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Multiscale Characteristics of Multisource Perturbations and Their Interactions for Convection-Permitting Ensemble Forecasting during SCMREX

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The multiscale characteristics of initial conditions (ICs), model physics (MO), and lateral boundary conditions (LBCs) perturbations, as well as their interactions, are investigated based on an experimental convection-permitting ensemble prediction system (CPEPS) used in Southern China, namely GM-CPEPS, with a focus on 32 12-h forecasts collected over a half-month period of the Southern China Monsoon Rainfall Experiment (SCMREX) in May 2014. GM-CPEPS includes 16 perturbed members based on the Global/Regional Assimilation and Prediction System (GRAPES) with the resolution of about 3 km.
Forecast perturbations differed from each other in terms of magnitude, evolution, and vertical distribution between components at different scales. The meso-β-scale MO perturbations show faster growth and saturation, as well as larger magnitude than the meso-α-scale ones, especially in the presence of moist convection. For IC perturbations, damping was present for nonprecipitation variables, while rapid growth and saturation occurred for precipitation. Adding LBCs perturbations to IC or MO perturbations caused linear impacts, which caused consistent, although small, perturbation increments. Nonlinear impacts of adding MO perturbations to IC perturbations were evident and were intrinsic to the predictability limits of IC and MO perturbations, which were closely related to moist dynamics. Specifically, meso-β-scale forecast perturbations generated by the combination of IC and MO perturbations will not grow when MO perturbations reach their saturation values and thus saturate at these saturation values, which are significantly smaller than the magnitudes of IC perturbations. These nonlinear impacts had the most significant effects on meso-β-scale precipitation perturbations and can effectively improve precipitation prediction. These results highlight the importance of developing multiscale and multisource perturbation methods for CPEPS design that reasonably include the interactions among different-scale perturbations from different sources, especially the nonlinear impacts of adding MO perturbations to IC perturbations.