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Retrieval of Cirrus Cloud IWC Profile from Ground-Based Remote Sensing Using the Synergy of Lidar and Multi-Spectral Infrared Radiometry

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Recent advances in satellite observational systems, in particular the active sensors of the A-Train constellation, have shown that cirrus clouds are the most frequently observed cloud type in the atmosphere. Although the strong influence of cirrus clouds on the radiative budget of the Earth has long been recognized, our knowledge of the variability of their microphysical and optical properties which determine their net radiative effect is still poor.
Infrared radiometry is a well-adapted tool to study the integrated properties of cirrus clouds and has been used in several ground-based and satellite studies. However, this passive measurement technique does not yield information about the vertical profile inside the cloud. Lidar systems in contrast provide vertical profiles of the power backscattered by atmospheric particles and hence give us access to the geometrical properties of the cloud, in particular the altitudes of the cloud base and top which implies important information about the cloud temperature. Furthermore, profiles of visible extinction and Ice Water Content (IWC) can be retrieved from these measurements. However, due to the backscatter-to-extinction ambiguity arising from the combination of scattering and absorption processes in the atmosphere, assumptions are required for the backscatter-to-extinction ratio when regarding Lidar measurements alone.

In this study, we propose a new algorithm to retrieve IWC profiles of cirrus clouds by using the synergy of ground-based Lidar and thermal infrared radiometer measurements. The algorithm is based on optimal estimation theory and combines the visible Lidar and thermal infrared radiometer measurements in a common retrieval framework to retrieve profiles of IWC together with a correction factor for the backscatter intensity of cirrus cloud particles. As mentioned above, in Lidar remote sensing problems one usually needs to introduce the backscatter-to-extinction ratio defined as the product of the single scattering albedo and the phase function in backscattering direction. These quantities are both linked to the IWC via the microphysical model of Baran et al. 2009. Since the phase function of ice crystals in backscattering direction has not yet been fully characterized, the calculation of the backscatter-to-extinction ratio with the above-mentioned definition introduces a large uncertainty on the retrieved IWC profile. The thermal infrared radiometer measurements are sensitive to the Ice Water Path (IWP) and hence they can be used to constrain the IWC and the backscatter-to-extinction ratio. As a consequence the value of the phase function in backscattering direction is constrained by these measurements under the assumption that the single scattering albedo is represented sufficiently exact in the microphysical model.