ENSEMBLE FORECASTS OF TORNADIC THUNDERSTORMS

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1. Research Activity Overview

Ensemble forecasting has proven valuable in medium-range global model forecasts (6-10 days) and now is a foundation in major operational forecast centers around the world (Kalnay 2003). Short-range ensemble forecasting (SREF, ~40 km resolution, 1-3 days) with limited-area models has been underway for some time (Du and Tracton 2001), and interest now is growing in storm-scale ensemble forecasts (Elmore et al. 2003; Levit et al. 2004; Kong et al. 2004). Still, the effectiveness of the stochastic-dynamic approach on the storm-scale has yet to be fully explored, particularly the degree to which theories of error growth and initial condition specification at larger scales apply to smaller ones.

Current activities at the Center for Analysis and Prediction of Storms (CAPS) involve the use of the Advanced Regional Prediction System (ARPS) to produce multiple-resolution ensemble forecasts of severe thunderstorms. One such case simulated is a tornadic thunderstorm complex that occurred in the vicinity of Fort Worth, TX on 28-29 March 2000. Because storm-scale forecasting generally requires very fine horizontal grid spacing (1-3 km), nested grids must be used. In this study, we use 24-km, 6-km, and 3-km spacing for the coarse, medium, and fine resolution domains, respectively. The fine 3-km domain is centered over Fort Worth with sufficient coverage for the features of interest. The 24-km domain consists of 238×150 horizontal grid points; while the other two consist of 180×180 each. All use 53 terrain-following vertical layers, with nonlinear stretching from 20 m at the ground to approximately 800 m at the top. For each nested domain, a five-member scaled-lagged average forecasting (SLAF) ensemble (one control forecast plus 4 perturbed members) (Ebisuzaki and Kalnay 1991) is generated. To construct the latter, the perturbation between a previous ARPS forecast and the current analysis is scaled based upon time (error growth) and then added to and subtracted from the analysis to form two (paired) members. A 5-member SLAF requires two successive previous ARPS forecasts.

Nested grids complicate the construction of ensemble forecasts because no unique strategy exists to link the grids. Several approaches have been tested so far. One of them, for instance, only has the control runs of the 6-km ensemble and 3-km ensemble nested successively from the coarser grids. The perturbed members are constructed directly for the two previous 24-km ARPS forecasts (interpolated onto 6-km and 3-km grids, respectively) and the current analyses on the finer grids.

For both the 24-km and 6-km ensembles, both cumulus parameterization and explicit ice-phase microphysics are used. For the 3-km ensemble, only the explicit microphysics scheme is applied. For the finer grids, WSR-88D Level III reflectivity data are included in the ARPS data assimilation system (ADAS) in addition to other observation data.

2. Storm-Scale Ensemble Results

For each grid, individual member exhibits diversity and captures the major precipitation systems. The hourly rainfall probability maxima from 3-km grid are reasonably well aligned with the rainfall cores in the Stage IV rainfall map (figures not shown). In general, the 3-km ensemble contains significantly greater detail compared to its coarser grid counterparts, and generally agrees more closely with reality. Though very simple, the SLAF ensembles do show very promising storm scale forecasting skill.

Figure 1 shows example ensemble forecast products from the 3-km grid, along with the WSR-88D radar reflectivity. At 3-km grid spacing, convection is explicitly resolved by the microphysics scheme, though this grid spacing is toward the upper limit of that deemed practicable for application to deep convection. Owing to the spatially intermittent nature of deep convection, the ensemble mean reflectivity forecast covers a much broader area than any of the individual forecasts, and each storm tends to be much weaker. For this reason, the ensemble probabilities might be more useful. As shown in Figure 1, the conditional probabilities of surface reflectivity exceeding 45 dBZ compare very favorably with the WSR-88D (KFWS) reflectivity map, though the low probability echoes over the southeastern portion of the domain are not shown in KFWS radar.

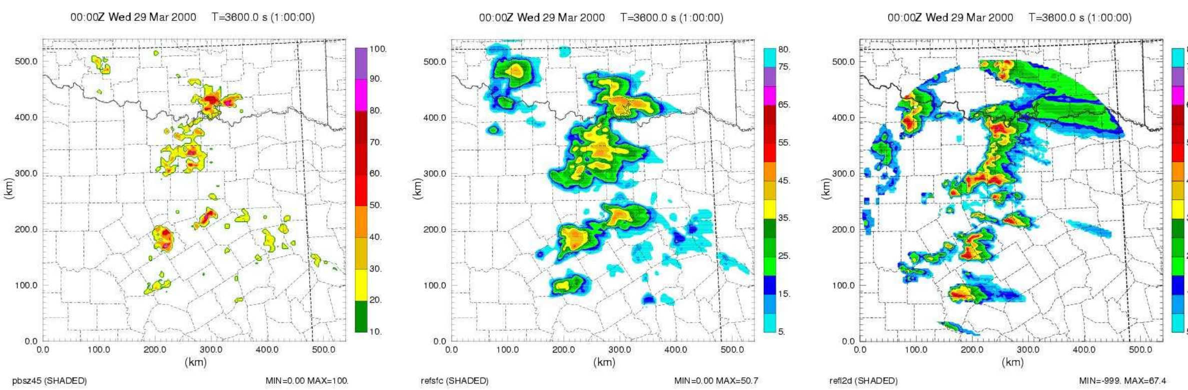

Figure 1. 1-h forecast probability of model-equivalent radar reflectivity ≥45 dBZ (left) and ensemble mean (center) from 3-km ensemble, and the Fort Worth WSR-88D lowest tilt reflectivity (right), valid 0000 UTC 29 March 2000.

References

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