoor/outdoor infiltration. In this project a field campaign has been conducted inside and outside a laboratory located at the INAIL research center of Monteporzio Catone, Italy.

Methodology and Results
A meeting room with dimensions 6mx8m has been selected as indoor environment. Five different indoor ventilation regimes were investigated: all windows and entrance door closed (RoomClsd); windows closed and the entrance door open (RoomOpn); entrance door closed and two windows opened at opposite position (2WinOpn); windows and door closed, local HVAC turned on with cooling off (HVAC-NotCool); windows and door closed, local HVAC turned on with cooling on (HVAC-Cool). Each test period represents a steady state condition and starts at 11.00am to end at 16.00pm. Measurements of indoor turbulence and mean wind components were carried out means of a triaxial sonic anemometers sampling at 32 Hz during a summer field campaign from 28/7/2107 to 5/8/2017. The total Particle Number Concentration (PNC) was measured by means of a Fast Mobility Particle Sizer (FMPS) working at 32 size particles fractions from 5,6 to 560 nm. In our analysis we have considered the TKE calculated using all Cartesian wind components. Table 1 shows the observed mean values of indoor U-component of wind, TKE and UFP in the different ventilation regimes. Figure 1 shows the average values of UFP against the observed TKE by the different ventilation regimes.

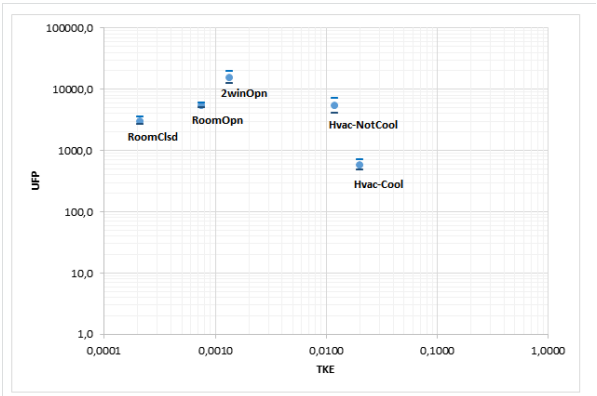

Figure 1 : relationship between PNC and TKE corresponding to different ventilation regimes

	U (m/s)	TKE (m2/s2)	PNC(#/cm3)
RoomClsd	0,09	0,0002	3059,9
RoomOpn	0,09	0,0007	5508,9
2winOpn	0,10	0,0013	15897,9
Hvac-NotCool	0,29	0,0118	5611,2
Hvac-Cool	0,29	0,0196	594,7

Table 1 : Average wind speed,TKE and PNC

In HVAC turned off conditions, the highest value of UFP is observed when windows are open (2winOpn), and TKE is $0.0013 m^2/s^2$. When room is totally closed (RoomClsd) the lowest value of TKE has been observed and the air may be exchanged with outdoor due to the windows leakages and building air system. In such situation the UFP is not so small even thought it is lower than the value obtained in the case of HVAC-NotCool. The minimum UFP average value is verified when HAVC and cooling are turned on (Hvac-Cool). In these conditions, the particulate matter may be well mixed and filtered by air conditioning as well as deposited on refrigerated coils (Siegel et al., 2003)reducing indoor PNC.

Conclusions
We have studied the indoor UFPs and its connection with indoor TKE in different ventilation regimes. We found that the observed average value of UFPs is mainly linked with the ventilation regimes and the TKE measurements should be take into consideration in order to explain the levels of indoor particulate matter. Our study is useful to confirm that ventilation systems impact on indoor pollutants concentration.

Acknowledgement
This work was supported by INAIL research funds for project VIEPI.

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THE IMPACT OF URBAN CANOPY METEOROLOGICAL FORCING ON AEROSOL CONCENTRATIONS

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Summary

The regional climate model RegCM4.4, including the surface model CLM4.5, was offline coupled to the chemistry transport model CAMx version 6.30 in order to investigate the impact of the urban canopy induced meteorological changes on the longterm aerosol formation over central Europe. A urban canopy impact on temperature, wind speed and turbulence was considered. These changes affected both primary and secondary aerosol concentrations and of course their gaseous precursors. It is found that the main contributor to the change of aerosol loading is the enhanced vertical turbulent mixing.

Introduction

Cities represent a certain meteorological forcing owing to their artificial surfaces they are covered. This leads to such effect like increased urban temperatures in contrast with rural ones decreased of humidity and decreases of wind speeds along with intensification of turbulence. These effects further influences species concentration as chemistry is strongly linked to meteorological conditions. To evaluate this influence, coupled climate-chemistry models are necessary as many feedbacks and competing effects take place simultaneously. Here, we apply a coupled system consisting of a regional climate model and a chemistry transport model to evaluate the urban canopy induced meteorological changes on the aerosol formation over central Europe.

Methodology and Results

The regional climate model RegCM4 (Giorgi et al., 2014) is used here along with the chemistry transport model CAMx (ENVIRON, 2016). A domain covering central Europe of 10 km x 10 km resolution is adapted and two climate simulations are performed to drive the chemistry, one with and one without urban surfaces considered. Chemistry is than driven with the resulting meteorology in an offline manner, while the urban impact on temperature, wind-speed and turbulence is gradually added to these meteorological fields. This allows us to examine the partial impact of each individual component.

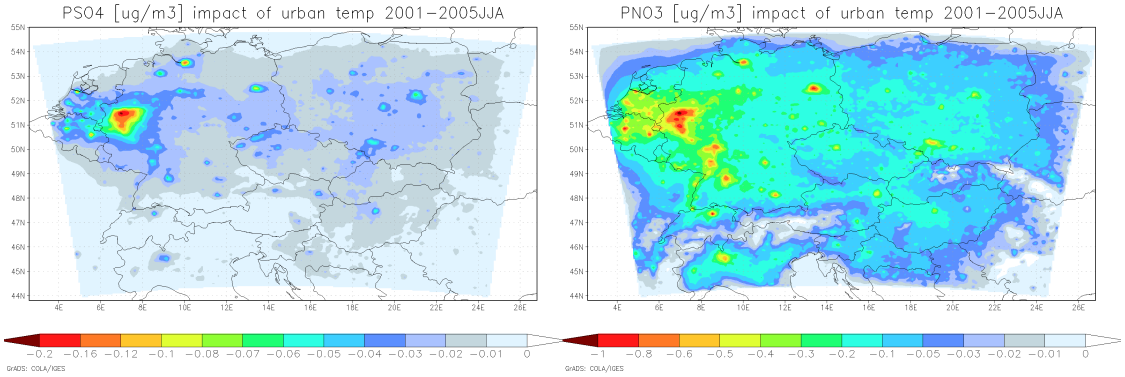

Fig.1 Impact of elevated urban temperatures to summer concentrations of sulphates (right) and nitrates (left).

The impact on temperature reaches 2-3 K over cities. Further a clear decrease of wind-speed is modelled due to urban canopy effects up to -1 m s^{-1} and an increase of eddy diffusion by 10-20 m^2s^{-1} with peaks around 60-70 m^2s^{-1}. The impact of increased urban temperatures on secondary inorganic aerosols is presented in Fig. 1. The impact on sulphates is small, reaching 0.2 μgm^{-3} over large urban agglomerations. A much higher decrease is modelled for nitrates, reaching -1 μgm^{-3}. Decreases were simulated for other secondary aerosols as well and the main reason for it was found to be decreased gaseous-to-aerosol partitioning. Significant impacts were simulated further due to urban wind decrease and increased turbulence (not shown here).

Conclusions

Urban meteorological effects are important to consider when modelling air quality over cities, as these effects lead to significant changes in pollutant concentrations.

Acknowledgement

This work has been funded by the Czech Science Foundation (GACR) project No. 13-19733P, by the project of OP PPR Proof of Concept, No. CZ.07.1.020.00.016_0230000108 and by the project UNCE 2040202013.

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INTERRELATIONS BETWEEN FORMALDEHYDE, CONVENTIONAL POLLUTANTS, NON-OXYGENATED VOCS, AND METEOROLOGY IN A RURAL FORESTED AREA IN NORTHERN IBERIAN PENINSULA

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Summary
An intensive measurement campaign was carried out in Summer 2016 (July 11th – September 30th) to improve the knowledge on the behavior of formaldehyde (HCHO), VOCs and ozone during the warm season in a rural area. The analysis has allowed us to define three situations, with similar meteorological and dispersive conditions, leading to different average profiles and maxima for HCHO and O_3.

Introduction
The monitoring site is located in a rural forested area more than 50 km away from cities or industries. Most VOC are locally produced but occasional transport of polluted air masses may occur. Biogenic VOCs emitted by natural sources play an important role in the ozone formation processes during the warm season. Their oxidation via HCHO (an important precursor of OH radicals), added to the arrival of anthropogenic VOCs and other conventional pollutants advected to the site under some meteorological conditions, make the characterization of O_3 episodes in such background areas a quite complex task.

Monitoring and methodology
The measurement database contains 75 days of data with 15-min averages of HCHO, conventional pollutants (CO, O_3, NOx, SO_2 and $PM_{2.5}$), and meteorological parameters (temperature, solar irradiance, relative humidity, precipitation, wind speed and direction), and hourly-averaged mixing ratios of non-oxygenated VOCs (63 C_2-C_{11} hydrocarbons, including isoprene and monoterpenes, and 3 chlorinated ones). HCHO was continuously monitored (AL4021 HCHO-analyzer, Aero Laser), with a detection limit of 0.1 ppbv. Non-oxygenated VOCs were hourly sampled in a thermal desorber unit (modified ATD400, Perkin Elmer), and analyzed using an automatic GC-FID (VOC Ozone Precursor Analyzer System, Perkin-Elmer) with detection limits below 0.10 ppbv for most compounds (Navazo et al., 2008). Data for conventional pollutants and meteorological parameters were supplied by the Air Quality Monitoring and Control Network of the Basque Government.

Results
Three main patterns have been identified (Figure 1):
(#1), 32% of the days, with overcast sky (average radiation, avg. Rad.: 135.0 W m^{-2}) and low temperatures (maxima < 20°C and avg. 12.9°C), leads to low mixing ratios of HCHO (< 2 ppbv), with low averages (0.61 ppbv) and O_3 < 112 µg·m^{-3}. The remaining conventional pollutants and non-oxygenated VOCs show a flat profile.
(#2), 55% of the days, with clearer and warmer days (avg. Rad.: 234.4 W m^{-2} and avg. T: 17.3°C) have intermediate values of all pollutants: HCHO < 6 ppbv (avg. 1.52 ppbv) and O_3 up to 150 µg·m^{-3}.
(#3), 13% of the days, are sky clear (avg. Rad.: 263.3 W m^{-2}) and hot, with máxima over 30°C (avg. 22.7°C). All pollutants rise to their highest values, with HCHO < 10 ppbv (avg. 2.75 ppbv) and ozone up to 202 µg·m^{-3}.

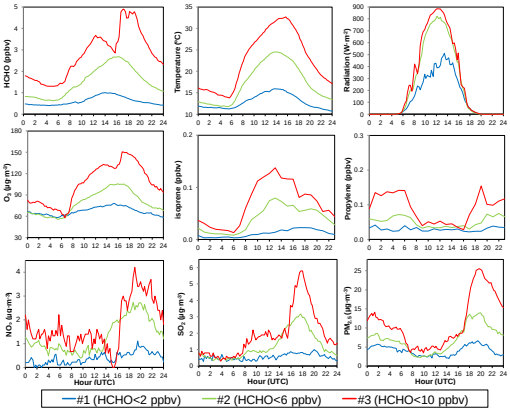

Figure 1. Average day for the three situations: 15-min averaged mixing ratios of HCHO and conventional pollutants (O_3, NO_2, SO_2, $PM_{2.5}$), temperature, radiation and examples of hourly-averaged mixing ratios (isoprene and propylene

Conclusions
A high-time resolution database of HCHO, pollutant concentrations, and meteorological parameters, obtained over a period of 75 days in Summer in a rural forested area, has been classified into three homogeneous groups ("patterns"), based on temperature and solar irradiance. Each group has a characteristic daily profile useful for the forecast of HCHO, O3 and some non-oxygenated VOC

Acknowledgement
Authors wish to thank for their financial aid to the Spanish Ministry of Science and Innovation (MICINN) for the PRORAT project (Ref.: CTM2013-45223-P), and to University of the Basque Country UPV/EHU (Ref.: GIU 13/25, GIU16/03, UFI 11/47 and EHU 13/47). We also acknowledge the Basque Government for providing data, and the Valderejo Natural Park staff for their help and support.

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THREE-DIMENSIONAL WIND ANALYSIS FOR AIR QUALITY MODELLING APPLICATIONS AT THE CIVITAVECCHIA PORT SITE (CENTRAL ITALY)

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Summary

We exploit data collected during an intensive field campaign (AirSea Lab, April 2016) in the port site of Civitavecchia (Central Italy) to analyse wind dynamics in the planetary boundary layer (PBL). The measurements analysis is coupled to results from the mesoscale meteorological model WRF, and linked to the impact on atmospheric composition using the chemistry-transport model CHIMERE. Usually, even at high horizontal resolution (~1 km), the modelling system has difficulties in accurately simulate the diurnal cycle of winds in breeze-dominated conditions, mostly because of excessive vertical turbulent transport of momentum. The collected observations of the wind structure, detailed in space and time, together with comprehensive measurements of the atmospheric composition (gas and size-resolved aerosol), offer an opportunity to validate and understand the behaviour of the available PBL turbulent mixing parameterizations.

