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Remote sensing of ice crystal asymmetry parameter from multi-directional polarization measurements

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The fundamental radiative properties of ice clouds for global climate model projections can be represented in terms of optical thickness, effective ice crystal size, and the asymmetry parameter of the scattering phase function. Satellite measurements such as those from MODIS are currently used to retrieve cloud optical thickness and effective radius, but cannot effectively constrain the asymmetry parameter. Moreover, such MODIS cloud products are sensitive to the asymmetry parameters of the ice crystal habits assumed in the retrievals. To our knowledge, no global surveys of the asymmetry parameter of ice clouds exist. While ice crystal habits are highly variable, it has been shown that the optical properties of complex crystals strongly resemble those of their components and that observed variations in the asymmetry parameter of ice clouds can be represented in terms of the aspect ratio and surface roughness of simple hexagonal ice crystal components. Multidirectional polarization measurements, such as those made by the Research Scanning Polarimeter (RSP), AirMSPI and POLDER instruments, provide sufficient constraints on aspect ratio and surface roughness to allow for a robust retrieval of the asymmetry parameter. Here we present a remote sensing technique to simultaneously retrieve ice crystal asymmetry parameter from multidirectional polarization measurements and ice crystal effective radius and ice cloud optical thickness from near-infrared and visible reflectances. After outlining the technique, we present an evaluation using a range of simulated conditions. Then we apply the approach to measurements from the airborne RSP taken during the CRYSTAL-FACE campaign, and compare results with those of the collocated MODIS Airborne Simulator and in situ Cloud Integrating Nephelometer measurements obtained within the same cloud. Finally, we explore the possibility to apply the technique to combined observations of the MODIS and POLDER instruments in the A-train constellation in order to obtain a global climatology of ice cloud asymmetry parameters that can be stratified by cloud optical thickness, cloud top temperature and particle size.