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Ice formation in ash-influenced clouds after the Eyjafjallajökull eruption in April 2010

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During the eruption episode of the Eyjafjallajökull volcano lidar measurements were of great importance for the documentation of the spatiotemporal development of the volcanic plume above the European continent. Besides the direct observation of the optical aerosol properties, polarization lidar measurements documented also the interaction of the volcanic aerosol with clouds. This conference contribution presents lidar observations of aerosol-cloud interactions at the two German EARLINET (European Aerosol Research Lidar Network) stations of Leipzig (51° N, 12° E) and Maisach (48.2° N, 11.3° E).

The study concentrates on cloud observations made between 16 April and 25 April 2010 when the plume of the first eruption period of the Eyjafallajökull volcano was advected towards central Europe. 90 distinct cloud layers that were embedded in the volcanic aerosol were observed during this time period. In order to investigate the effect of volcanic aerosol on heterogeneous ice formation, the phase state of each cloud layer was categorized according to its light-depolarization properties as either ice-containing or pure liquid-water.

The effect of the volcanic aerosol on the formation and phase state of the observed free-tropospheric clouds was manifold. Volcanic ash particles were found to be very efficient ice nuclei as soon as cloud top temperatures reached values of below -10 °C. Whereas no indications for heterogeneous ice formation were found in the observed cloud layers with top temperatures of above -10 °C, only ice-containing clouds were observed at temperatures of below -15 °C. Under non-volcanic aerosol conditions a 90% probability of cloud freezing is reached only at cloud top temperatures of below -25 °C. The high freezing efficiency of the volcanic ash is attributed to the good suitability of insoluble volcanic ash particles for crystal nucleation via contact freezing or immersion freezing. However, indications were found that high concentrations of water-soluble volcanic sulphate can suppress heterogeneous freezing of supercooled droplets down to temperatures of -35 °C.

At temperatures of below -40 °C volcanic aerosol was found to contain efficient deposition freezing nuclei. Under humidity conditions saturated with respect to ice only, a cirrus cloud formed in the volcanic aerosol at temperatures between -41 °C and -54 °C. The observed low cloud optical depth of approximately 0.01 suggests the formation of a small number of small ice crystals via the direct deposition of water vapour onto the surface of the volcanic aerosol particles.

An indirect effect of the volcanic eruption on cloud processes was the suppression of the formation of contrails caused by an extensive shutdown of air traffic over large parts of central Europe between 16 April and 21 April 2010. When flights were resumed on 22 April 2010, contrails that formed in the ash plume were observed between 7.5 and 9 km height above Leipzig. The contrails persisted over 4 hours, suggesting a considerable impact of these anthropogenic clouds on the radiation budget of the atmosphere.