Fig.1 The Civitavecchia port m instruments deployed during the AirS

Introduction

Deterministic air quality applications by means of Eulerian chemistry-transport models need accurate simulation of basic meteorological fields, such as temperature, wind, and precipitation. In the PBL, even at horizontal resolutions as high as 1 km, there is a need for parameterization of turbulent motions, but there is no unique and universal solution to the problem for all places and circumstances. Often, the main limitation to a careful validation and "tuning" of modelling systems is the lack of vertically resolved observations.

Methodology and Results

During the AirSeaLab campaign in Civitavecchia, a large set of instruments were deployed to investigate atmospheric composition and meteorological parameters. Among these, sodar, ultra-sonic anemometers and a micrometeorological station provided accurate characterization of the 3-D wind and thermal structure, PBL height and turbulent fluxes of heat, radiation, and momentum. The observation of the PBL evolution, and of the vertical structure of the atmosphere was complemented by a lidar-ceilometer profiler. Information on aerosol composition, size distribution, and optical properties was collected by a number of state-of-art instruments operated at ground level in the port area. As a first step towards a full meteo-chemical comparison between modelled and measured quantities, in this work we use the WRF-CHIMERE modelling system to simulate, at 1 km horizontal resolution, the meteorological and chemical state of the atmosphere in the area. In particular, we test several parameterization for the PBL turbulent mixing and for land-atmosphere exchange. We analyse and interpret advantages and disadvantages of the different model configurations in terms of skills in reproducing air quality related pollutant concentrations near the ground.

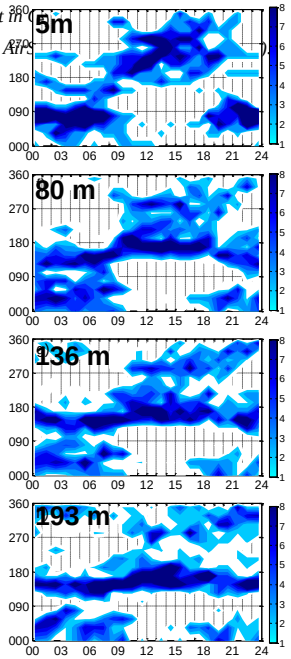

Fig.2 Wind speed direction (y-axis) as a function of the hour of the day (x-axis) as observed at different altitudes during the AirSeaLab campaign showing a nearly periodic swings driven by the land-sea breeze.

Conclusions

Preliminary results suggest that WRF Bougeault-Lacarrère (BouLac) PBL scheme reproduces reasonably well the observed daily cycle, but tends to predict higher wind speeds especially near the surface. The introduction of the BEP urban canopy model helps reducing the wind bias, introducing an additional friction term.

Acknowledgements

Computational resources were provided by CINECA in the frame of Iscra-C ALTARIS7 project. Observations were carried out in the framework of the CNR-AirSeaLab Project and of the LACOST Program ('Osservatorio Ambientale di Civitavecchia' and ENEL). We thank the Civitavecchia port Authority for hosting the 2016 monitoring campaign.

ON THE DIRECT MEASURE OF DRAG FORCE OVER SIMPLIFIED GROUPS OF OBSTACLES

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Summary
This paper presents an analysis of drag force measured in the wind tunnel using a balance. The aim of the research is to study the variation of the drag force within a large range of porosity, both regular and staggered. Results are discussed in light of better parametrizations of urban effects within dispersion model.

Introduction
In the study of flow and pollutant dispersion in the urban environment, it is crucial to represent the mechanisms at the soil-atmosphere interface where the forcing induced by the ground on atmospheric air occurs. For all the problems related to human activity, we are almost exclusively interested in the impact on ground of phenomena or objects located in the vicinity of the ground. The ultimate goal of the present work is to measure the drag force on simplified regular and staggered arrays of obstacles of different porosity using a direct method (balance) in a wind tunnel.

Methodology and Results
There are various methods to assess the drag force, both indirect and direct. A direct method consists of using a balance that is typically more accurate than the pressure-derived method (Buccolieri et al., 2017). Drag force measurements were performed in the Laboratoire de Mecanique des Fluides et d'Acoustique de l'Ecole Centrale de Lyon using balance (Figure 1). Several configurations of arrays of obstacles of different height, both regular and staggered, were studied. Specifically porosities (i.e. the ratio between the volume occupied by the obstacles and the total volume of the array) of 98%, 94%, 89%, 84%, 75% and 56% were used, which correspond to spacing between cubes of 3H, 2H, 1.5H, 1H and 0.5H, with H the height of the obstacle. Results show that the relationship between force and velocity satisfies a quadratic law of the type $F = \alpha V^2$ and the force increases with increasing obstacle height and for staggered arrays (Figure 2) due to larger frontal areas exposed to approaching flow. The influence of porosity, as well as shear stress and the corresponding friction velocity are also assessed. The drag force due to the cubes is finally parametrized using the canopy-drag length scale and results are discussed.

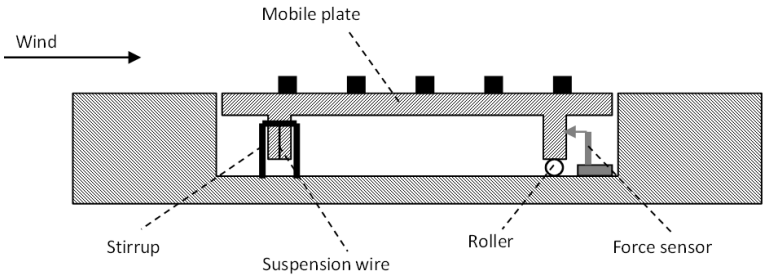

Fig. 1 Diagram of the balance used in the wind tunnel

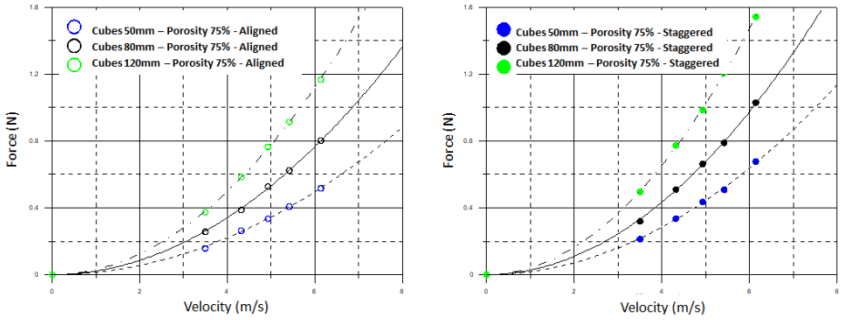

Fig. 2 Example profiles of the drag force for aligned and staggered arrays of 75% porosity and different obstacle height

Conclusions
An experimental investigation of the drag force acting on regular and staggered arrays of obstacle characterized by different porosities is presented. The total drag force acting on the array was measured in wind tunnel using a balance (direct method). 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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ESTIMATES OF DIRECT RADIATIVE EFFECTS OF BACKGROUND AND SMOKE AEROSOLS IN IR SPECTRAL RANGE FOR SIBERIAN SUMMER CONDITIONS: RESULTS OF NUMERICAL SIMULATION

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Summary

One of the quantitative characteristics of aerosol impact on the Earth's radiation budget is the aerosol direct radiative effect (DRE), calculated as the difference between radiative influxes at different atmospheric levels in the presence of aerosol and in its absence. In this work, we presented estimates of direct radiative effects of background and smoke aerosols, obtained using original statistical algorithms and different OPAC models for typical background conditions and conditions of 2012 smoke haze over the territory of Siberian region.

Introduction

Earlier, we obtained estimates of aerosol DRE in the solar spectral range, using vertical profiles of aerosol characteristics according to data of aircraft sensing over the territory of the Western Siberia (background conditions) and in the northeastern regions of Siberia in August 2012 (smoke haze). For a more complete understanding of specific features of how the radiation budget is formed under the climatic conditions of Siberia, in this work we present the results of DRE simulation for the same atmospheric conditions in the longwave spectral region (Φ_{LW}), and also compare them with DRE in the solar spectral range (Φ_{SW}) and with carbon dioxide forcing (F_{CO2}).

Methodology and Results

The broadband fluxes of upward and downward radiation in the solar (0.2-4 μm) and thermal (4-50 μm) spectral ranges were simulated using statistical algorithms, implemented in the vertically inhomogeneous model of the atmosphere. The algorithms take into account the absorption and scattering of radiation by air molecules, aerosol and cloud particles, as well as reflection from the underlying surface. The molecular absorption is accounted for using k-distribution method (solar range) and «randomization in frequency» (IR range). The transmission functions and molecular absorption coefficients were calculated using HITRAN2012 database, MT_CKD2.5 continuum model, and AFGL «midlatitude summer» meteorological model. The radiation calculations were performed for different values of aerosol optical depth (AOD): $\tau_{0.55} = 0.12$ (background), $2 \le \tau_{0.55} \le 5$ (smoke), and two carbon dioxide concentrations: 280 and 400 ppm (Panchenko et. al., 2016).

In the absence of the necessary information on aerosol optical characteristics, the fluxes in IR spectral region were simulated using OPAC aerosol models (Hess et al., 1998). Their use is justified by the satisfactory agreement between spectral variations in the ratio of the aerosol optical depth $\tau_\lambda / \tau_{0.55}$ and in the single scattering albedo in the wavelength range of 0.44-0.87 μm: with the «continental averaged» model (background) and with the «continental polluted» model (smoke).

From analysis of results of numerical simulation we can draw a few conclusions.

1. The main aerosol effect in the thermal spectral range is manifested in the transparency window 8-13 μm: e.g., when $\tau_{0.55} = 0.12$ (background) and $\tau_{0.55} = 2$ (smoke), and when the height's layer with maximal concentration of aerosol particles is H=2 km, the contribution of Φ_{LW}(8-13 μm) to Φ_{LW} exceeds 95% at the bottom of the atmosphere (BOA), increasing to the range from 78% to 90% at the top of the atmosphere (TOA).
2. When AOD grows and the height H is fixed, the Φ_{LW} value increases: at H=2 km, as $\tau_{0.55}$ changes from 2 to 5, Φ_{LW}(z=0) rises from 5.3 to 12.2 W/m^2, and Φ_{LW}(z=100 km) rises from 0.7 to 1.5 W/m^2.
3. Daily average aerosol effect Φ_{LW}^{day} under the background conditions is small, and the ratio $R = 100\% \times \Phi_{LW} / \Phi_{SW}^{day}$ does not exceed 3% in absolute value. The smoke aerosol radiative effect and the ratio R are maximal under the conditions of the largest turbidity $\tau_{0.55}^{a} = 5$: at z=0 we have $R \approx 9\%$ (H=2 km), and at z=100 km we have $R \approx 16\%$ (H=5 km).
4. Under the background conditions, the carbon dioxide radiative forcing exceeds the aerosol DRE at TOA and BOA. Under the conditions of severe smoke pollution, Φ_{CO2} at BOA is approximately a factor of 5-10 smaller than $\Phi_{LW}(z=0)$, while $\Phi_{LW}(z = 100 \text{ km})$ at TOA may be either smaller or larger than F_{CO2}, depending on the height H and AOD.

Conclusions

The presented results should be considered as a first-approximation DRE estimates in the thermal spectral range. More grounded estimates can be made after ascertainment of aerosol optical models, as well as after the calculations will use the profiles of meteorological parameters, characteristic for a given region, taking into account their variations during the day.

Acknowledgement

This work was supported in part by RFBR (through the grant no. 16-01-00617-a)

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SHORTWAVE RADIATION AND TEMPERATURE EFFECTS OF BACKGROUND AND SMOKE AEROSOL IN THE ATMOSHERE OF SIBERIA ON THE BASIS OF EMPIRICAL DATA

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Summary

The paper presents quantitative estimates of the distribution of the absorbed solar radiation and temperature effects in the background atmosphere and under conditions of extreme smoke haze in Siberia obtained using empirical data and numerical modeling. Vertical profiles of the aerosol characteristics are created on the basis of the empirical model constructed from the results of aircraft sensing of the angular scattering coefficient and the concentration of absorbing substance at different heights. It is shown that under smoke haze conditions the radiative influence of aerosol particles with a high «black carbon» content on the daily influx of solar radiation in the central part of the smoke layer exceeds 50%. The change in air temperature due to the absorption of solar radiation at daytime is approximately 2.5–5.5°K when the smoke aerosol optical depth (AOD) varies in the range $2 \le \tau_{0.55} \le 4$.

Introduction

During summer 2012 in the Siberian region, the conditions of small-gradient baric filed had led to formation of a stable anticyclone, the consequences of which had been forest and peat fires on the territory of Omsk, Tomsk, Novosibirsk regions, a part of Krasnoyarsk Krai, Khanty-Mansi Autonomous Okrug, and Yakutia. The purpose of the paper is to estimate the radiative and thermal effects of aerosol in the extremely smoke-laden atmosphere and compare them to the corresponding characteristics under the background conditions of the Western Siberia on the basis of empirical model of the vertical profiles of aerosol optical characteristics (Panchenko et al., 2016) and methods of numerical simulation of solar radiative transfer.

