EMS Annual Meeting Abstracts
Vol. 8, EMS2011-528, 2011
11th EMS / 10th ECAM

Forecasting the weather
- ensemble techniques
in probabilistic weather prediction

Contribution of lidar measurements to characterize volcanic aerosols as demonstrated in case of the Eyjafjallajökull eruption

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In the course of the eruption of the Icelandic volcano Eyjafjallajökull in April/Mai 2010 it became obvious that lidar observations are an excellent tool to characterize aerosol plumes. This includes monitoring of the dispersion of the layers in space and time, and the assessment of optical and microphysical parameters. Lidar derived data sets were used to validate chemistry transport models (e.g., MCCM) and supported VAAC for air traffic control. The benefit of lidar data will further increase when data assimilation will be more mature, when networks (lidars including ceilometers, and sun photometers) are extended and become operational.

In this paper we briefly outline the potential of advanced lidar systems to characterize volcanic ash plumes. We report on continuous measurements with two EARLINET Raman and depolarization-lidars conducted at Maisach close to Munich, Germany. During the Eyjafjallajökull event the temporal development of the ash-plume could be documented in near real-time by means of range corrected signals. The optical characterization includes the backscatter coefficient at three wavelengths (355 nm, 532 nm, 1064 nm), and the extinction coefficient and particle linear depolarization ratio at two wavelengths (355 nm, 532 nm). Of special interest are intensive aerosol properties as they can be used to distinguish between aerosol types, e.g., volcanic ash, desert dust or biomass burning aerosols. For economic reasons (flight planning) primarily information of extensive properties, in particular mass concentrations, are in the focus of interest.

It was found that the pure volcanic ash plume, observed until noon of 17 April over Maisach, is characterized by lidar ratios of $50 < S_p < 60$ sr at 355 nm and $45 < S_p < 55$ sr at 532 nm. The linear depolarization ratio showed wavelength independent values of δ_p as high as $0.35 < \delta_p < 0.38$, indicating that the particles were non-spherical. The combination of these parameters is unique, so that the identification of ash layers is possible. Later, volcanic aerosols were mixed into the boundary layer. The relative contribution of boundary layer aerosols and the volcanic ash particles could be estimated from depolarization measurements.

The maximum extinction coefficient of the ash layer over Maisach was 0.75 km^{-1} for all lidar wavelengths, corresponding to a maximum mass concentration of approximately 1.1 $\mathrm{mg\,m}^{-3}$ over Maisach. It should be stressed that the retrieval of the mass concentration critically depends on the microphysics of the particles and requires numerical model calculations that have to take into account the shape of the particles. As a consequence, the frequently used Mie theory is not applicable and more complex approaches must be used (T-matrix, discrete dipole approximation, geometrical optics). Due to the ambiguity of the inversion process and measurement-errors, relative uncertainties of the mass concentration are in the order of 40 %.

Finally, we want to mention that the lidar measurements could be used to refine estimates of the source strength of the volcanic eruption.