Gwangju Institute of Science and Technology

University of Hertfordshire UH

British and Korean Lidars for ATLID Validation (BAKLAVA)

Matthias Tesche[1], Boyan Tatarov[1], Sung-Kyun Shin[1], Youngmin Noh[2,3], and Detlef Müller[1,2]

[1]School of Physics, Astronomy and Mathematics, University of Hertfordshire, Hatfield, United Kingdom (contact: m.tesche@herts.ac.uk)
[2]Gwangju Institute of Science and Technology, Gwangju, South Korea
[3]now at: Department of Environmental Engineering, Pukyong National University, Busan, Republic of Korea

Executive summary

Measurements with two unique spectrometric aerosol Raman lidars located in the United Kingdom (51.75 °N; 0.24 °W) and the Republic of Korea (35.23 °N;126.84 °E) will be conducted during EarthCARE overpasses to validate the aerosol and cloud profile products obtained from ATLID observations.
The *Lidar Spectroscopy Instrument* (LiSsI, *Tesche et al.*, 2018) at the University of Hertfordshire (UH), Hatfield, UK, and the *Multiwavelengths Raman Spectrometer Lidar in East Asia* (MRS.LEA, *Tatarov et al.*, *2012*, *Noh et al.*, 2016), at the Gwangju Institute of Science and Technology (GIST), Gwangju, Republic of Korea, are globally unique in their capability to enable multiwavelength spectrometric profiling of Raman scattering and depolarisation of gaseous and particulate pollution.
The parameters of relevance for the validation of ATLID data products that will be delivered from measurements with LiSsI and MRS.LEA are profiles (all at 355 nm) of the attenuated backscatter coefficient (up to an altitude of at least 30 km), the aerosol backscatter and extinction coefficient, the lidar ratio and the particle linear depolarisation ratio. Both instruments also provide the base and top heights of aerosol layers as well as the base height of optically thick cloud layers and the base and top heights of optically thin cloud layers.

Contribution to the mission objectives

BAKLAVA is aimed at assessing and reducing the uncertainties in ATLID products through comparison with independent measurements performed with depolarisation Raman lidars operating at 355 nm.
We will validate EarthCARE aerosol and cloud profile observations using independent ground-based measurements of clouds and aerosols over Hatfield, United Kingdom (LiSsI operational since 2018) and Gwangju, South Korea (MRS.LEA operational since 2009, gradual increase in measurement capability).
From these co-located measurements we will assess accuracy, resolution, and stability of the ATLID instrument as well as the EarthCARE data retrieval and processing.
We will focus in particular on the evaluation of clouds and aerosols represented in the geophysical products ATL_NOM_1B, ATL_FM__2A, ATL_AER_2A, ATL_TC__2A, ATL_EBD_2A, ATL_CTH_2A, ATL_ALD_2A, AM__ACD_2B.
The collocation of observations with EarthCARE and the statistical evaluation of results within BAKLAVA will adopt the strategy developed within EARLINET and use the trajectory matching approach of *Tesche et al.* (2013) to assure that the ground-based lidars sample the same air mass as EarthCARE (see colocation criteria for details).

LiSsI and MRS.LEA: technical specifications

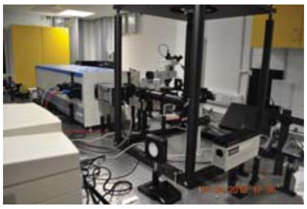
Emitter setup of LiSsI and MRS.LEA

Instrument	LiSsI	MRS.LEA
Laser name	Continuum Powerlite Furie LD	Continuum Surelite III-10
Laser type	Nd:YAG, injection seeded	Nd:YAG
Wavelength and pulse energy	7500 mJ @1064 nm 5000 mJ @532 nm 2500 mJ @355 nm	640 mJ at 1064 nm 154 mJ at 532 nm 140 mJ at 355 nm
Beam divergence	0.5 mrad (0.1 mrad, , 5-fold beam expansion)	1.0 mrad 0.2 mrad, 5-fold beam expansion
Repetition rate	10 Hz	10 Hz
Linewidth	<0.003 cm^{-1}	1 cm^{-1}
Pulse duration	<15 ns	<10 ns

Measurement capabilities

	LiSsI			MRS.LEA		
Wavelength (nm)	355	532	1064	355	532	1064
Backscatter coefficient	X	X	X	X	X	X
Extinction coefficient	X	X	(X)	X	X	
Lidar ratio	X	X	(X)	X	X	
Depolarisation ratio	X	(X)		X	X	
Stokes vector	(X)			(X)		