Methodology and Results

The input parameters of the empirical model are the data on the angular scattering coefficient, mass concentration of absorbing substance («black carbon»), parameter of condensation activity, and aerosol particle size distribution function. Aircraft measurements in 1999-2011 were generalized to retrieve the vertical profiles of aerosol optical characteristics in the interval of 0.37-0.87 μm under background conditions. The optical characteristics of smoke aerosol were determined according to data of ground-based and aircraft measurements, performed onboard OPTIK Tu-134 aircraft laboratory (operated by Institute of Atmospheric Optics, SB RAS) in northeastern regions of Siberia (55–62°N, 83–130°E) along the route Mirny – Yakutsk – Bratsk – Novosibirsk in August 2012. The aerosol optical depths at λ=0.55 μm in the background atmosphere and extreme smoke were 0.12 and 2.1; the column-averaged single scattering albedos (SSAs) were 0.94 and 0.88. Under the smoke conditions, the SSA value was lower than the average single scattering albedos, retrieved according to data of AERONET observations in boreal forest area (0.95-0.96).

An original algorithm of the Monte Carlo method was used to simulate the fluxes of upward and downward solar radiation (0.2-5.0 μm). The radiation calculations were performed for the astronomic conditions of Tomsk, corresponding to July 15.

The numerical simulation of diurnal values of radiative characteristics gave the following results. The vertical profiles of aerosol extinction and absorption coefficients and absorbed radiation correlate among themselves and reach the largest values in the middle part of the smoke layer. A detailed analysis shows that absorption maximum is positioned higher (3-4 km) than the positions of maximal values of extinction and absorption coefficients (2-3 km), primarily because above the level z=3 km there is a dense smoke, which decreases the flux of total solar radiation at the top boundary of underlying atmospheric layers.

The largest change in temperature is observed in the middle part of the smoke layer, where the heating rates are 2.5°K/day at $\tau_{0.55} = 2$, increasing to 5.5°K/day at $\tau_{0.55} = 4$ (see Fig.1). The surface-adjacent atmospheric layers are heated weaker, especially at morning and evening hours.

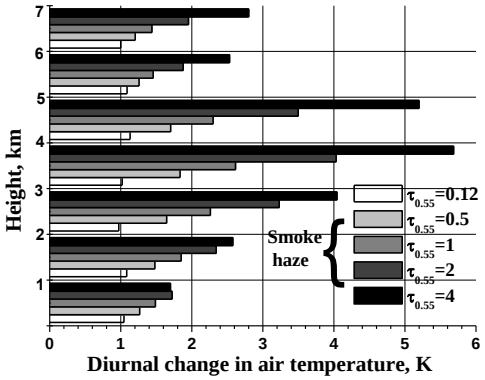

Fig.1 Change in air temperature during daytime, K

Conclusions

Under the background conditions, amount of energy absorbed in the 1-km atmospheric layer is determined by the stratification of water vapor concentration; the aerosol radiation effect does not exceed 10% even in the lower 1-km layer. In the presence of optically dense strongly absorbing smoke, a dominating role in determining the absorption of solar radiation is played by aerosol particles with high «black carbon» content: the aerosol radiation effect is tens of a percent, and, depending on AOD, it reaches 50-80% in the layer of 3-4 km.

Acknowledgement

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ASSESSMENT OF PLANETARY BOUNDARY LAYER SCHEMES IN MODELING THE DISPERSION AND SEDIMENTATION OF VOLCANIC ASH IN ECUADOR

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Summary
We modeled the dispersion of volcanic ash for 4 eruptions which took place in Ecuador during the last 6 years, using 7 planetary boundary layer schemes for the meteorological driver. The linear correlation coefficient (R^2) of the comparison between records and computed values of ash fallout was equal or higher than 0.5 for all the eruptions, when using the MYJ scheme. In other assessments, the MYJ was among the PBL schemes which provided good performance when modeling the dispersion of pollutants in Ecuador. These results suggest the MYJ scheme could be a good choice for modeling purposes in this region.

Introduction
Volcanic ash can cause critical air pollution events and other significant impacts. Atmospheric transport models (ATMs) are pivotal for modeling volcanic ash dispersion and deposition. One of the components of any ATM is the meteorological driving model, which describes the state and evolution of the atmosphere in which the volcanic ash is introduced. One important meteorological parameter that influences in the dispersion of pollutants is the Planetary Boundary Layer (PBL). Turbulence is the dominant mechanism that transmits surface forcing throughout the PBL. Turbulence operates on scales that cannot be explicitly represented on grid scales and time steps used in most mesoscale models. Hence, its effects are expressed in modeling trough PBL parameterization schemes. PBL schemes need to be assessed, especially in places where turbulent processes are particularly complex, such as the Andean region of Ecuador.

Method and Results
We used the global GFS data to generate the initial and boundary conditions over Ecuador, for simulating the meteorology with the Weather Research & Forecasting (WRF3.7.1) model. After, the meteorological outputs were ingested into the Fall3dV7.1.4 model to simulate ash dispersion and sedimentation from 4 eruptions at Tungurahua (15-Dec-2012, 14-Jul-2013 and 1-Feb-2014) and Cotopaxi volcanoes (14-Aug-2015, Fig. 1). Simulations were done considering 7 PBL schemes for WRF: 1 Yonsei University (YSU), 2 Mellor-Yamada-Janjic (MYJ), 3 Hong and Pang (GFS), 4 Mellor-Yamada Nakanishi and Niino Level 2.5 (MYNN2.5), 6 Boulac PBL (BL) and 7 Shin-Hong (SH). Modeled ash fallout quantities were compared with records from ashmeters located around these volcanoes (Fig. 2). The linear correlation coefficient (R^2) was equal or higher than 0.5 for all the eruptions, when using the MYJ scheme (local and 1.5 order of closure scheme, Fig. 3).

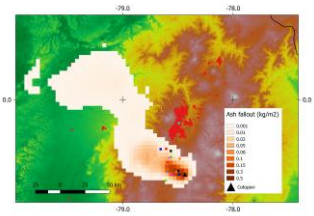

Fig.1 Cotopaxi (14-Aug-2015): modeled ash fallout using the MYJ PBL scheme.

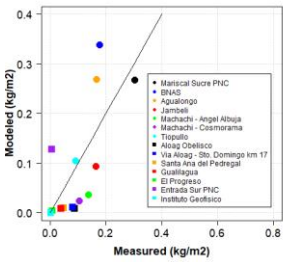

Fig.2 Cotopaxi (14-Aug-2015): comparison with measurements at 14 stations (R^2=0.5)

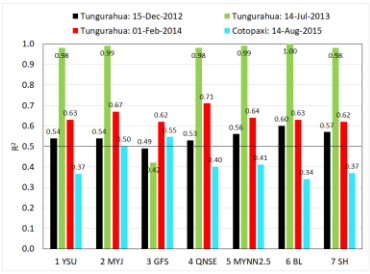

Fig. 3 Modeling performance measured by the linear correlation coefficient (R^2)

Conclusions
The MYJ was the PBL scheme that provided better performance when modeling the dispersion of pollutants in the Andean region of Ecuador (e.g. Parra, 2017). These results indicate that the MYJ PBL scheme could be a good choice for volcanic ash dispersion and air quality modeling purposes in this region.

Acknowledgement
This research is part of the project “Calidad del Aire en el Ecuador” funded with a USFQ Poli Grant 2017. Simulations were done at the High Performance Computing system at the USFQ.

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A SENSITIVITY ANALYSIS FOR DETERMINING OPTIMUM WRF AND CALPUFF CONFIGURATION FOR OPERATIONAL AIR QUALITY FORECAST. APPLICATION TO A CASE STUDY IN THE PORT OF HUELVA (SOUTHERN SPAIN)

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Summary

Meteorological inputs are of great importance when implementing an air quality modelling system. The aim of this study is to define a standardized methodology to determine the best meteorological configuration to reduce the uncertainty of the model predictions. To do this, a detailed sensitivity analysis to different parameterizations and schemes of the Weather Research and Forecast (WRF-ARW) model has been realized. A sensitive analysis was done in order to evaluate some simulated meteorological variables (temperature, relative humidity, wind velocity and wind direction) and achieve the optimum WRF configuration. Since the better options for WRF simulations were chosen, a new sensitivity analysis was done to determine the optimum CALPUFF-CALMET configuration for air quality forecasting.

Introduction

The goal of this study is to achieve the optimum configuration of meteorological model WRF and dispersion model CALPUFF in order to obtain better results in air quality forecasts. A region in Southern Spain, Huelva, was selected for the development of this work. An operating prediction system will be used as early warning system and will allow improving the air pollution and risk management associated to the Port of Huelva.

Methodology and Results

The Port of Huelva is one of the most important industrial sources in the South of Spain. Moreover, this area coexists with the city of Huelva, greenhouse zones and some nature reserves like Doana Park. Meteorology can greatly affect the atmospheric pollution generated by the Port, because the activities here carried out (loading and unloading operations and material handling) are mainly an important source of particles; meteorological parameters, such as wind speed and wind direction, are highly significant in dispersion of these particles. Here is defined the methodology to obtain the optimum WRF and CALPUFF configuration, and then it was applied over the Port of Huelva and surroundings. Statistical evaluation was done for meteorological and air quality forecast. Options that provided better results and, therefore, were selected in simulations, are listed in below.

Scheme or parametrization	WRF Selected option	CALMET Selected option
Initialization	GFS0.25	-
Microphysics	SBU-Lin	-
Longwave radiaion	RRTMG -	
Shortwave radiation	Dudhia	-
Cumulus	Kain-Fritsch	-
Surface Layer	MM5 similarity	-
Planetary Boundary Layer	YSU (d01,d02,d03) / LES (d04)	-
Vertical levels number	36	20
Diffusion 6th order option	Knievel	-
Diffusion 6th order factor	0.36 (d03)	-
Damping	Rayleigh	-
Topography	GTOPO30 (d01,d02) / ASTER (d03,d04)	ASTER
Land Uses	GLC (d01,d02) / CLC2006 (d03,d04)	CLC2006
Nudging	Grid nudging (d01) / Obs. nudging (d02,d03)	-
Kinematics effects	-	Yes (IKINE)
Vertical velocity adjustement	-	Yes (IOBR-O'Brien)
Diagnostic wind module	-	Yes (IWFCOD)

Conclusions

An air quality modelling system has been developed in the Port of Huelva area. Some experiments modifying physical and dynamical configurations, vertical levels, topography or land use databases, were done in order to determine the best configuration for WRF and CALPUFF. A sensitivity analysis for each configuration was carried out for this purpose. This meteorological and air quality prediction system could be developed in any region of interest.

HYBRID ARTIFICIAL NEURAL NETWORK COUPLED WITH KALMAN FILTERS FOR AIR QUALITY FORECASTING IN GUADALAJARA, MEXICO

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Summary
This study aims to develop a novel hybrid scheme of Artificial Neural Networks (ARN) coupled to a non-linear Kalman filter for air quality forecasting in Guadalajara Metropolitan Area, in Mexico. ARN's are widely used for air quality forecasting, however these schemes need large amounts of data regarding the pollutants concentration levels and meteorological data in order to manage reliable forecasting. To address this issue, we present a scheme consisting of Neural Network models assisted by nonlinear Kalman filter that manage to considerably improve the forecasting performance, adding robustness in case of lack of data, and reducing the need of retraining over time.

Introduction
As in many megacities, air pollution is a growing concern, and poor air quality episodes have become more frequent. In Guadalajara city, in Mexico, government agencies have the Atmospheric Monitoring System for the Guadalajara Metropolitan Area, SIMAJ (http://siga.jalisco.gob.mx/), that presents real time air pollution measurements, but fails to provide specific forecasting of air quality. ARN models can be used to predict air quality behavior (Russo, *et. al.* 2013), but their performance is severely hindered by the quality of the available information. Coupling an ARN prediction model with a non-linear Kalman filter scheme, introduces robustness to the forecasting process in case of the lack of data. In addition, this hybrid-forecasting scheme does not require complex ARN architectures and is able to predict air quality levels for a 48-hour horizon, within reasonable tolerances.

Methodology and Results
The hybrid ARN + Kalman forecasting system was constructed using air quality and meteorological data from years 2013 and 2014, obtained from SIMAJ. We treated these data sets, first by removing the spurious data, then by filling in the empty spaces with sliding window averages, and finally normalizing the data taking into account the limit values defined by the respective standards. We determined the variables with statistical significance using principal component analysis. We constructed the respective training sets for a Feed-forward ARN with two hidden layers of neurons; the pollutant concentration values for a 48-hour horizon were defined as the target values. The neural networks were trained using the error back-propagation scheme; we tried from 10 to 15 neurons on both hidden layers, and then selected the one with the best correlation coefficient. We used 50% of the data for the training process, and 50% for validation and testing.
We used a novel scheme on coupled ARN with non-lineal Kalman filter that corrects the quantitative errors of the ARN, as described in Ramírez-Álvarez *et. al*., 2013. The prediction error covariance was defined as the measurement error covariance, to reduce the prediction error. The hybrid ARN + Kalman scheme achieved better correlation coefficient values, in comparison to the simple ARN, as shown on table 1. An example of the hybrid scheme performance is shown in figure 1.

