Using Polarimetric Doppler Radar Observations to Probabilistically Inform a New Class of Particle-Property Predicting Bulk Ice Microphysics Schemes

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Ice clouds exert an important influence on our planet's radiative budget and climate, yet the microphysical processes governing their evolution (vapor deposition, riming, aggregation, sedimentation) remain poorly understood. Consequently, these processes are crudely represented in bulk and bin microphysics schemes with process rate equations that are weakly constrained by measurements and observations. Laboratory measurements give important constraints, but are limited in their applicability owing to the small range of phase space available to experimental devices. Observations (e.g., polarimetric and/or multi-frequency radars) can help bridge this gap, as these systems provide substantial information on ice growth over a wide range of conditions. However, most traditional bulk ice microphysics schemes do not predict the radar-observed quantities required to make a meaningful comparison with observations. This necessitates prescribing these quantities in the forward observation operator externally from the microphysics model, making meaningful evaluation of microphysics schemes impossible.

A new class of microphysics schemes has been developed that explicitly predict ice particle properties (e.g., aspect ratio, density, fall speed) according to the processes controlling growth. These models predict the quantities needed to directly link model variables to radar observables. Using the model-predicted particle properties and our new probabilistic polarimetric radar forward operator that maps modeled ellipsoids to representative electromagnetic scattering properties of detailed ice particles, we demonstrate constraint of our ice microphysics scheme using scanning polarimetric X-band and profiling Ka-band Doppler radars at the U.S. Department of Energy's North Slope of Alaska observing site. We show where observations give information on the physics of ice particle growth, and where simulation and observational uncertainties need to be reduced, or additional constraints must be added, for meaningful and unambiguous conclusions to be drawn from radar measurements.

Keywords: Ice microphysics, Snow, model parameterizations, forward operator