(X) - yet to be implemented, hardware available



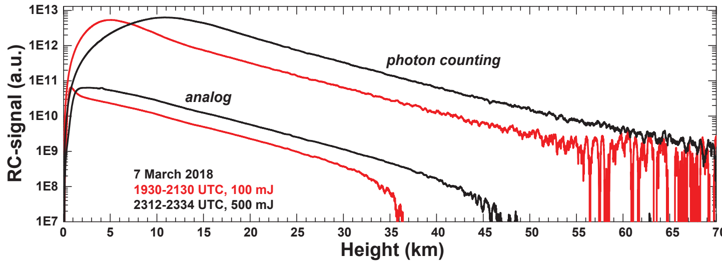
Receiver setup of LiSsI

Receiver optics	
Telescope	Schmidt-Cassegrain, 14 inch
Focal length	3910 mm
Field of view	0.5 – 4.0 mrad, adjustable
HORIBA 1250M Research Spectrometer	
Focal length	1.25m
Aperture	F/9
Spectral range	0-1500 nm mechanical range (1200 g/mm grating)
Grating size	110 mm × 110 mm
Dispersion at 500 nm	0.65 nm/mm (with 1200 g/mm grating)
Accuracy	± 0.15 nm
Repeatability	± 0.005 nm
Gratings and resolutions at 313.183 nm	2400 g/mm blaze 250 nm, max resolution 0.003 nm 1800 g/mm blaze 400 nm, max resolution 0.004 nm 1200 g/mm blaze 330 nm, max resolution 0.006 nm 600 g/mm blaze 500 nm, max resolution 0.012 nm
Detection	
Mie and Rayleigh scattering	355 nm, PMT HV-R9880U-20, bandwidth 1.3 nm 532 nm, PMT HV-R9880U-20, bandwidth 1.3 nm 1064 nm, APD InGaAs50, bandwidth 4 nm
Spectroscopic 1 Licel SP32-20	Hamamatsu H7260-20, 0.8 mm × 7 mm × 32 anodes spectral response 300-920 nm
Spectroscopic 2 Princeton Instruments PI-MAX4 ICCD camera	1024× 1024 imaging pixels; 12.8 mm × 12.8 mm pixels Gen III filmless intensifier Sensitive range 290-710 nm QE>20% in range 355-700 nm; QE>40% in range 410-640 nm
Data acquisition system	
Mie and Rayleigh scattering	Licel transient recorders, 16 bit, 20 MHz A/D converters scattering maximum count rate 250 MHz, variable range resolution
Multi-anode PMT	Single-photon counting system, maximum count rate 100 MHz, 50 ns resolution
ICCD	Digitization 16 bit, 32 MHz, minimum gate width 2 ns

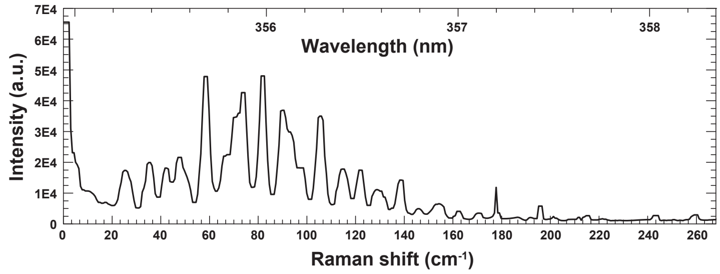
Receiver setup of MRS.LEA

Receiver optics	
Telescope	Schmidt-Cassegrain, 14 incn
Focal length	3910 mm (14 inch)
Field of view	0.5 – 4.0 mrad, adjustable
Channels(nm)	$355^{\parallel}$, $355^{\perp}$, 355,361, 387, 407, $532^{\parallel}$, $532^{\perp}$, 546, 607, 1064
Bandwidth (nm) of interference filter	5, 5, 10, 3, 0.72, 0.97, 1, 1, 3, 0.45, 1
Detection and data acquisition system	
Detectors for different channels	HAMAMATSU R3234-01 for $355^{\parallel}$, $355^{\perp}$, 361, 387, 407, 546, 607 HAMAMATSU R3236 with PMT cooler for 1064 HAMAMATSU R7400-20 for 355, $532^{\parallel}$, $532^{\perp}$
Data acquisition	MCS PCI photon counting 150 MHz (15 m vertical resolution)
Data acquisition	Licel TR20-160, 12 Bit 20 MHz analog and 250 MHz photon counting

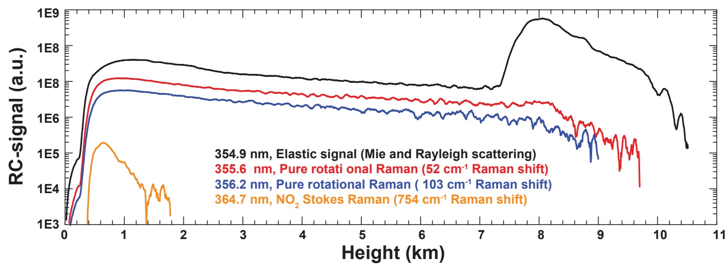
LiSsI: measurement examples



LiSsI measurements at 532 nm in the evening of 7 March 2018, smoothed with a 300-m window length.