Horizon (hours)	Hidden layer neurons	RNA correlation R	RNA + Kalman correlation R
+1	10	0.9226	0.9990
+2	11	0.8701	0.9963
+3	11	0.8356	0.9931
+4	13	0.8218	0.9915
+8	13	0.7990	0.9980
+12	11	0.7897	0.9265
+24	13	0.6944	0.9830

Table 1. Forecasting correlation coefficients for CO forecasts in "Las Águilas" station location.

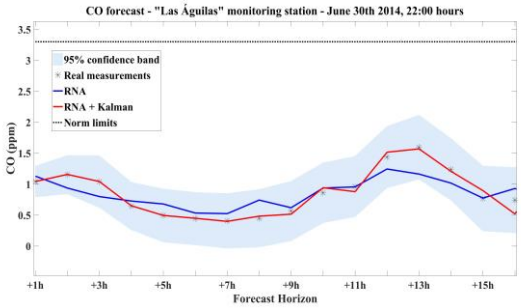

Fig. 1 CO forecast with hybrid model.

Conclusions
The hybrid ARN model coupled to a Kalman filter, manages to correct the neural networks predictions, significantly improving its performance. Kalman parameter tuning is a key issue; the measurement error covariance is set to equal the ARN prediction error covariance. Kalman provides the model robustness, and allows its use online without the need for periodic updates. Nonetheless, the correct ARN architecture design plays a major role in the forecasting process.

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SURFACE OZONE EXCEEDANCES IN ITALY:
STATISTICAL ANALYIS AND MODELLING IN THE PERIOD 2002-2016

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Summary
This study aims at investigating the impact of heat waves on the ozone season and at studying the role of meteorological and other variables as ozone drivers, by applying a statistical regression analysis of ozone seasons from 2002 to 2016. Identification and characterization of consecutive days exceeding the threshold imposed for ozone by current legislation and of high-temperature and high-humidity events demonstrate a negative impact of the heat wave on the average duration and on the maximum concentration of ozone events. High ozone episodes are not straightforwardly linked to high temperature episodes. Furthermore, the application of the statistical method shows the weight of other variables, such as Euro vehicle emissions regulations, on the probability of ozone events.

Introduction
The link between air quality and meteorological variables is recognized and the effect of the temperature on the ozone production is well established in literature (Jacob and Winner, 2009). In this work, we investigate how the heat wave occurred in the summer 2015 affected the ozone season (May-September) of the same year; furthermore, we focus on the temperature weight as driver of high ozone episodes compared to other variables.

Methodology and Results
We performed a quantitative examination of the 2015 ozone season in comparison to years 2002-2016, based on a dataset of surface ozone concentrations from 24 selected air quality monitoring stations across Italy. A dataset for observed weather parameters for the same period has been also assembled. We compared the ozone seasons in this time range in terms of the number of exceedances of limit values set by the European directive for ozone, identifying and characterizing consecutive occurrences of high concentration ozone events; consecutive days exceeding thresholds for temperature and humidity have been identified in order to study the link between ozone and meteorological variables. Results reveal a 2015 ozone season among the most critical of recent years in Italy, with an average duration and a maximum concentration of high ozone episodes close to 2006 and 2003, years characterized by significant heat waves (see Fig.1 and Fig.2, Falasca et al. 2016). Moreover, we investigated the influence of a set of independent variables on the probability of high ozone events through a multivariate logistic regression model confirming the key role of meteorological variables for the probability of high ozone episodes and highlighting the role of the introduction of Euro regulations, the altitude, and the number of inhabitants as predictors.

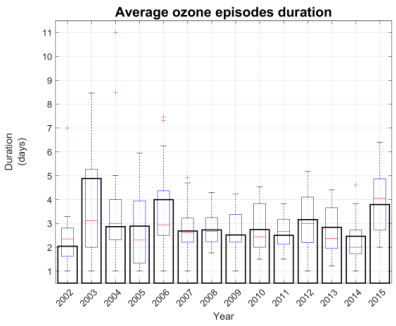

Fig.1 Analysis of events for 8h average ozone: duration

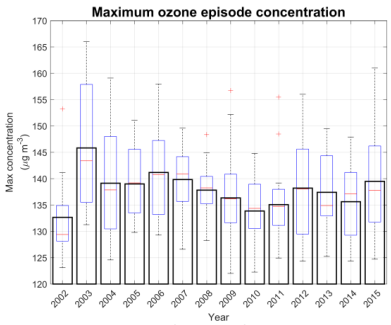

Fig.2 Analysis of events for 8h average ozone: maximum concentration

Conclusions
This study confirms the important and well documented role of weather conditions, particularly temperature, on ozone production. It also demonstrates the role of different types of variables (total inhabitants in a buffer area, vehicle emission standard, altitude, month, year) as ozone drivers, thus providing essential elements to develop mitigation strategies of heat waves, whose frequency is increasing as a result of climate change.

Acknowledgement
This work was partly founded by the ECOREGIONS project, Identificazione di regioni eco-climatiche in Italia per un sistema di allerta precoce per le malattie trasmesse da vettori, Istituto Zooprofilattico Sperimentale "G. Caporale" Teramo, codice IZS AM 05/14 RC. We acknowledge Regional Environmental Protection Agencies (ARPA) for proving the concentration data of Ozone.

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SENSITIVITY STUDY OF THE AIR QUALITY MODELLING TOOL WRF-CHIMERE TO HORIZONTAL RESOLUTION AND URBAN CANOPY MODELS OVER ITALY

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Summary
Sensitivity tests were designed and run with the modelling tool WRF-CHIMERE at high resolution in order to investigate the effect of horizontal model grid size, emissions inventory resolution and different urban canopy models over two urban areas in Italy, characterized by different number of inhabitants, extension and geographical location. The work helped to point out that there is no unique response of the modeling tool to the tested configurations and that the effectiveness of the various improvements changes with the city and with the variable.

Introduction
Air quality is considered a topic of great importance especially in urban areas whose population is continually growing; the European Directive (2008/50/EC) encourages the use of modelling techniques to support observations in the assessment and forecasting of air quality and therefore a deep knowledge of performances of the modelling tool over urban areas is needed. In this work, we studied the effect of spatial resolution of horizontal grid and emissions inventory, among the most critical aspects of atmospheric chemical modelling (e.g. Kuik et al., 2016), through numerical experiments over two Italian urban areas; we also performed numerical experiments aimed at investigating the effect of using different urban canopy models.

Methodology and Results
We performed numerical experiments with the modelling chain based on the WRF meteorological model and the CHIMERE chemistry- transport model over the urban areas of Milan and L'Aquila (Northern and Central Italy respectively) for January and July 2010. Four nested domains covering Europe, Italy, a region of Italy and an urban area were simulated with horizontal resolution rising to 1.333 km for WRF and 0.015° for CHIMERE. Tests include a reference case using an urban bulk parameterization and the national inventory CTN-ACE (5 km), four simulations with two urban canopy models available on WRF with default and tuned values of the urban parameters, a simulation with the CTN-ACE inventory downscaled through the spatial redistribution of anthropogenic emissions based on the GlobCover landuse dateset. Results show that the increase in spatial resolution yields benefit for PM10 simulation at both L'Aquila and Milan (see Fig.1), but not for ozone. The benefit deriving from introducing urban canopy models other than the bulk parameterization is negligible compared to the bias with observations, also in the version with adapted values of urban parameters (see Fig.2). The use of the downscaled inventory improves simulated values, even if the benefit is small compared to the bias with observations for both PM10 and ozone at both locations.

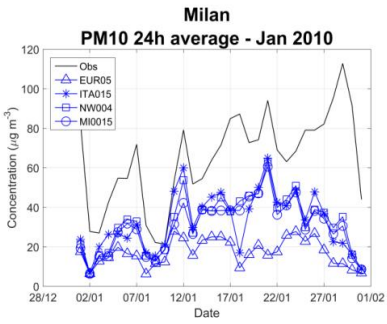

Fig.1 Average monthly time series of PM10 at varying model horizontal resolution

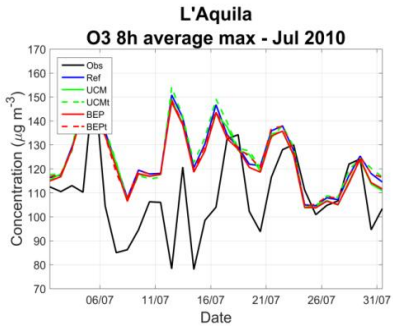

Fig.2 Average daily maximum of 8-hours O3 using different urban canopy models

Conclusions
This study shows how the performances of the WRF-CHIMERE modelling tool vary with the introduction of some improvements in air quality simulation over two Italian cities. The Directive (2008/50/EC) assigns a significant role of supplement and sometimes of replacement of fixed measurements to the models in the assessment of the ambient air quality, making strategic realistic studies such as this one.

Acknowledgement
This work was carried out in the frame of the "Smart Clean Air City L'Aquila" project, Italian Ministry of the Economic Development, codice programma n. M/0007/03/X23. The computational resources were provided by CINECA in the frame of IscraC projects NMTFEPRA and PANCIA.

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DISPERSION MODELING OF RADON TO AID EMISSION ASSESSMENT: THE PRIDNEPROVSKY CHEMICAL PLANT

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Summary
In this study, dispersion modelling of radon around the uranium mill tailings of the former Pridneprovsky Chemical Plant in Ukraine was carried out with the aid of two atmospheric dispersion models. Emission data come from measurements of radon exhalation rates. The simulations were compared to the yearly averaged measurements of concentration data. Both models were able to reasonably reproduce average radon concentration at the tailing site outside the industrial area. At the same time, both models significantly underestimate concentrations as compared to measurements collected at the industrial site. Only by addition of significant radon emission rate from the whole industrial area in addition to emission rates from the tailings could explain the observed concentration measurements.

Introduction
The Pridneprovsky Chemical Plant (PChP) was one of the largest uranium processing plants in the USSR. The radioactive waste from the production was stored in 9 tailings, 7 of which are situated inside the PChP industrial area, while the 2 Sukhachivske tailings and a uranium ore storage facility lie outside the PChP industrial area and also outside the city of Dniprodzerzhynsk, as shown in Fig. 1. After the collapse of the USSR, the uranium processing ceased. There is ongoing work to assess and remediate the radiological situation of the area. This work includes monitoring of radon exhalation rates and air concentrations. In this study (Kovalets *et al.*) we use the radon exhalation rates as emission input to atmospheric dispersion simulations, to verify if the exhalation rates can explain the measured radon concentrations in air.

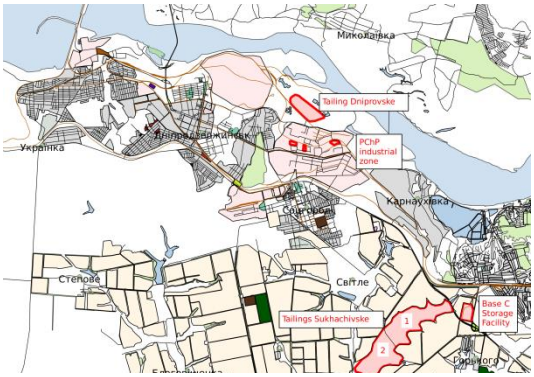

Fig. 4Map of Dniprodzerzhynsk and the uranium tailings.

Methodology and Results
Three different emission scenarios were used for the atmospheric dispersion simulations of the PChP industrial site. Emission Case I only included radon emissions from areas with known sources and where measurements exist. For each tailing the emission rate used was the average value from all measurements at that tailing. Emission Case II included the sources from Case I together with conservative estimates for sources for those tailings and areas that were known to contain radon. Emission Case III, included the same additional sources from Case II, but the emission rates for the sources in Case I were replaced by the maximum value measured at each tailing site. For the Sukhachivske sites, only Emission Case I was used.

Dispersion modelling was done using the gaussian puff model *CALMET/CALPUFF* and the Eulerian model *Airviro Grid*. Input meteorological data for the models were taken from the meteorological stations in Dniprodzerzhynsk and Dnipropetrovsk, together with model data from ECMWF and NCEP.

For all areas the two dispersion models produce results that are in agreement. For the Sukhachivske sites (outside the industrial area), the measured concentrations of radon agrees well with both dispersion models. For the industrial area PChP, however, the modelled concentrations are lower than the measured concentrations, for Emission Cases I and II. For the Emission Case III the modelled concentrations agree fairly well with the measurements.

Conclusions
The underestimation of the modelled radon concentrations as compared to the measurements for the PChP industrial site is likely caused by the existence of sources outside the uranium tailings.

Acknowledgement
This work was supported by Swedish International Development Cooperation Agency, SIDA. The first and third author was supported with the grant of the President of Ukraine Φ 62/006.

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μ-MO: SIMULATING THE DISPERSION OF NO_X EMISSIONS BY TRAFFIC AND DOMESTIC HEATING IN MODENA

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Summary

Goal of this project is to assess the road traffic and domestic heating impact on air quality in the urban area of Modena, a city in the central Po valley (Northern Italy), by performing the Parallel-Micro-SWIFT-SPRAY (PMSS, Arianet srl, Italy and Aria Technologies, France) model over a domain of 6 km x 6 km with a high horizontal resolution (4 m), by using a 16 core workstation (64 GB total memory). A run of the system on two weeks has been performed and is presented.

