Aerosol-cloud interactions in Saharan mineral dust over the Eastern Mediterranean

M. Dollner[1], J. Gasteiger[1,a], K. Kandler[2], M. Schöberl[1,3] A. Sudharaj[2], B. Witschas[4] and B. Weinzierl[1]

[1] University of Vienna, Faculty of Physics, Aerosol Physics and Environmental Physics, Wien, 1090, Austria
[2]Institute of Applied Geosciences, Technical University Darmstadt, Darmstadt, 64287, Germany
[3]University of Vienna, Vienna Doctoral School in Physics, Vienna, 1090, Austria
[4]Deutsches Zentrum für Luft- und Raumfahrt (DLR) e.V., Institut für Physik der Atmosphäre, Oberpfaffenhofen, 82234, Germany
[a]now at: Hamtec Consulting GmbH @ EUMETSAT, Darmstadt, Germany
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Presenting author email: maximilian.dollner@univie.ac.at

Mineral dust is one of the most substantial contributors to the atmospheric aerosol load by mass, yet a comprehensive understanding of associated atmospheric processes remains not well understood. While laboratory experiments have determined mineral dust's capacity as cloud condensation nuclei (CCN) and ice nucleating particles (INPs), atmospheric measurements are rare.

This study presents unique in situ and remote sensing observations of dust-embedded clouds in the Mediterranean on 20 April 2017, during the A-LIFE campaign. The campaign utilized the DLR Falcon research aircraft to explore the characteristics of mixtures of absorbing aerosols throughout their atmospheric lifetime. Employing in situ measurement techniques for shadow images and particle size distributions of aerosol and cloud particles, relative humidity, and cloud liquid water content (LWC), along with remote sensing measurements of a Doppler wind lidar (DWL), we characterize microphysical properties of dust and cloud particles.

A key instrument in this study is the second-generation Cloud, Aerosol, and Precipitation Spectrometer (CAPS), which captures shadow images and records size distributions of coarse-mode aerosol and cloud particles. For the analysis of the data recorded with the Cloud and Aerosol Spectrometer (CAS) within CAPS, we are introducing a novel size distribution retrieval, considering instrumental uncertainties. This retrieval, utilizes a Monte Carlo method and reports particle sizes as geometric diameters, accounting for non-sphericity and refractive index of measured particles. The hotwire sensor of the CAPS, responsible for the LWC measurements, was calibrated with a newly developed machine learning (ML) method also introduced in this study.

The study presents a detailed analysis of clouds embedded in a dense mineral dust layer, revealing two separate aerosol-cloud interaction processes occurring in the dust-embedded clouds. First, examining ice crystal measurements at the cloud top and size distributions from the mineral dust layer supports the hypothesis of heterogeneous ice nucleation, aligning with laboratory experiments and widely used INP parameterization. The second process involves small-scale CCN activation of mineral dust particles, resulting in small liquid droplets (~10 µm). The analysis demonstrates that mineral dust particles with activation diameters as small as 0.13 to 0.23 µm act as CCN and activate into cloud droplets, consistent with laboratory studies. DWL observations affirm small-scale vertical lifting as the catalyst for a significant increase in water supersaturation, creating an environment conducive to initiating the CCN activation of mineral dust.