Development of CloudSat/CALIPSO- and EarthCARE-algorithms for studies of cloud macroscale- and microphysical properties

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This work improved on cloud mask, cloud particle type and cloud microphysics algorithms that can be applied to CloudSat-CALIPSO and EarthCARE satellites. We first revised the cloud mask algorithm designed for CALIPSO lidar developed by Hagihara et al., to increase the detectability of cloud bottom regions in CALIPSO lidar observations. Algorithm for cloud particle type (cloud phase and orientation of ice particles) developed by Yoshida et al., is also refined. Introducing the new function, cloud particle phase near cloud bottom is better characterized by the revised algorithm. Retrieval algorithm for ice cloud microphysics is also carried out to extend the one developed by Sato and Okamoto with modified look up tables for ice particles. That for water cloud microphysics was newly implemented.
The refinements were achieved by using the new type of ground-based lidar, Multiple-Field of View Multiple Scattering Polarization lidar (MFMSPL) with cloud radar. MFMSPL was designed to measure enhanced backscattering and depolarization ratio comparable to space-borne lidar. The system consists of five sets of parallel and perpendicular channels with different zenith angles. We first evaluated our former cloud mask scheme. It was applied to the data obtained by the MFMSPL and it was found that the cloud mask scheme underestimated cloud top portions. New cloud mask scheme showed improvement in the detectability of cloud top portions. Co-located 95GHz cloud radar and MFMSPL with the new cloud mask scheme showed good agreement at the cloud top altitude. The cloud mask scheme also has a function to identify fully attenuated pixels where lidar and cloud radar signals are totally attenuated.
Our former cloud particle type algorithm was evaluated by the observed attenuated backscattering coefficient and depolarization ratio by off-beam channels of MFMSPL. Extinction-depolarization ratio diagram is created based on the observed data. The analyses of MFMSPL show that large depolarization ratio with small attenuation can be caused by water clouds. The features have not observed in the CALIPSO lidar data since our former cloud mask scheme did not detect cloud bottom portions in the analysis of CALIPSO lidar data and such features are found in the regions newly detected by the improved cloud mask algorithm. The new feature is implemented in the refined cloud particle type algorithm to better discriminate ice and water where lidar signals are largely attenuated and depolarization ratio increased.
We report the results of global analyses of cloud fraction, ice/water fraction and ice/water microphysics by using CloudSat and CALIPSO. We also discuss possible extension of the algorithms for cloud profiling radar (CPR) and high spectral resolution lidar (ATLID) on EarthCARE.

Keywords: cloud, radar, lidar

