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Separation of volcanic ash and sulfate aerosol based on lidar-photometer observations in central Europe after the eruption of the Eyjafjallajökull volcano

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Combined measurements of EARLINET polarization lidars and AERONET sun photometers are used to separate the contribution of sulfate and ash to volcanic aerosol layers and to retrieve respective height-resolved mass concentrations for observations of the Eyjafjallajökull aerosol plume in April and May 2010. Knowledge of the ash mass concentration is vital for air traffic regulations and the validation of ash dispersion models. Lidar observations of the linear particle depolarization ratio (δ) enable a height-resolved discrimination of backscattering related to sulfate (δ=0.01) and ash (δ=0.36). Sun photometer measurements of the ratio of volume concentration to AOT are used to estimate sulfate and ash mass concentrations and to derive respective extinction-to-mass conversion factors. The AERONET-derived fine mode is assumed to represent sulfate aerosol while the coarse mode is expected to be composed of ash particles. The high level of consistency between the AERONET observations of fine-mode and coarse-mode AOTs and respective polarization lidar observations of sulfate- and ash-related backscatter profiles corroborates that detailed information of volcanic aerosol layers can be obtained from a combination of the two instruments. The method is applied to observations at Cabauw, the Netherlands, and Hamburg, Leipzig, and Munich, Germany. The derived ash mass concentrations are in good agreement with coincident in situ observations performed aboard the DLR Falcon research aircraft.

A maximum ash AOT of 1.0-1.2 was observed on 16 April 2010 at Hamburg. An almost pure ash layer was present from 2.0-5.75 km height. Maximum particle depolarization ratios and lidar ratios in the ash plume were 0.34 and 50-55 sr, respectively. The AERONET fine-mode fraction was about 15%. The estimated ash mass concentration reached values of 1000 $\mu g/m^3$. The column ash load of the 4 km deep plume was 1750 mg/m^2. The volcanic plume reached Leipzig about 6-9 hours after it had passed Hamburg. The maximum ash-related 500-nm AOT was 0.7. Peak ash mass concentrations again were of the order of 1000 $\mu g/m^3$. The maximum ash load was about 1000-1200 mg/m^2. On 19 April 2010 (more than 100 h after the emission) aged volcanic layers passed Leipzig for a second time. On that day the DLR Falcon performed in situ observations which covered the height range from 2-9 km over Leipzig. Meanwhile, the aged ash plume over Leipzig consisted of two ash-containing layers: one below 3 km height and one from 3.5-6 km height. In the lower layer, sulfate particles considerably contributed to the observed backscatter coefficients. The AERONET fine-mode fraction was 77%. The lidar-based sulfate backscatter fraction was 76%. The sulfate mass concentration in the volcanic layer from 1-2 km height increased from 50 $\mu g/m^3$ in the morning to almost 100 $\mu g/m^3$ in the late afternoon. The ash mass concentration was 50 $\mu g/m^3$ in the free tropospheric layer. It showed peak values of up to 375 $\mu g/m^3$ in the lower layer from 2-2.5 km. The DLR Falcon observed ash mass concentrations on the order of 40 $\mu g/m^3$ at heights around 4-4.5 km and values above 200 $\mu g/m^3$ in the layer below 3 km height.