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Using BOSS to learn microphysical process rate information from polarimetric radar observations

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Representing microphysics within weather and climate models is challenging because we lack fundamental understanding of microphysical processes and are limited by the computational inability to track each hydrometeor within a cloud system. Microphysics schemes parameterize rates for specific processes such as drop evaporation, collision-coalescence, or collisional-breakup, but their inherent assumptions lead to uncertainty in model solutions which are often difficult to understand and quantify. Observations such as those from polarimetric radar provide insight into the microphysical evolution of clouds, but alone they are unable to provide quantitative information about the process rates that lead to this evolution. The Bayesian Observationally Constrained Statistical-Physical Scheme (BOSS) is a recently-developed bulk microphysics scheme designed to bridge the gap between observations and the processes acting on individual drops, such that process rate information can be directly learned from polarimetric radar observations. BOSS operates with no predefined drop size distribution (DSD) shape and makes few assumptions about the process rate formulations. Because there is no prescribed DSD shape, a new moment-based polarimetric forward operator is used to relate model prognostic moment output to polarimetric radar variables. Process rates are written as generalized power functions of the prognostic DSD moments (related to bulk quantities such as mass concentrations), with flexibility to choose the number and order of the prognostic DSD moments and number of power terms in the process rate formulations. The corresponding process rate parameters are constrained directly with observation using Markov chain Monte Carlo in a Bayesian inference framework, allowing BOSS to learn microphysical information directly from observations while simultaneously quantifying parametric uncertainty. The process rate formulations in BOSS can be made systematically more complex by adding more terms and/or more prognostic DSD moments, which allows us also to track down sources of structural uncertainty. In this study, we use a detailed bin microphysics scheme as “truth” to generate the constraining observations synthetically, which include profiles of polarimetric radar variables (Z_H, Z_{DR}, K_{DP}) and vertical fluxes of prognostic DSD moments at the surface. An error analysis shows that BOSS produces process rate profiles similar to those of a bin scheme when only provided polarimetric rain profiles and surface prognostic moment fluxes. We also display initial results where BOSS is used to estimate microphysical process rate information from real polarimetric radar observations.