Overview of measurements performed by the Raman Lidar BASIL in the frame of the Convective and Orographically-induced Precipitation Study

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7th COPS Workshop, 27-29 October 2008, Strasbourg, France
**BASIL Raman Lidar**

**Measured parameters:**
- Particle backscattering coeff. @ 355, 532 and 1064 nm $\beta$
- Particle extinction coeff. @ 355 and 532 nm $\alpha$
- Depolarization ratio @ 355 & 532 nm,
- Atmospheric temperature
- Water vapour mixing ratio
- Relative humidity from simultaneous measurements of temperature and water vapor mixing ratio

**COPS Web Page**
http://www.cops2007.de/

**Operational Products**
- Particle backscattering @ 532 and 1064 nm for 58 days
- Water vapour mixing ratio and temp. data for selected IOPs: 20 June, 15-16 July, 20 July and 1-2 August
- All other data available on request

**Raman lidar measurements**
(25 May – 30 August 2007)

More than 500 hours of measurements distributed over 58 days
Observation of a Saharan dust outbreak on 1-2 August 2007
Determination of size and microphysical particle parameters
Particle Backscatter Ratio at 1064 nm, 1-2 August 2007

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Water Vapour Mixing Ratio
1-2 August 2007

out-flow boundary
The retrieval scheme employs Tikhonov’s inversion with regularization.

Algorithm developed at the Physics Instrumentation Center.


In the solution of the inverse problem, particle size distribution $f(r)$ is approximated by the superposition of base functions $B_j(r)$ as:

$$f(r) = \sum_{j=1}^{q} c_j(z)B_j(r)$$

where $c_j(z)$ are the weight coefficients.

Base functions have a triangular shape on a logarithmic-equidistant grid.
Inversion with regularization

\[ r_{\text{min}} = 0.05 \, \mu\text{m}, \quad r_{\text{max}} = 15 \, \mu\text{m} \]

\[ 1.3 < m_r < 1.6 \]

\[ 0 < m_i < 0.04 \]

Mean radius \( r_{\text{mean}} \)
Effective radius \( r_{\text{eff}} \)
Number concentration \( N \)
Surface concentration \( S \)
Volume concentration \( V \)

Numerically integrating \( f(r) \) over the size interval \([r_{\text{min}}, r_{\text{max}}]\)
Focus: two specific times when aerosol loading was higher
21:00-21:30 UTC on 1 August 2007
00:00-00:30 UTC on 2 August 2007 (red dashed lines in figure)

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1 August 2007, 21:00-21:30 UTC

2 August 2007, 00:00-00:30 UTC

averaging layers
1710-2100 m
2100-2490 m
2490-2910 m
2910-3210 m
3690-4110 m
4110-4500 m
4500-4920 m
5310-5700 m

400 m thick

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Particle size distribution

**Dust particles**: non-spherical

Retrieval of particles parameters challenging

Mie kernel functions for spherical particles may not be appropriate for dust particles

Presently, we are developing **phase functions of dust part.**, considering ensemble of spheroids

\[ 0.1 \, \mu m < r_{\text{mean}} < 0.2 \, \mu m, \]
\[ 0.1 \, \mu m < r_{\text{eff}} < 1.0 \, \mu m \]
\[ 5 \, \mu m^3/cm^3 < \nu < 46 \, \mu m^3/cm^3 \]

**1 August 2007, 21:00-21:30 UTC**

**2 August 2007, 00:00-00:30 UTC**
Low depolarization values in the lower layer
The air masses observed in Achern in the altitude region 3.5-5 km a.g.l. originated in the mixed layer over the Saharan desert.
Substantial increase in particle backscattering when RH > 75 %

Swelling tendency of hygroscopic aerosol particles at large RH values

Trend compatible with partially soluble aerosol particles

Back-trajectories show that airmasses originated in the Saharan desert transited for several days over the Atlantic Ocean

Aged dust particles presumably mixed with maritime aerosol during the advection to the measurement site and partially coated with hygroscopic material

1 August 07, 22:00-23:00 UTC, Δt=2min, 3-5.5 km
Lidar and radar measurements in the melting layer: observations of dark and bright band phenomena

Changes in scattering properties of precipitating particles take place during the snowflake-to-raindrop transition, near the $0^\circ$C isotherm.

