1.17 A PROBABILISTIC POLARIMETRIC RADAR FORWARD MODEL FOR SMALL ICE PARTICLES

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Polarimetric radar observations provide information about the physical properties of ice particles; this information is valuable for better understanding cloud and precipitation systems, as well as evaluating microphysical model simulations of such systems. Comparisons of polarimetric radar observations and microphysical model output require a forward model to convert the physical properties simulated within the microphysical model to the polarimetric radar observables.

In the most detailed microphysical models, ice particles are characterized with a maximum dimension, an aspect ratio, and a bulk effective density; these properties must also be used to determine the scattering properties of the ice crystals. Frequently, scattering of these ice crystals is represented by homogeneous, bulk-density spheroids, with the assumption that the ice particle mass is evenly distributed throughout its volume. The scattering is then calculated (for particles small relative to the radar wavelength) using the Rayleigh approximation with an effective dielectric constant that approximates a mixture of ice and air.

However, this method often underestimates the values of the polarimetric radar quantities. For example, errors in differential reflectivity (ZDR) can be up to 4.5 dB for low-density, and low-aspect-ratio branched planar ice crystals. Calculations with numerical techniques such as the Discrete Dipole Approximation (DDA) accurately capture the scattering of ice crystals with detailed shapes but require relatively large computational resources, and provide no estimate of the uncertainty in scattering due to the uncertainty in the assumed shape.

To address these issues, an analytical forward model for the polarimetric radar variables is developed that also provides estimates of the uncertainty in the radar variables due to the ambiguity in ice crystal structure for a given effective density. This forward model was generated using several thousand DDA calculations for a variety of realistic ice crystal shapes, sizes, and aspect ratios. The scattering of each realistic ice crystal was then assumed to be represented by an equivalent solid-ice spheroid. This mapping from model-predicted ice particle properties to solid-ice spheroids is performed analytically using fits of the changes in maximum dimension and thickness as functions of effective density and aspect ratio. The scattering properties are then calculated for the equivalent solid-ice spheroids using the Rayleigh approximation. The variability in the equivalent solid-ice spheroids for a given maximum dimension, aspect ratio, and effective density is then used to estimate uncertainty in each of the radar variables due to the natural variability in ice particle structure.

Comparisons of the radar variables calculated with DDA and with the analytical forward model show negligible biases in the backscatter cross-section, Z_{DR}, and specific differential phase. Forward simulations of the radar variables from microphysical model output are more consistent with radar observations than the

Rayleigh approximation for homogeneous, reduced-density spheroids, where low biases in these variables occur. These improvements in realistically capturing the scattering of natural branched planar ice crystals and estimates of the uncertainty in the radar variables due to structural variability will allow for retrievals of the physical properties of ice particles from radar observations.