Introduction

Some of the most critical air pollutants in terms of health effect are the Nitrogen Oxides (NO_x), whose mainly impacts causing inflammation of the airways, lung functions decrease and can also increase the incidence of a wide range of diseases and cancer. The major sources of NO_x are combustion processes, which may be stationary (domestic heating or fuel combustion for power generation) or mobile such as transport: it is therefore essential to be able to estimate their contribution in order to improve existing urban development planning, support urban mobility scheduling and local government's choices on sustainable mobility. Therefore, the purpose of this project is to estimate the NO_x concentration fields due to the vehicular and domestic heating emission in the urban area of Modena.

Methodology and Results

A 3D wind and turbulence field reconstruction and numerical particle air pollution dispersion was performed on a 6km x 6km square domain covering the city of Modena with a horizontal grid resolution of 4 meters (square cells). Given the low altitude difference between different areas of the city, a flat domain was considered and a 3D buildings reconstruction was made by using the SHAFT pre-processor: 25,600 polygons were transformed into approximately 146,000 triangular prisms directly usable by Parallel-Micro-SWIFT.

The 3D fields of wind, temperature and turbulence were obtained for 20 vertical levels from 2m up to 500m above the ground with a logarithmic trend with the mass-consistent wind field model Parallel-Micro-SWIFT by taking into account the presence of buildings in the domain. The hourly meteorological data set used as input were derived from CALMET and COSMO mesoscale model simulation by ARPAE Emilia-Romagna (the local Environmental Protection Agency), which provides a vertical profile of temperature, humidity, wind intensity and wind direction inside the investigated domain. In addition mixing height values and main turbulence parameters (i.e. friction velocity, Monin-Obukhov length and convective velocity scale) are also given.

The vertical grid structure used by Parallel-Micro-SPRAY consists of 5 levels with a logarithmic progression up to 500m above the ground level with 3m height for the first layer close to the soil to represent ground level concentrations.

The methodology chosen for evaluate traffic emissions pairs a traffic model (PTV VISUM) with an emission model (TREFIC) implementing the COPERT IV official methodology. In this way NO_x atmospheric emissions are calculated for each road segment in terms of pollutant mass per trip unit by the combination of traffic flows and vehicular fleet composition depending on the type of fuel, engine capacity, load displacement and the EURO emission standard. Whereas domestic heating emissions was derived by neighbourhood domestic natural gas consumption data provided by Modena Municipality.

A simulation for two weeks between October 28 and November 8, 2016 was performed (see hourly concentrations map example Fig.1) and simulated concentrations were compared to local air quality measurements collected at the traffic urban monitoring stations.

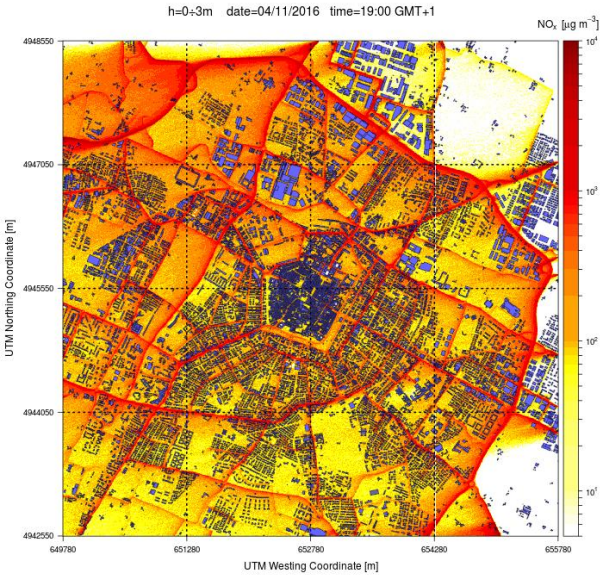

Fig.1 NO_x hourly concentrations map on November 4th 2016, from 6:00 p.m. to 7:00 p.m.

Conclusions

This paper shows the great capability of the PMSS model to simulate 3D air pollutant dispersion with a very high-resolution on a sizeable domain. This can be exploited as a tool in decision support system and to estimate the source-apportionment of urban NO_x between road traffic emission, domestic heating and regional background with high level of accuracy in Modena.

METHODOLOGY FOR INVERSE DISPERSION MODELLING IN URBAN AREAS

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Summary
The study aims to functionally test a methodology for the identification of the location of an unknown source of hazardous airborne agents in urban areas, as a result of accidental or malevolent releases. The methodology is based on the estimation of the back-trajectories of inert particulates, through the utilization of measurements from sensors and the reversing of the pre-computed flow field. Quantification of the uncertainties due to the turbulence generated by the urban morphology is necessary. The methodology was applied for the cases of a source of emissions upstream of a single building and of the Mock Urban Setting Test (MUST) as an idealized urban roughness. Results confirm that the methodology can form a useful tool for the identification of the location of an unknown source of emissions in cases of emergency in urban areas.

Introduction
The aim of this study is to develop a methodology for the identification of the location of an unknown source of hazardous airborne agents, as a result of accidental or malevolent releases in urban areas. The methodology utilizes a grid of sensors for the provision of coupled concentration and wind flow measurements within an area of interest and a database of pre-computed flow fields for the local prevailing conditions. When a threat is detected, the appropriate wind field is selected based on the measured wind flow parameters and retrieved from the aforementioned database. A reverse simulation is then performed during which the sensor locations are set as sources with weighted release rates. This way the back trajectories of the particles are then calculated and the source location is identified by statistically analyzing the number of trajectories which tend to converge at a specific point. For the purposes of this study, the ANSYS CFX 16.2 Computational Fluid Dynamics (CFD) model was applied.

Methodology and Results
The methodology was first applied for the hypothetical case of a source of emissions upstream of a single building. As a first step, a simulation during which an adequate number of inert particulates were released from a known source was performed and results for the estimated number of particulates were extracted at 9 different locations, representing hypothetical sensors. Then the numerically estimated wind filed was reversed and a dispersion simulation was performed, having set these 9 locations as sources of particulates with statistically weighted release rates. Results showed that the majority of the backward trajectories converged to an area close to the source (Fig. 1). The methodology was then applied for the case of the geometry of the wind tunnel model used in the Mock Urban Setting Test (MUST) experiment of the University of Hamburg Meteorological Institute. As a first step a simulation was performed to numerically estimate the flow field. At a second step, wind tunnel concentration measurements at specific points - sensors, were used to estimate statistically weighted release rates. These points were set as sources of emissions and a dispersion simulation under a reversed wind field was performed to calculate the back-trajectories. Results showed that the majority of the back trajectories converged to an area close to the location of the source (Fig. 2). However, compared to the single cube case, a larger number of trajectories diverged for the target – source.

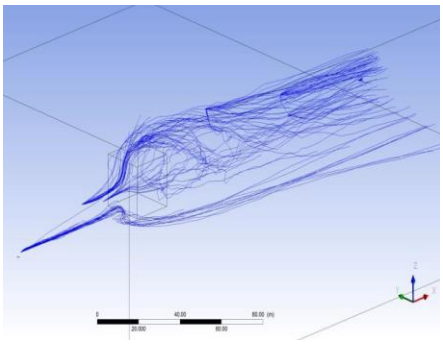

Fig 1: Numerically estimated back trajectories in the case of a single cube

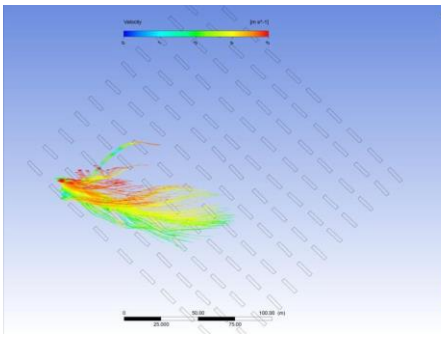

Fig.2 Source apportionment of PM10 using combined dataset

Conclusions
Results confirmed that the proposed methodology can be utilized to identify the location of unknown sources in cases of accidental or malevolent releases in urban areas. However it needs to be further tested under realistic conditions, during which a larger number of the back trajectories should be expected to diverge. In such cases statistical analysis to identify the location of the source based on the number of the trajectories which tend to converge should be applied. The methodology should be further developed to be applicable also for the identification of the terms of the source.

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TEMPORAL VARIATIONS IN LONG-RANGE ATMOSPHERIC TRANSPORT OF AIR MASSES AND ANTHROPOGENIC HEAVY METALS TO THE RUSSIAN ARCTIC: 1986-2016

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Summary
The study aims to analyze long-term, year to year, and seasonal variations in the processes of atmospheric transport of air masses and anthropogenic heavy metals (HM) to seven points in the Russian Arctic. 5-day backward trajectories of air mass transport (HYSPLIT4 model) for every day of a month were computed for each point during four months (Jan, Apr, Jul, Oct) through 30 years. Calculated values of HM concentrations in air and precipitations, total HM fluxes onto the surface, HM concentrations accumulated in snow by the start of spring melting period show high temporal variations and can be comparable with the same characteristics in the middle latitudes.

Introduction
Air mass transport to the Arctic is the most rapid way to bring pollution from industrial areas to the Arctic. This effect is relevant not only for atmospheric science. Ecologists, economists and politicians are interested a lot in understanding and estimating the accompanying processes.

Methods and approaches
Long-term, year to year, and seasonal variations in the processes of air mass transport to some Russian Arctic points were analyzed through 30 years (1986-2016) for four months of a year (Jan, Apr, Jul, Oct). We studied seven "investigation points" in the Russian Arctic: three points are placed on the islands – Frantz-Josef Land (FJL), Severnaya Zemlya (SZ) and Wrangel Island (WI), four points – in nature Reserves on the Northern coast of Eurasia – from Kola Peninsula to the delta of the Lena River. Two from these points (FJL and SZ) are situated near 80N latitude, while the rest five ones – at different longitudes in the vicinity of 70N.
For each point we analyzed 5-day backward trajectories of air mass transport (computed with 1-hour step by the Model HYSPLIT4 on the website [www.arl.noaa.gov/ready]) for every day of a month – in their spatial distributions. Trajectories were classified in four groups, according to where air masses come to the point from: Europe, Asian, American or the Arctic Ocean territories. These monthly distributions were related to monthly mean values of six atmospheric circulation indices (ACI from website [ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/tele_index.nh]). Some correlations (not very high) show certain slight connections of air mass transport processes with ACI system for different parts of Eurasian Arctic.
We consider seven anthropogenic heavy metals (HM) – Pb, Ni, Cu, Zn, As, Cd, Cr – as pollution transported by air masses to the investigation points. Our approach for calculation of long-range atmospheric transport was presented in our previous works [1,2]. Anthropogenic emissions of HM from Russian sources were taken from information bulletins of official Russian statistics (for example, [3]). Pollution parameters computed for the Arctic environment are: HM concentrations in air and precipitations, total HM fluxes onto the surface (monthly or in a year), HM concentrations accumulated in snow by the start of spring melting period.

Results
The main results concerning temporal variations in pollution characteristics are as follows: (1) increase of the share of marine air masses coming to North Eurasian islands during 30 years, and, thus, decrease of the share of polluted continental air; (2) high variations from year to year in atmospheric circulation causing high interannual variations in all pollution parameters; (3) strong industrial sources of Ni and Cu situated in the Russian Arctic (on Kola Peninsula and in the Norilsk vicinity) may give so high HM contributions to the Arctic that maximal values of nickel and copper concentrations can be comparable with the same characteristics in the middle latitudes.

Conclusions
Measurement results from only one season or even one year should not be used for long-term conclusions or forecasts. Also, it's not right to do any conclusions on environmental conditions from measurements of only one pollution component or at only one point.

Acknowledgement
Author acknowledges the Air Research Laboratory for website opened for everybody use to compute air mass trajectories.

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A SIMPLE AIR POLLUTION DISPERSION MODEL DEVELOPED IN DIFFERENT REAL URBAN STREET CANYONS

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Summary

This work presents the development and evaluation of an operational model (Semi-Empirical Urban Street (SEUS)) to estimate the passive pollutants concentration in air within urban canyons. The model depends on vehicular emission, canyon width, urban background concentration and natural and vehicular induced turbulence.
SEUS is evaluated with observational information from three real urban canyons in the cities of Birmingham (England), Copenhagen (Denmark) and Buenos Aires (Argentina). The different scatter plots between the estimated and observed concentrations and statistical indicators show that the model, which require few input data and has the advantage of being very simple to operate, is adequately developed.

Introduction

Atmospheric dispersion models can be classified by their level of complexity or the principles on which they are based. The numerical or CFD models numerically solve equations describing the dynamics and thermodynamics of airflow. This leads to the implementation of very elaborate and highly complex models, which results in an important limitation in the resolution.
In this way, the parametric models (Berkowicz et al., 1997, Mensink et al., 2006) are a simple and reliable method that allows an approach to the study of air pollution in the streets. This paper presents a semi empirical model which requires little input information and can be easily implemented in a spreadsheet, not requiring large computational times.

