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Remote sensing of particle size profiles from cloud sides: Observables and retrievals in a 3D environment

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Deep convection plays an essential role for climate since it is a key processor of aerosol particles and trace gases and has a large influence on the solar radiation budget as well as on the global water cycle. The lifetime and albedo of deep convective clouds are influenced by the interactions between the cloud droplet growth and the aerosol uptake. The monitoring of the microphysical processes throughout the deep convective cloud becomes therefore increasingly essential for a better understanding of earth's climate.

While remote sensing techniques have become more and more sophisticated, cloud sides have remained a terra incognita to most of them. As remote sensing applications from space usually can only observe cloud tops, information about the vertical process from aerosol activation to rainout of large cloud droplets is scarce. Yet it is precisely the vertical evolution of the effective radius profile that is responsible for the observable value at cloud top which, in turn, has probably the largest influence on cloud albedo and therefore on the solar radiation budget. For this reason, the remote sensing of cloud sides using reflected solar radiation was recently proposed as a new method to gain new insights into the vertical structure and processes in deep convective clouds. To meet these challenges, a multi-sensor aerosol / cloud scanner is installed on the roof at the Meteorological Institute Munich, comprising a spectrometer, covering the solar spectrum from 0.4 to $2.5\,\mu m$ and the thermal from 8 to $14\,\mu m$, a cloud radar (36 GHz) and a multi-wavelength LIDAR system.

Though classical retrievals like Nakajima-King perform well in 1D environments, they fail when faced with the small scale structure of cloud sides. In order to better understand the challenges to be met, 1D retrievals will be taken to their limits when applied to more complex cloud geometries. Thereby we examine the influence of a unknown cloud surface orientation on 1D retrievals, which are based on reflected solar radiation. Since cloud inhomogeneity does not only influence measured reflectivities but also obscures the relative contribution of individual layers to the overall retrieval we furthermore present a Monte Carlo based weighting technique to cope with mixed-phase clouds and vertical gradients in cloud droplet size.

In combining the gained insights, we have adopted a statistical approach for the development of a 3D retrieval of the effective radius and the corresponding uncertainties. To this end, extensive Monte-Carlo calculations of the 3D radiative transfer have been conducted to account for the ill-posed problem which is caused by various 3D-effects. It was recently proposed to combine remote sensing methods using reflected solar radiation with active methods like cloud radar. We will therefore assess the potential for new insights in vertical profiles of phase and particle size. In addition, we will present first measurements obtained from the installed spectrometer.