Ice particle morphology and microphysical properties of transparent cirrus clouds inferred from CALIOP–IIR measurements

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Microphysical properties and ice particle morphology of cirrus clouds are important for estimating the radiative forcing associated with these clouds. Many satellite measurements allow us to estimate the cloud optical thickness (COT) and cloud-particle effective radius (CER) of cirrus clouds over the globe via multiple retrieval methods such as the bi-spectral method using visible and near-infrared cloud reflectivities, the split-window method using thermal infrared brightness temperatures and the unconstrained method using lidar signals. However, comparisons among these retrievals exhibit discrepancies in some cases due to particular error sources for each method. In addition, methods to infer ice particle morphology of clouds from satellite measurements are quite limited. To tackle these current problems, we develop an optimal estimation based algorithm to infer cirrus COT, CER, plate fraction including horizontally oriented plates (HOPs) and the degree of surface roughness from the Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP) and the Infrared Imaging Radiometer (IIR) on the Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) platform. A simple but realistic ice particle model is used, and the bulk optical properties are computed using state-of-the-art light-scattering computational capabilities. A rigorous estimation of the uncertainties related to the surface properties, atmospheric gases and cloud heterogeneity is performed. A one-month global analysis for April 2007 with a focus on HOPs shows that the HOP fraction has significant temperature dependence and therefore latitudinal variation. Ice particles containing many HOPs have small lidar ratio due to strong backscattering. The lidar ratio of cirrus clouds has a negative correlation with the temperature where the cloud temperature is warmer than −40℃, for which the median HOP fraction is larger than 0.01%.

Keywords: Cloud properties, Satellite remote sensing, Oriented ice crystals