Methodology and Results

The Semi-Empirical Urban Street (SEUS) (Venegas et al, 2014) model is based on the normalization of air pollutant concentration (C) within urban canyons: $C = E\ U_s^{-1}\ W^{-1} + C_b$, where E is the emission mass flow rate per unit length, W is the width of the barrel, C_b is the urban background concentration and $u_s = (aU^2 + bv^2)^{1/2}$, is the velocity of dispersive scaling. U is the ambient wind, v is the average speed of traffic, a and b are dimensionless empirical parameters. These empirical parameters included in the model were obtained using real data from four canyons of European cities. Parameter a depends, among other factors, on the street geometry, wind direction and position of the air quality sampler and b depends on the flow conditions of the vehicles.

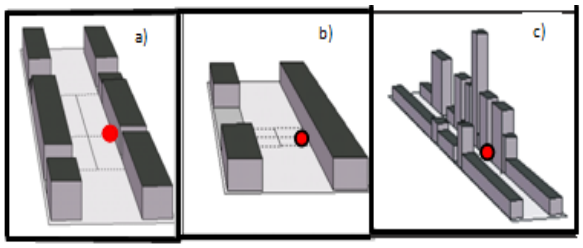
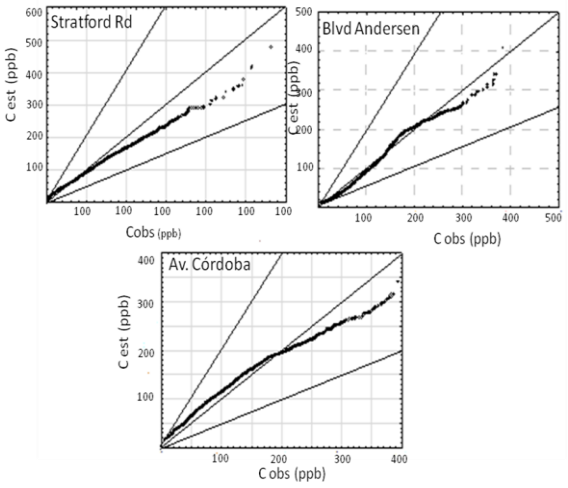


Fig 1 : Canyons shames: (a) Stratford Road, (b) Boulevard Andersen and (c) Av. Córdoba Red point represents the monitor location.

For the evaluation of the model, we used registered data from three real urban canyons: Stratford Rd. (Birmingham), Boulevard Andersen (Copenhagen) and Av. Córdoba (Buenos Aires) (Fig 1). SEUS model has a very good performance estimating the observed data (Fig. 2). The three canyons show low bias (<10.32 ppb), normalized mean square error (<37%) and a great fraction of estimated values are between 0.5 and 2 observed value (>72.6%).



Conclusions

The performance of the model improves on more regular canyons. It requires a small amount of input information and, because of its simplicity, it can be easily implemented in a. For this reason, it is a useful tool for air quality applications.

Acknowledgement

The work was supported by PICT2012-1667 project of the National Agency of Scientific and Technological Promotion (ANPCyT) and CONICET. We acknowledge Environmental Protection Agency of the City of Buenos Aires (APRA) and the National Meteorological Service (SMN) for providing the necessary data for the investigation.

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USE OF WRF METEOROLOGY IN THE LOTOS-EUROS CHEMISTRY TRANSPORT MODEL

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Summary

An interface to WRF meteorological input was developed for the LOTOS-EUROS model, and simulations at various resolutions were performed with WRF and the default ECMWF meteorology. Results were compared with observations over Germany. Differences in performance were related to differences in meteorological input: in particular boundary layer height caused differences in modelled concentrations.

Introduction

The chemistry-transport model LOTOS-EUROS has a long record in air pollution modelling. As an operational model it provides the Dutch smog forecast, it is part of the MACC/Copernicus ensemble and specific services , it provides air quality forecast over China as part of the Marco Polo project and is part of the SDS-WAS dust forecast. In off-line applications it has an even longer history with process studies, air quality assessment studies and with emission and climate scenarios studies. By default, ECMWF forecasts are used as input meteorology. Recently an (off-line) interface to WRF meteorology was developed. The first motivation to use WRF meteorology is the availability of meteorology at higher resolution than provided by ECMWF, thus enabling a better spatial resolution of LOTOS-EUROS simulations. The second motivation is the recent release of an open source version of the LOTOS-EUROS model. Many potential users do not have access to ECWMF meteorology but can use WRF meteorology. To make the coupling more efficient, LOTOS-EUROS was adapted to be able to run on the WRF grid to avoid interpolations.

Methodology and Results

The steps that were needed to use WRF output in LOTOS-EUROS were conversions for the different vertical layer structure of the model. In addition some derived variables had to be computed. The impact of WRF meteorology on concentrations of ozone, NO2 and particulate matter concentrations was investigated over Europe and Germany (high resolution) for episodes in 2014, as compared to ECMWF meteorology at comparable resolution and ground observations. For many episodes, stations and species the performance was comparable for the three simulations (Fig. 1), but also remarkable differences were found. They can be related to differences in the input meteorology from WRF and ECMWF, e. g. differences in cloud cover, rain, radiation and in particular in boundary layer height. It has to be noted that for a different set-up of WRF the meteorological input for LOTOS-EUROS will be different, with impact on modelled concentrations.

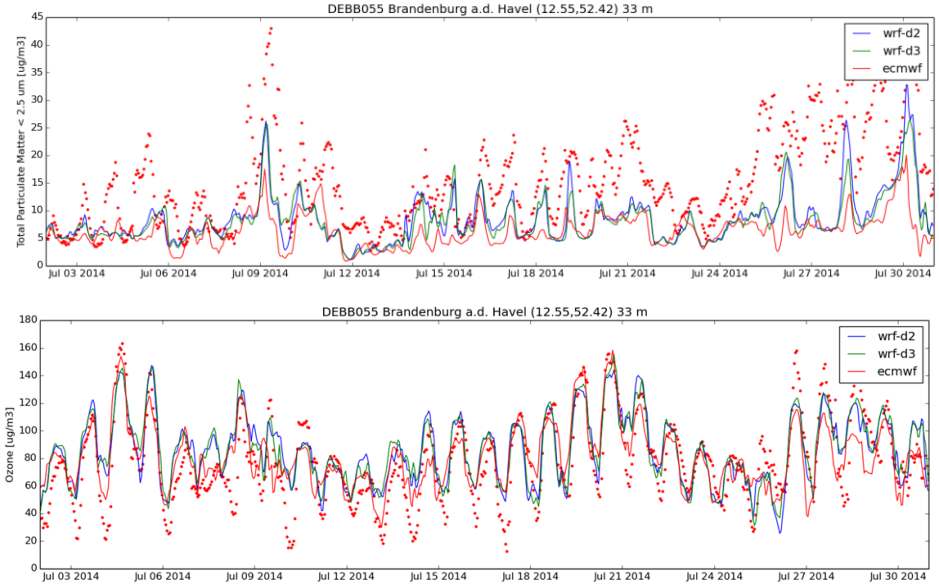

Fig. 1 Comparison of observed and modelled PM2.5 and ozone concentrations using ECMWF meteorology and WRF meteorology at two different resolutions

Conclusions

The technical process of coupling was successful. In general LOTOS-EUROS results from the WRF and ECMWF meteorology showed the same features but notable differences were also found that could be linked to differences between meteorological input.

A FRAMEWORK FOR AIR QUALITY MODELLING USING OPENFOAM

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Summary
A dispersion modelling framework based on OpenFOAM has been developed and applied for a central area in Gothenburg. Dispersion is described using RANS (Reynolds Averaged Navier Stokes) and the standard k-ε turbulence models with adaptions for vegetation and traffic induced turbulence. To allow comparison with limit values from EU air quality directives, hourly concentrations are produced by combining concentrations fields for representative meteorological conditions and considering background levels and chemical transformation. To make the results from CFD (Computational Fluid Dynamics) calculations comparable to limit values, yearly statistics are normally calculated by weighting and combining concentration fields for a representative set of meteorological conditions. A new weighting method is used that allows calculation of hourly concentrations for a full year. The method is implemented into a framework for local scale dispersion modelling based on OpenFOAM and its use is demonstrated for a dense urban area in Gothenburg. A comparison with monitoring data shows good agreement.

Introduction
In recent years, city planners in Swedish cities have been focusing on creating a more compact urban environment, reducing travel distances and thereby creating a more sustainable environment. In these environments it is sometimes challenging for city planners to find suitable space for e.g. schools, playgrounds, without the risk of exposure to high levels of air pollution.
CFD has been used for many years, with varying degrees of success, to capture the strong concentration gradients seen in these environments. This work is an effort to further refine these methods.

Methodology and Results
RANS (Reynolds Averaged Navier Stokes) are solved using the steady-state incompressible solver simpleFoam that is part of OpenFOAM and the k-**ε** turbulence model. Modifications are made to the solver and turbulence model to allow the description of influence from non-uniform ground roughness, tree canopy (Dalpé & Masson, 2009) and traffic induced turbulence (Konno et al., 2009).
The study case computational domain covers an area of 1 km^2. The domain is discretized by a hexahedral unstructured mesh of 8 million cells. For the study case, NO_x concentrations are calculated for 18 wind directions (20° sectors) and 3 different wind speeds. Emissions from 170 road links are divided into groups having similar time-variations. This way, the dispersion from all sources within an emission group can be described by the same concentration field.

Figure 13. Computational mesh.

Emissions are calculated using emission factors from HBEFA 3.1 and released into the CFD model using source terms within a 3m high volume above the road surface.
Hourly concentrations are estimated for year 2014. Conversion from NO_x to NO_2 is calculated on an hourly basis following Berkowitz et al (2011). Background concentrations are taken from the urban background station Femman in central Gothenburg. Meandering on a shorter time-scale than one hour is represented by weighting concentration fields for different wind directions, assuming a normal distribution in wind direction deviation. Statistics comparable to air quality standards are calculated for the complete 3D-field. A comparison against available monitoring data indicates a good agreement.

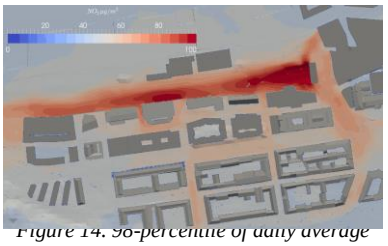

Figure 14. 98-percentile of daily average NO_2 [µg/m^3]at 2m above the round.

Conclusions
The simulations successfully manage to capture the main feature of the dispersion. A tunnel exit in the area is identified as an important source of pollution. Further validation and a sensitivity analysis regarding choice of meteorological cases will presented. Ongoing work involves using LES/RANS hybrid turbulence models to describe the flow and dispersion.

Acknowledgement
The Swedish Research Council FORMAS has contributed with funding. The city of Gothenburg is acknowledged for providing the required input data.

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OPTIMIZATION OF DUST-BINDNING USING THE NORTRIP-MODEL

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Summary
Dust-binding is used in large scale in Stockholm in order to reduce the high levels of ambient particulate matter, PM10 in spring (and occasionally in winter). However dust-binding is expensive and time consuming for the City. The NORTRIP-model was used to optimize the use of dust-binding in Stockholm. Several scenarios were tested for a six years period. The model results show that it is possible to optimize the appliance of dust-binding in Stockholm.

Introduction
PM10 is one of the most difficult environmental quality standard addressed in Sweden and Scandinavia. PM10 particles originates from a variety of sources; natural, e.g. sea salt and sand, and human made e.g. road wear, tire wear, brake wear and traffic exhaust. A significant source of ambient PM10 is traffic induced suspension. The suspension in Sweden typically occurs in March and April when the snow layer is melted and the streets are dry, but the cars still have studied tires. A dry street is crucial for the road dust to suspend into the air. A way to prevent road dust to suspend into the air is to lay out a dust-binding substance on the road. In Stockholm a dust-binding solution called CMA (Calcium Magnesium Acetate) is used as 25 % solution. CMA is applied on more than 30 streets in Stockholm three times a week between November and May except during snow covered streets. The CMA has shown to have a positive effect on the PM10-levels (Norman and Johansson 2006).

Methodology and Results
Dust-binding substances are expensive and time consuming to apply to the streets. During the previous seasons has CMA been applied up to 90 times between November and April on 35 inner-city streets in Stockholm. To study the optimization of the appliance of CMA in Stockholm different scenarios have been modeled using the NORTRIP-model. The NORTRIP-model is a road emission model, which uses meteorological data, traffic data combined with data on salting, sanding and cleaning to calculate PM10 suspension into the air (Denby et al 2013a, Denby et al 2013b). The model simulations were done using the inner-city street, Hornsgatan, as an example. The dust-binding in the model was also combined with spraying the road with water in order to test if the combination could increase the effect on PM10 in the air. Water was only added to the model after the 15th of March because it was assumed the temperature would not sink below 0 °C after this date.

Several different scenarios were used to see if it was possible to minimize the usage of CMA and at the same time keep the PM10 level low. All scenarios were compared with the scenario of not applying any CMA or water. All scenarios were tested for a six years period, i.e. 2011-2016.

The model results showed that it is better to apply CMA every day during periods with high PM10 rather than just manage to target the highest days alone. The total concentration of ambient PM10 in 2016 was reduced by 4.7 % when the 45 highest days were treated with CMA. This could be compared to a 6.4 % reduction when CMA was applied during dusty periods, all periods added up to 46 days. Another observation made was that applying CMA in March and April has a greater effect then applying CMA in November to February. The total concentration of ambient PM10 in 2016 was reduced by 2.1% if the CMA treatment started on the 1st of November as planned, and by 1.6 % if the treatment started on the 24th of February when the high PM10 season normally begins, showing that only a small further reduction was calculated if CMA treatments tartted already in November. It was also shown that a thin layer of water (0.3 mm) applied to the street between dust-binding occasions had a significant effect on the ambient PM10 concentrations. Adding water to the street in between days of dust-binding after the 15th of March 2016 reduced the total concentrations of PM10 in 2016 by another 1.5 % compared to only using dust-binding.

