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An analysis of multiple approaches for mesoscale ensemble forecasting

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Mesoscale (10-2000 km) meteorological processes differ from synoptic circulations in that mesoscale weather changes rapidly in space and time, which renders it less predictable. Mesoscale processes are influenced by synoptic circulations, and can be caused by local topography and underlying surface physical properties. Physical processes such as radiative transfer, cloud and precipitation, boundary layer mixing, etc., sometimes play dominant roles in shaping the regional weather and climate. Thus, unlike the global ensemble systems in which attention is mostly focused on initial conditions, adding perturbations associated with the fast growing modes, mesoscale ensemble prediction systems need to address the uncertainties associated with other aspects of modeling systems. It is known that relatively large errors in mesoscale models often lead to an unrealistically small spread and large systematic errors in ensemble forecasts.

To accommodate the broad factors that control mesoscale weather forecasts, multiple approaches are designed to construct a mesoscale ensemble. This includes perturbations to model initial conditions (IC), lateral boundary conditions (LBC), model physical parameterizations (PP), and the underlying land-surface (LS) characteristics. In the ensemble system, the LBC perturbation includes approaches of deriving LBCs from different global models, and adding large-scale phase errors and model error statistic using a 3DVAR scheme. The IC perturbation consists of perturbing observations and data analysis weighting, and an Ensemble Transform Kalman Filter (ETKF) approach. The PP perturbation includes alternating between different parameterization schemes and perturbing the most sensitive and uncertain parameters in some schemes. Finally, the LS perturbations are constructed to consider the uncertainties in land surface properties (e.g. albedo, vegetation, greenness factor, etc.). An off-line high- resolution land-surface data assimilation system is used to generate an ensemble

of land-soil thermal and moisture states to facilitate the LS perturbation.

The approach described above results in a huge ensemble that is prohibitively expensive at present. Fortunately, it is known that certain response function (i.e. forecast variables of interest) are more sensitive to one set of controlling factors than another, and these sensitivities may vary with the weather regime. Thus, to mitigate the rank-deficiency issue, a two- tier ensemble system is designed. The first tier contains an ensemble perturbation generator. In this tier, tools are developed to generate perturbations to all important mesocale modeling components, producing a library of potential ensemble members which is as complete as possible. The second tier, where ensemble members execute and cycle, contains a member (perturbation) selecting tool that chooses the most important members from the library on the first tier according to the application goals and weather scenarios, and constructs an ensemble with a size appropriate for the available computing resource. In collaboration with the US Army Test and Evaluation Command, such an ensemble system has been implemented on a 69-node, 272-processor Linux cluster. The system is capable of running a 55-member nested-grid ensemble with a fine mesh of 230 by 230 km and a 3.3 km grid increment. The system cycles at 6-hr intervals, producing 3648 h forecasts in each cycle. The system started operational production in January 2007. Forecasting examples and preliminary system evaluation will be reported at the meeting.