- **Maximum** in radar reflectivity at microwave wavelengths (Radar bright band).
- **Minimum** in particle backscatter in the optical domain (Lidar dark band, Sassen and Chen, 1995)
Instruments considered

Lidar measurements supported by:

- Cloud radar MIRA 36 (36 GHz, 0.83 cm, Ka-band), Univ. of Hamburg
- Dual-polarization micro rain radar (24.1 GHz, 1.24 cm, K-band), Univ. of Hamburg
- Clear air wind profiler (1.29 GHz, 23.24 cm, UHF band), the Univ. of Manchester

Unique data set

None of the previous reported measurements could rely on:

- MW lidar backscatter, extinction and depolarization data,
- MW radar reflectivity, depolarization and Doppler velocity data

Additional ancillary information on the state of the atmosphere was provided by:

- Radiosondes, launched every three hours during each measurement session
- Sodar
- Microwave radiometer
- Disdrometer

This large “ensemble” of instruments makes the collected dataset unique for the study of precipitating hydrometeors in the melting layer.

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23 July 2007

Temperature

Freezing level ~ 3350 m a.g.l.

Radar bright band 2950-3000 m a.g.l.

Lidar dark band 2850-2900 m a.g.l.

Lidar bright band 2700-2750 m a.g.l.

Lidar depol 25-30 % @ 3200 m, ~ 10 % @ 2850 m a.g.l.

Radar depol peak @ 2900 m a.g.l.

Radar Doppler velocity (@) reaches its plateau @ 2600-2700 m

Unexpected low values of lidar depolarization at the height of the lidar dark and bright bands, which may imply that precipitating particles are almost spherical or have a more regular shapes.
Simulation approach: • a Mie scattering code
• melting layer model

We combine:

Mie computations based on a concentric/eccentric sphere code

- Mie code for large particles with off-centre inclusions
- Ice core at the top/bottom of the water shell.

Melting hydrometeor model:

- water shell + ice core

(Yokoyama and Tanaka, 1984; Olson et al., 2001)

Evidence: Abrupt increase of $\beta$ for melt. ratios of 0.6-0.8
Structural collapse of partially melted snowflakes, leading to a decrease of lidar backscattering as a result of the reduced particles size and concentration (approx. 450-500 m below the freezing level).

Progression of the melting process, leading to a sudden increase of lidar backscattering when melting ratio is smaller than 0.8.
Comparison on water vapour and aerosol measurements from the Raman lidar BASIL with runs from Meso-NH model and other mesoscale models

Water Vapour Mixing Ratio, BASIL - Rhine Valley Supersite, 15 July 2007

ΔT: 5min
Comparison on water vapour and aerosol measurements from the Raman lidar BASIL with runs from mesoscale models

The model, in this case, appears slightly moist, with the upper humid layer extending higher up (4 km instead of 3 km)

ΔT: 5min
**Water vapour inter-comparison effort**

Comparison of measurements (quality assurance) from different water vapour remote sensing systems. Assessment of accuracy and precision.

**Figure:**
- Integrated water vapor over time in UTC (RADIO, GPS, MWR, BASIL).
- Water vapor mixing ratio (g/kg) vs. Height (m) for SAFIRE, DLR, and Bias.
- IGN Raman Lidar vs CNRS DIAL comparison in mean profiles.
- RS92 vs RS80 inter-comparison at 11:59 UTC on 13 July 2007.

**Comparison of measurements:**
- RS92 vs RS80 at 13 July 07, Time 11:59 (UTC).
- IGN Raman Lidar vs CNRS DIAL in various profiles.
- Quality assurance and assessment of accuracy and precision.
Passage of the frontal zone, with a Mesoscale Convective System inbedded

Cloud deck at 2 km represents a mid-level outflow from the thunderstorm/MCS.

The waves like structures seen in the data just prior to the arrival of the thunderstorm are due to shear between inflow and outflow regions.
Upper tropospheric humidity and its relation to deep convection and high clouds

BASIL – Rhine Valley Supersite (Lat: 48.64 ° N, Long: 8.06 E, Elev.: 140 m)
25-26 July 2007 – Water vapour mixing ratio

ΔT = 5 min, Δz = 150 m
Current research topics

- Raman Lidar observations of a Saharan dust outbreaks: determination of size and microphysical particle parameters.
- Lidar and radar measurements of the melting layer: observations of dark and bright band phenomena.
- Study of the evolution of MCSs based on Raman Lidar observations of particle backscatter, water vapour and temperature.
- Comparison of measurements (quality assurance) from different water vapour remote sensing systems. Assessment of accuracy and precision, and comparability of meteorological data.
- Comparison on water vapour and aerosol measurements from Raman lidar with runs from Meso-NH model and other mesoscale models.
- Upper tropospheric humidity and its relation to deep convection and high clouds