

Identification of Mixed Phase Clouds Using Combined CALIPSO Lidar and Imaging Infrared Radiometer Observations

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The thermodynamic phase of clouds detected by the Cloud Aerosol Lidar Pathfinder Satellite Observation (CALIPSO) lidar is determined based on the relationship between two quantities measured at 532 nm: the layer-integrated depolarization ratio (δ_v) and the layer-integrated attenuated backscatter (γ'_{532}). Using the so-called Hu diagram relating δ_v and γ'_{532} , which was established from Monte Carlo simulations, CALIPSO can effectively discriminate between liquid water clouds, clouds composed of randomly oriented ice (ROI) crystals, and ice clouds that contain some fraction of horizontally oriented ice (HOI) crystals. The latter are characterized by contributions from specular reflections of laser light from horizontally aligned crystal facets that generate strongly enhanced backscatter coupled with reduced (to near zero) depolarization. HOIs were frequently observed at the beginning of the CALIPSO mission, when the platform was tilted at an angle of 0.3° off nadir, but they are only rarely seen since December 2007 when the tilt angle was changed to 3° off nadir.

In this presentation, we propose an extended Hu diagram that additionally identifies mixed phase clouds by incorporating perfectly co-located effective diameter (D_e) retrievals in the thermal infrared window obtained from the CALIPSO Imaging Infrared Radiometer (IIR). First, we characterize the location of the water clouds in the Hu diagram as a function of cloud top temperature. In doing so, we see a marked change for top temperatures smaller than 238 K, when ice is expected in the upper portion of the cloud, which represents less than 1 % of the supercooled water clouds. The IIR effective diameters are larger in these mixed phase clouds than in those clouds having top temperatures warmer than 238 K, which can be purely liquid. Second, by adding collocated D_e information, we show that the HOI class clusters into two families of δ_v - γ'_{532} relationships, suggesting mixed phase clouds with smaller D_e and pure ice clouds with larger D_e . The observed δ_v - γ'_{532} relationships for these two clusters are shown to be consistent with Monte Carlo simulations published in the literature. Using this new technique, approximately 30 % of HOI clouds with layer centroid temperature larger than 245 K are identified as mixed phase HOI clouds, while this fraction is less than 1 % in colder HOI clouds.