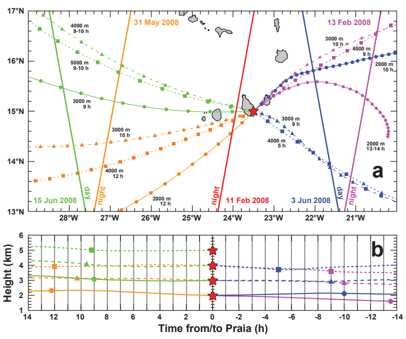


Pure rotational Raman spectrum of air at 2017 UTC on 4 November 2017 averaged over 10 shots (1 s). Laser power: 300 mJ at 354.9 nm. ICCD time gate: 0.03-2 μs (4.5-300 m). Grating: 1200 g/mm. Entrance slit: 50 μm. Spectral resolution ≈ 5 cm^{-1}.



Elastic and Raman signals between 1726 and 1735 UTC on 3 Nov. 2017 averaged over 5400 shots (9 min). Laser power: 300 mJ at 354.9 nm. Detector: 32 channel PMT. Channel size: 1 mm. Grating: 1200 g/mm. Entrance slit: 50 μm. Spectral resolution ≈ 0.667 nm.

Collocation criterion



We will apply the trajectory matching method employed by *Tesche et al.* (2013) to collate CALIPSO observations of Saharan dust with ground-based observations at Praia, Cape Verde, during SAMUM-2 to find the segment of the EarthCARE ground track along which ATLID is most likely to observe the same air parcels that have been observed at the ground sites with a time delay determined by the length of the trajectories.

- ► overpasses west/east of the ground site are connected through forward/backward trajectories starting/arriving over the location of the ground site
- ► the along-track latitudinal interval of the satellite measurement most appropriate for comparison is given by the intersections between satellite ground track and trajectories at different height levels (thus accounting for along-track shear)
- ► in most cases, the vertical displacement along the trajectories is small if the distance between satellite ground track and ground station is less than 100 km
- ► aerosol profiles of ground-based and spaceborne instruments are not expected to show a large height shift of features
- ► larger disagreements in the comparison might be introduced when aerosol at different height levels is transported with different velocity
- ► across-track shear can be accounted for by averaging several hours of ground-based measurements for the comparison to an individual satellite overpass
- ► we will use a temporal window of 3 h for ground-based validation measurements following the approach used in the European Aerosol Research Lidar Network (EARLINET) for validation measurements of the CALIPSO lidar (*Pappalardo et al.*, 2010). This window will be centred on the time of an EarthCARE overpass in cases where the distance between EarthCARE's ground track and the ground sites is less than 500 km.
- ► in case of a larger distance, the time window will be moved to start earlier or later before the EarthCARE overpass depending on whether it will occur downstream or upstream of the ground-based lidar site, respectively.

References

Pappalardo et al. (2010), EARLINET correlative measurements for CALIPSO: First intercomparison results, J. Geophys. Res. Atmos. 115, doi:10.1029/2009JD012147.
Tatarov et al. (2012), Record heavy mineral dust outbreaks over Korea in 2010: Two cases observed with multiwavelength aerosol/depolarization/Raman-quartz lidar, Geophys. Res. Lett. 39, doi:10.1029/2012GL051972.
Noh et al. (2016), Vertically-resolved profiles of mass concentrations and particle backscatter coefficients of Asian dust plumes derived from lidar observations of silicon dioxide, Chemosphere 143, 24-31.
Tesche et al. (2013), Ground-based validation of CALIPSO observations of dust and smoke in the Cape Verde region, J. Geophys. Res. Atmos. 118, 2889-2902, doi:10.1002/jgrd.50248.
Tesche et al. (2018), Lidar spectroscopy instrument (LiSsI): An infrastructure facility for chemical aerosol profiling at the University of Hertfordshire, ILRC28, https://doi.org/10.1051/epjconf/201817601008.