Conclusions
This paper shows that it is possible to optimize the appliance of CMA in Stockholm compared to what is currently done, in order to prevent resuspension of road dust into the air. The results from the NORTRIP-model showed that applying CMA every day during periods with high ambient PM10 in March and April had larger effect than just manage to target the highest days alone. Applying CMA in March and April has a greater effect then applying CMA in November to February. Adding water to the street in between days of dust-binding in springtime reduced the PM10 more compared to only using dust-binding.

Acknowledgement
This work was a Degree Project E in Meteorology at Department of Earth Sciences, Uppsala University. The work was supported by VINNOVA within the OPTIDRIFT project.

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MODELLING OF BENZO(A)PYRENE IN SE SPAIN TO DETERMINE LEVELS, HUMAN HEALTH FACTORS AND CLIMATE CHANGE EFFECTS

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Summary
Benzo(a)pyrene (BaP), the only polycyclic aromatic hydrocarbon (PAH) having an established legal limit for its presence in the atmosphere (1 ng/m^3 in particulate matter; Directive 2004/107/EC, amended by Regulation 219/2009) was selected as the model semivolatile organic contaminant (SVOC) to evaluate the performance of chemistry transport models (CTMs) when studying those chemicals. The BaP distribution was represented by the Weather Research and Forecasting (WRF)+CHIMERE system with success, supporting the use of combinatory approaches of field observations and models to extend the awareness about the levels, behaviour and fate of these compounds of concern for humans and the environment.

Introduction
The atmosphere is a privileged route of exposure to contamination, especially via the particulate material. An example of the chemical of concern are PAHs, which are ubiquitous compounds of hazardous potential due to their carcinogenicity and mutagenic properties, which can have a negative effect on human health (Kim et al., 2013). PAHs are released into the environment through natural and anthropogenic sources and can be found in either gas or particulate phase in the atmosphere, the latter being the case BaP. In air quality studies it is always important to describe not only the current status but also possible climate change effects (Jiménez-Guerrero et al., 2013) as well as health parameters directly linked with the presence of harmful compounds (WHO, 2010).

Methodology and Results
The WRF+CHIMERE system, with a resolution of 9 km for the Iberian Peninsula and 3 km for the SE Iberian Peninsula was employed against the available field-based observations, from December 2012 to November 2013. The modelled atmospheric concentrations of BaP present normalised biases under 30%. The fact that both +/- biases are found indicates that the model is not generally inclined towards overprediction or underpredicion. The deviations only range between +1.63 pg/m^3 over the northern Iberian Plateau (Peñausende station, close to the Spanish-Portuguese border) and -4.59 pg/m^3 (San Pablo de los Montes station, in the southern-central Iberian Plateau). The maximum climatic BaP value is under 0.1 ng/m^3, with some areas exceeding the target value of 0.01 ng/m^3. A general strong seasonality is observed, with the highest values (over 12 pg/m^3) appearing at wintertime over large populated areas (Murcia) and industrial zones and the lowest during summer in the Mediterranean Sea.

Conclusions
A reliable monitoring network for the target pollutants over SE Iberian Peninsula based on passive air sampling can we established, since a state-of-the-art chemistry transport model reproduces the presence of SVOCs (BaP) with high accuracy in the target domain.
Some limitations include the PUFs being more likely to entrap gas-phase than particulate material and the initial model validation representing a climatologically significant period (2006-2010) and not our BaP sampling period (2012-2013).

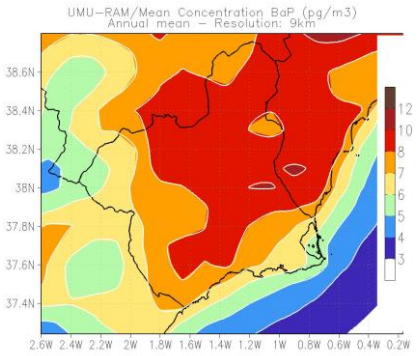

Fig.1 Modelled annual mean concentrations of benzo(a)pyrene in SE Spain

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MONITORING OF AMBIENT AIR POLLUTION VIA LOCAL REMOTE SENSORS AND ITS EFFECTS TO AGRICULTURAL CROPS IN PAKISTAN: A THREAT TO THE FUTURE FOOD SECURITY OF SOUTH ASIA?

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Abstract: Although ozone is well-documented to affect crop yields in the densely populated Indo-Gangetic Plain, there is little knowledge of its effects around cities in more remote areas of south Asia. We surveyed crops around the city of Peshawar, Pakistan for visible injury, linking this to active samplers equipped with remote sensors technology that were used for the first time in this region. Foliar injury was found in the field on potato, onion and cotton when the mean monthly ozone concentration reached 35-55ppb. The symptoms on onion were reproduced in ozone fumigation experiments, which also showed that daytime ozone concentrations of 60ppb and above significantly reduce the growth of Pakistani varieties of both spinach (Beta vulgaris) and onion. Aphid infestation on spinach was also reduced at these elevated ozone concentrations. The ozone concentrations in Peshawar are comparable to those through many parts of northern south Asia, where ozone may therefore be a significant threat to sensitive vegetable crops in peri-urban regions.

Keywords: Food security Ozone air pollution vegetable crops Peshawar South Asia

SAHARAN-DUST CONTRIBUTION TO PM10 LEVELS IN ITALY OVER THE 7-YEAR PERIOD 2006-2012

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Summary
We assess the contribution of Saharan dust to the PM10 levels in Italy over the 7-year period 2006-2012. To this purpose, we use the methodology recently proposed by Barnaba et al. (2017), hereafter B2017. This builds on the European Guidelines set to guide Member States in the estimation of natural contributions to the EU-regulated PM10 metrics, and partially modifies them to better adapt to the Italian case. The data analysis confirms and extends in time some preliminary results obtained at the national level for the year 2012 in B2017. Furthermore, use of additional PM2.5 datasets allowed further supporting the hypothesis of an important resuspension effect of desert dust along the major traffic routes of the country.

Introduction
Due to the proximity to the Sahara desert, transport of desert dust to Europe affects the PM air quality metrics regulated by the EU Directive 2008/50. Quantification of this natural contribution is important since, if proved to cause PM10 exceedances, these latter can be considered not as such for the purpose of the Directive. Additionally, long-term assessment of the desert dust contribution to PM10 values is fundamental to investigate possible effects of desert dust on citizen's health.

Methodology and Results
We collected PM10 datasets from over 1000 monitoring stations in Italy over the period 2006-2012. We then fixed specific criteria for the single PM10 records to be sufficiently representative and produce statistically significant results. This filtering procedure left datasets from 304 PM10 monitoring sites. Daily-average PM10 data from each of these sites were used as input to the methodology set up by B2017 to quantify desert dust impact on PM10 values. This makes also use of model-based desert dust transport forecasts (Basart et al., 2012) to flag the transport of desert dust at each site over the country on a daily basis.
Results reveal a clear latitudinal gradient of desert dust frequency (Figure 1a), which reflects into a similar gradient of desert-dust impact on the yearly average PM10 (Figure 1b). However, when quantifying the desert-dust mass associated to each desert-dust affected day, this picture significantly changes (Figure 1c). In fact, the latitudinal feature is no more detectable and desert-dust loads are rather found to be higher in areas corresponding to high traffic routes. This confirms and extends results obtained by B2017 over a one-year record (2012), and further supports this effect being related to resuspension of desert dust by traffic. To further explore this hypothesis, in this study we also used PM2.5 data in those Italian regions were this information was available over the long-term. Our results show that the same feature is not visible on the PM2.5 records, in agreement with the fact that, rather than on PM2.5, resuspension is expected to play a role mainly on the coarse fraction of PM10.

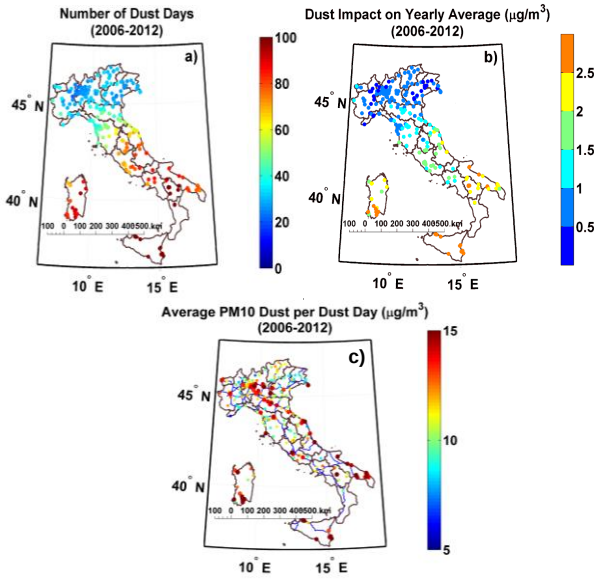

Fig.1 Site-resolved statistics (2006-2012) of: a) number of days per year classified as 'dust affected', b) mean desert-dust impact on yearly average PM10 and c) mean impact of desert dust per day of desert-dust advection (blue lines are maior Italian routes).

Conclusions
Assessment of desert dust impacts on EU-regulated PM10 loads is important both for complying with the EU air quality Directive and to provide a base for health impacts studies. By employing a methodology recently proposed by B2017, we were able to quantify this impact over the whole Italian territory and over a 7-year period.

Acknowledgement
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STUDY OF THE CONTEMPORARY OCCURRENCE OF HIGH LEVELS OF AIR POLLUTANTS AND POLLENS IN THE CITY OF ROME

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Summary

In this work, the status and trends of air concentration of PM_{10}, $PM_{2.5}$, NO_2, O_3, airborne pollens (belonging to 5 families allergenic: Betulaceae, Cupressaceae / Taxaceae, Graminaceae Oleaceae and Urticaceae) and alternate fungal spore were studied, for the city of Rome, over a period of eighteen years (from 1999 to 2016).

For atmospheric pollutants, air concentration values recorded by the monitoring stations of the Rome air quality network were used, while data of pollen and spores concentrations were collected and measured by the aerobic monitoring center of Tor Vergata University of Rome.

the Statistical analysis highlighted the periods of the year in which the highest levels of concomitant allergens and atmospheric pollutants occur, it also pointed out the influence of meteorological parameters and of the flowering calendar on concentration levels during the four seasons.

Introduction

Urban green is an important aspect in the quality of life of citizens of modern cities. Nevertheless some ornamental plants cause allergic diseases in sensitive subjects that may be worsened by air pollution.

Studies on air quality are usually addressed to the evaluation of single substances and their specific effects: little is known about the cumulative effect that different pollutants may have on human health. Even less is known about possible combined action of traditional air pollutants with pollen and spores that have huge effects, in terms of allergies and asthma, on citizenship of the urban areas (D'Amato *et al*., 2007).

Methodology and Results

Time series of pollutants and pollens analysis, using Seasonal Kendall test, has been applied. The statistical analysis allowed to highlight when concomitant high levels of allergenic species and air pollution occur and the influence of meteorological parameters (see Fig. 1). and of the flowering calendar.

Maximum air concentrations of pollen and atmospheric pollutants happen, in Rome, in different seasons: during the winter for particulate matter and nitrogen oxides, during the spring for main pollens and during the summer for ozone (see Fig. 2). The comparative analysis of the time series established that the greatest overlap period is between February and March in the study area. The analysis of concentration trends, from 1999, shows a statistically significant decrease of PM_{10}, $PM_{2.5}$ and NO_2 and an increase of Urticaceae (all other parameters were stable).

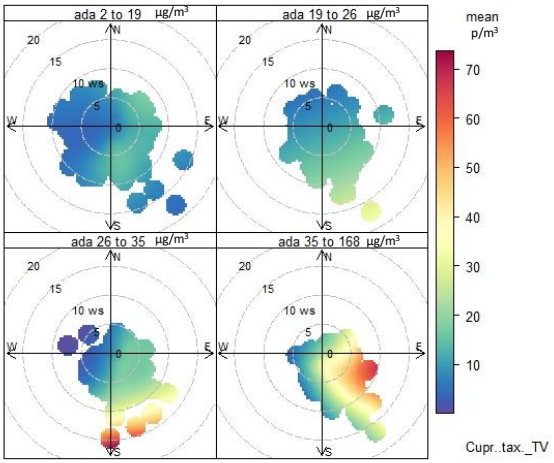

Fig.1 Cupr/Tax pollen pollution rose depending on PM_{10} concentrations

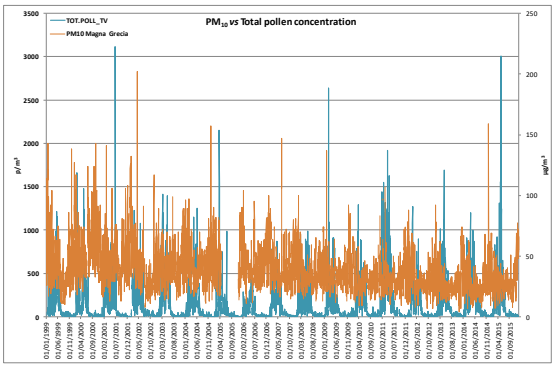

Fig.2 PM_{10} and pollen concentrations in Rome: comparing trends

Conclusions

Nowadays the absence of legal limits that directly link certain concentrations of pollen or aerated spores and human health does not allow an absolute assessments of the air quality. The onset of allergic symptoms occurs when pollen concentration, reaches a defined value, called threshold; but this threshold varies not only from individuals but also in the same individual during the season. Anyhow, the results of this study, based on a very large database, can support targeted medical studies and allow a deeper understanding of atmospheric pollution in urban areas.

