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Development of a seamless mesoscale ensemble data assimilation and prediction system

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Ensemble-based mesoscale data assimilation and probabilistic forecasting are traditionally separated in their developments. However, an accurate forecast of probabilistic distribution functions of state variables is in fact equally important for both ensemble-based data assimilation and probabilistic prediction. Poor sampling and forward propagation of initial states and model uncertainties lead to inaccurate probabilistic forecasts and deficient estimate of background error covariance required for Ensemble Kalman Filter data assimilation (EnKF). Thus a well-formulated ensemble prediction system should provide more accurate estimate of the forecast error covariance for EnKF. On the other hand, EnKF is an effective tool for sampling the model initial condition uncertainties that are highly desirable for mesoscale ensemble prediction. It should be noted that mesoscale processes are more complicated than global models and may be dominated by physical processes at times. Thus mesoscale model forecast errors (uncertainties) depend heavily on parameterized physical processes that contain many assumptions and uncertain parameters. A seamless ensemble data assimilation and probabilistic prediction scheme can address the issues on both aspects.

An innovative seamless mesoscale ensemble data assimilation and prediction system has been developed at NCAR. The system contains two major sub-modeling systems. One is the NCAR mesoscale Ensemble Real-Time Four Dimensional Data Assimilation (E-RTFDDA) and forecasting system has been developed at NCAR and the other is the NCAR DART (Data Assimilation research Testbed) EnKF modules. E-RTFDDA, built based on WRF and MM5 models, contains diverse ensemble perturbation approaches that take into account of uncertainties in all major modeling system components to produce multi-scale, continuously-cycling probabilistic data assimilation and forecasting. A 30-member E-RTFDDA system with three nested domains with grid sizes of 30, 10 and 3.33 km has been operating for US Army test ranges since September 2007. In the seamless system, the NCAR DART EnKF tools are integrated to E-RTFDDA to formulate an integrated ensemble data assimilation and prediction capability. With this system, EnKF takes advantages of E-RTFDDA by deriving error covariance with an addition of the multiple-perturbation-approach E-RTFDDA forecasts and then it feeds E-RTFDDA with a subset of initial condition perturbations derived from the EnKF perturbation members.

Numerical experiments have been conducted for a Cold Air Damming weather event over the Northeastern US to validate and assess the theory and the advantages of the seamless ensemble data assimilation and prediction system. The modeling results and the directions for further improvements will be presented.