How much can we learn about rain microphysics from polarimetric radar observations?
An investigation of information content and parameter estimation using the Bayesian Observationally-constrained Statistical-physical Scheme (BOSS)

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Bulk microphysics schemes exhibit deficiencies that are due in part to their simplified representation of a complex natural state, and in part due to a fundamental lack of understanding of microphysical processes. Polarimetric radar observations provide necessary 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) bridges this gap, allowing information on microphysical processes to be gained by models from observations. BOSS operates without a predefined drop size distribution (DSD) shape and makes no assumptions about parameterized process rates. Instead, BOSS uses a Monte Carlo Markov Chain sampler within a Bayesian inference framework to constrain model microphysics directly with polarimetric radar observations. 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. In this study, we use synthetic radar observations in an idealized framework to constrain BOSS. We explore the information content that is gained from different observed polarimetric radar variables (\(Z_H\), \(Z_{DR}\), \(K_{DP}\)) with respect to various modeled warm rain microphysical processes (evaporation, collision/coalescence, and drop breakup). BOSS has the flexibility to choose the type and number of prognostic DSD moments predicted. We use this flexibility to explore the information content gained by polarimetric radar variables when BOSS predicts the 0\(^{th}\) and 3\(^{rd}\) DSD moments (M0M3 BOSS), the 3\(^{rd}\) and 6\(^{th}\) moments (M3M6 BOSS), and the 0\(^{th}\), 3\(^{rd}\), and 6\(^{th}\) moments (M0M3M6 BOSS). When compared to knowledge of moment flux alone, we show that constraining BOSS with a profile of polarimetric radar information improves the constraint of process rates, therefore leading to improved rain rate estimation. Interestingly, individual polarimetric radar variables provide different amounts of information gain among unique simulations defined by different initial conditions. The polarimetric variable that produces the most information gain also changes between simulations, suggesting that each polarimetric radar variable provides unique information to BOSS. The inclusion of higher order prognostic moments is also shown to improve process rate constraint and rain rate estimation due to the better correlation between higher order moments and the polarimetric radar variables used to constrain BOSS. We also display initial results of BOSS constrained by real polarimetric radar observations within a limited subset of warm rain cases.

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