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ACTIVE BIOMONITORING OF AIR POLLUTION IN BAKU, THE CAPITAL OF AZERBAIJAN

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Summary

Devitalized *Sphagnum girgensohnii* Russow (in moss-bags) as a biomonitor species for the first time were used to characterize different pollution sources at a local scale and long-range transport of air pollutants in the capital of the Republic of Azerbaijan. Two complementary analytical techniques were used: neutron activation analysis and atomic absorption spectrometry. A total of 39 elements were determined: Na, Mg, Al, Cl, K, Ca, Sc, V, Cr, Mn, Ni, Co, Fe, Zn, As, Br, Sr, Rb, Mo, Sb, I, Ba, Cs, La, Sm, Hf, W, Au, Th, U, Cu, Cd, and Pb. Multivariate Statistical Analysis (Factor Analysis) allowed characterization of potential pollution sources.

Introduction

Atmospheric pollutants have a severe adverse effect on human health. About half of the urban population being monitored is exposed to air pollution that is at least 2.5 times higher than the levels World Health Organization recommends (WHO, 2014). Industrial emission sources in Azerbaijan are mostly concentrated in Baku and Sumgayit, and associated with the oil industry. The long history of oil exploitation in the country has left Azerbaijan with a massive legacy of oil and other chemical pollution, both land-based and offshore. The Absheron Peninsula (which includes Baku and Sumgayit) and the Caspian Sea are considered to be among the most ecologically devastated areas in the world because of severe air, soil and water pollution (UNEP, 2009). The moss bag technique is the most commonly reported method of active biomonitoring with terrestrial mosses. The technique is a simple and cost-effective way of evaluating air quality. For the first time NAA was used to determine a large set of elements, previously not assessed in air pollution of the study area.

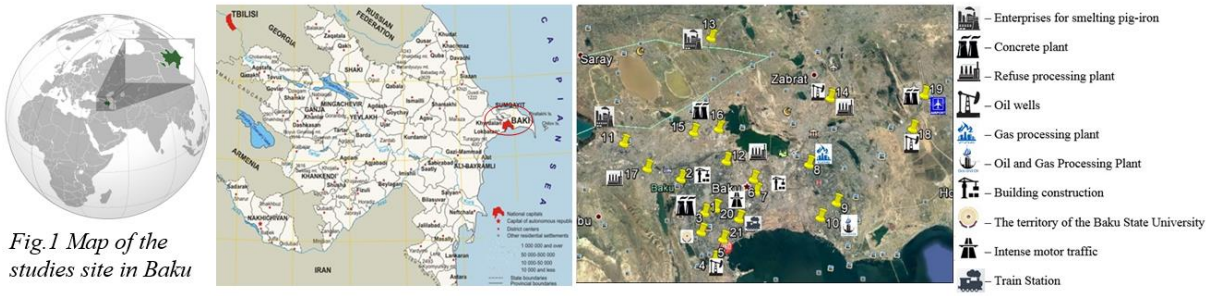

Fig.1 Map of the studies site in Baku

Methodology and Results

Samples of moss *Sphagnum girgensohnii* Rusow collected in the pristine wetland area of Central Russia were exposed at twenty-one urban sites on the Absheron peninsula for 3 months starting from November 2016 (see Fig.1). The moss samples were subjected to multi-element epithermal neutron activation analysis (INAA) (Frontasyeva, 2011) and statistical analysis revealed: *Factor 1* represents light (Mg, Al, Sc, and V) and heavy (Fe, Sr, Cs, Th, and U) crust components, however, sampling site 4 characterized by the highest value most probably is associated with the clustering of pollution sources: oil and gas wells and heavy traffic vehicles. *Factor 2* is a combination of halogens (Cl, Br, I), marine elements Na, Cl and industrial elements Zn and Sb which correspond to the highest value of the sampling site 14 enterprises for smelting pig iron; waste processing and pharmaceutical plants and a railway junction. *Factor 3* (K and Rb) is associated with the vegetation in the green areas of the sampling sites 6, 9, 20, 13 and 16. *Factor 4* (Cr and Ni), both toxic elements, which showed themselves in the sampling site 3 in the vicinity of the chemical laboratory of the Faculty of Ecological and Soil Sciences of Baku State University and in the sampling site 15 mostly associated with pig iron smelter and factories for the production of paints.

Conclusions

As industry continues to increase in that region, heavy metal deposition and organic contaminations were found in the result of the latest air surveys. Today, Azerbaijan realizes the importance of low-carbon development and is now looking to foster the development of a green economy and shift away from its reliance on fossil fuels.

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AIRBORNE PARTICULATE MATTER MONITORING IN NAIROBI, KENYA USING CALIBRATED LOW COST SENSORS

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Summary
This study investigated the use of low cost optical particle counters (OPCs) to measure particulate matter (PM) pollution in Nairobi, Kenya, in February and March 2017. Measurements were performed in three locations, an urban background and urban roadside site (at the top of a tower block and a busy roadside location, respectively) and one in a rural location, Nanyuki, at an aerial distance of 110 km north (upwind) of Nairobi. The concentration of $PM_{2.5}$ and PM_{10} regularly exceeded WHO daily guidelines at the urban sites, with exceedances often double the guidelines at the roadside site. This study provides much needed calibrated data, of high temporal resolution, on the PM loadings in a rapidly developing and urbanising East African country.

Introduction
PM poses a significant risk to human health by increasing the likelihoods of respiratory and cardiovascular disease.[1] There is typically a lack of PM data for cities located in low to middle income countries (LMICs). Although measurements of PM loadings in Nairobi exist, there is a paucity of long-term measurements with appropriate calibration. Existing measurements in the city highlight that PM concentrations regularly exceed WHO guidelines, both in the PM_{10} and $PM_{2.5}$ mass fractions e.g. Gaita et al. (2014).[2] Low cost sensors offer the possibility of long term measurements in Nairobi and other LMIC cities.

Methodology and Results
OPC sensors (Alphasense OPC-N2) had their data logged using Raspberry Pi 3 minicomputers, housed in weather resistant casing and placed in areas free from obstruction. The measured OPC-N2 particle number concentrations were calibrated using a regression curve obtained from co-located measurements that provided gravimetric concentrations of $PM_{2.5}$ and PM_{10}. Meteorological measurements were also taken at the tower block site, which were also appropriate for the roadside location. Previous measurements indicate that high relative humidity (RH) can lead to inaccurate measurements. [3] Nairobi in the season of the measurement period is typically dry (RH < 80%) and the measurements were not affected by changes in RH.

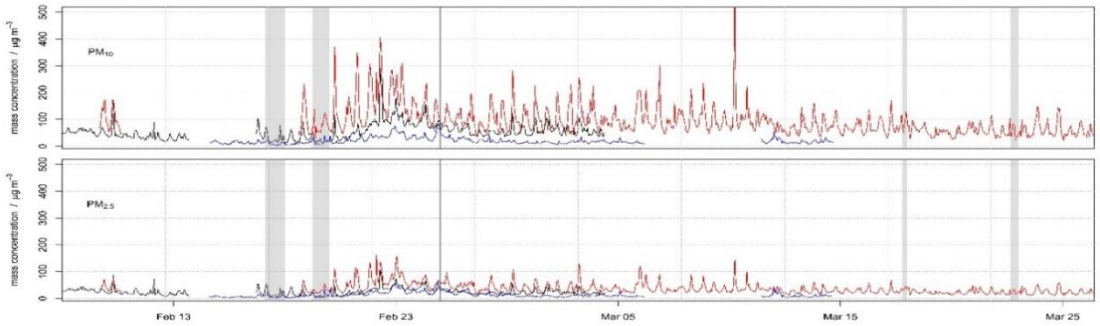

Figure 1. Hourly time series data showing PM_{10} and $PM_{2.5}$ mass concentrations. Red line = urban roadside, black line = urban background and blue line = rural background. Grey shading represents rain events at the urban locations.

The average $PM_{2.5}$ and PM_{10} mass concentrations were 36.6 µg m^{-3} and 93.7 µg m^{-3}, respectively. The urban roadside site had the highest number of days in excess of WHO guidelines for $PM_{2.5}$ and PM_{10}. For $PM_{2.5}$ and PM_{10}, the concentrations measured at the urban roadside site exceeded WHO recommendations 85% and 90% of days, respectively. Furthermore, they exceeded double the recommendations on 13% and 40% of days, respectively. The urban background site only exceeded the guidelines for approximately one third of the sampling days. The roadside and urban background sites show clear diurnal patterns consistent with vehicular traffic being a major source of PM in Nairobi.

Conclusion
This study provides high temporal resolution $PM_{2.5}$ and PM_{10} measurements that can be utilised for health related assessments and the implementation of transport and land use policy. It shows that low cost sensors can be used for monitoring LMIC countries along as the appropriate calibration approach is undertaken.

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PERFORMANCE OF LOW COST AIR QUALITY SENSORS IN A REAL WORLD APPLICATION

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Summary

This study aims to test low cost air quality sensors in a realistic experimental framework. A set of 4 sensor units, each measuring NO, NO_2, RH and T, have been deployed at the same air quality monitoring site reference instruments for 3 months. Afterwards, the sensor units were moved to 2 different air quality monitoring sites to test 3 different calibration algorithms: multivariate linear regression, support vector machine regression and random forest. All methods show good agreement with the reference measurements, with support vector machine and random forest outperforming multivariate linear regression and showing comparable results in terms of performance for both sites and both pollutants.

Introduction

Interest in low cost air quality sensors has been rising in the scientific community over the last years, because of their wide range of possible applications and the recent increase in precision and accuracy. Several studies investigated the response behaviour of these sensors focussing on the measurement principle (e.g. metal-oxide or electrochemical based), on the calibration method (e.g. in the laboratory or in the field), or on the calibration model (e.g. linear regression and machine learning). Only few studies analysed the sensor performance in field conditions on the long-term (e.g. Mueller et al., 2017). The operation of low-cost sensors still poses some challenges: the sensitivity, selectivity and stability of the sensors as well as the most effective calibration strategy.

Methodology and Results

In this study 4 sensor units were used, which have been jointly developed by Empa and Decentlab GmbH (Duebendorf, CH). Each unit includes two electrochemical NO sensors, two electrochemical NO_2 sensors (Alphasense NO-B4 and NO2-B43F) and a sensor for atmospheric relative humidity and atmospheric temperature (Sensirion SHT21). During a 3 month calibration period, the units were deployed at a rural air quality monitoring station (Haerkingen, CH) next to a major highway, exposed either to traffic emissions or clean air masses depending on wind direction. Afterwards, 2 units were deployed for 3 months at a central urban traffic site in Lausanne and 2 units at a central urban background site in Zurich, both in Switzerland. The performance of three different algorithms on the calibration and the deployment datasets were compared: the algorithms include Multivariate Linear Regression, Support Vector Machine regression and Random Forest regression. The two latter methods outperformed linear regression on the deployment dataset according to all considered goodness-of-fit indexes. The response by each covariate across the three methods has been compared. Sensor drift over time was investigated by analysing target plots variability over time for all the three methods. The resilience of the tested calibration methods to sensor drift and degradation has been investigated. Finally, the benefit of the chosen redundancy of electrochemical sensors has been exploited.

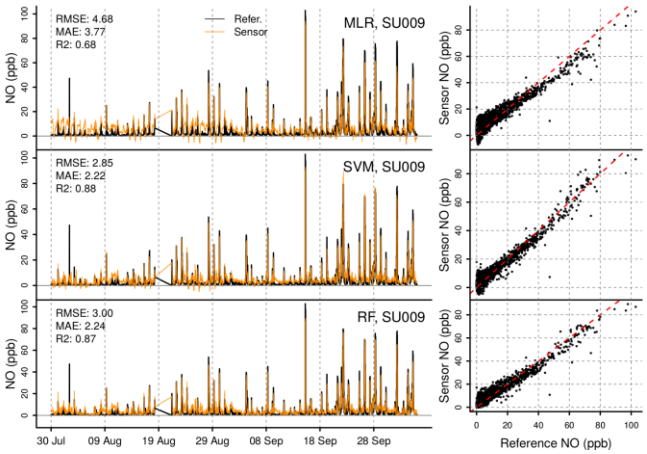

Fig.1 Comparison of NO in Zurich by reference instrument and by sensor estimate using the three regression methods

Conclusions

There is a clear need for studies investigating the performance of low-cost air quality sensors for extended time periods in order to identify fields of application and procedures for the operation of low-cost sensors. In this study, sensors calibrated using Random Forest regression showed the overall best performance followed by Support Vector Machine and finally by Multivariate Linear Regression.

Acknowledgement

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