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APPLICATION OF SHORT-RANGE NWP MODEL ENSEMBLES TO SEVERE STORM FORECASTING

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1. INTRODUCTION

The use of ensembles in numerical weather prediction (NWP) has become common at national forecasting centers recently (e.g., Tracton and Kalnay 1993; Molteni et al. 1995), although the notion of combining forecasts to improve accuracy has been around for some time (Thompson 1977). Most of the operational effort has been directed towards medium-range forecasting (e.g., 5-14 days). Information from the ensemble about the large-scale flow has proven to be useful from a forecasting perspective (Tracton 1994). The use of higher-resolution models focusing on short-range forecasting (0-48 hours) was discussed by Brooks and Doswell (1993) and Harrison (1994). Recently, the National Meteorological Center (NMC) began running an ensemble of ten members of the 80-km horizontal grid spacing version of the Eta model (Black 1994) on a weekly basis. This is part of a pilot project to look at Short-Range Ensemble Forecasting (SREF). The project is described in Brooks et al. (1995). Briefly, the different forecasts are initialized using six different analyses, prepared routinely at NMC, and with two pairs of perturbation prepared using the method of breeding of growing modes (Toth and Kalnay 1993). Error characteristics of the ensembles have been discussed by Hamill and Colucci (1996). Here we use one case from the SREF experiment to motivate discussion of the use of ensembles on the 0-48 hour time range, focusing on the potential utility of SREF for the forecasting of severe convection.

2. MESOSCALE MODELS IN FORECASTING

The use and interpretation of mesoscale model output for short-range operational forecasting of severe convection presents challenges and opportunities not found in longer-range forecasting. In particular, the time scale implies a desire to know details of the environmental conditions not necessary on the longer range, where a general feel for the situation may be all that is needed or possible. Cortinas and Stensrud (1995) discussed the use of output from an individual mesoscale model forecast. They suggested that the use of model-predicted fields such as Convective Available Potential Energy (CAPE) and Storm-Relative Environmental Helicity (SREH) could be useful in identifying areas of potential supercell thunderstorm threats.

Another approach, of course, is to consider the areas in which the model generates convection. As Cortinas and Stensrud (1995) point out, this forces a reliance on the accuracy of the convective parameterization, which may or not be a good idea, depending on the situation. There is the further problem that the parameterization scheme acts to eliminate the conditions that led it to initiate convection. Thus, in the absence of high temporal sampling of the model, it may be impossible to determine operationally the nature of the environment in which the convection formed.

Ensemble forecasting presents an opportunity for short-range, high resolution models to be used for the forecasting of severe convection in new ways. Severe convection is by its nature a rare event at any one location and it represents the concatenation of processes and ingredients in such a way that what may seem like a very low probability event many hours in advance becomes a much higher probability event as time goes on. The use of multiple forecasts in an ensemble setting may provide insight into this process.

3. 9 MAY 1995 FORECAST

One of the first ensembles run was initialized on 9 May 1995 at 1200 UTC. Briefly, there was a small outbreak of strong to violent tornadoes in northern Illinois on the evening of the 9th. Severe weather became more widespread on the 10th, affecting much of the area from eastern Ohio through central Pennsylvania, south to northern Georgia and Alabama. Isolated severe weather reports occurred in Florida,

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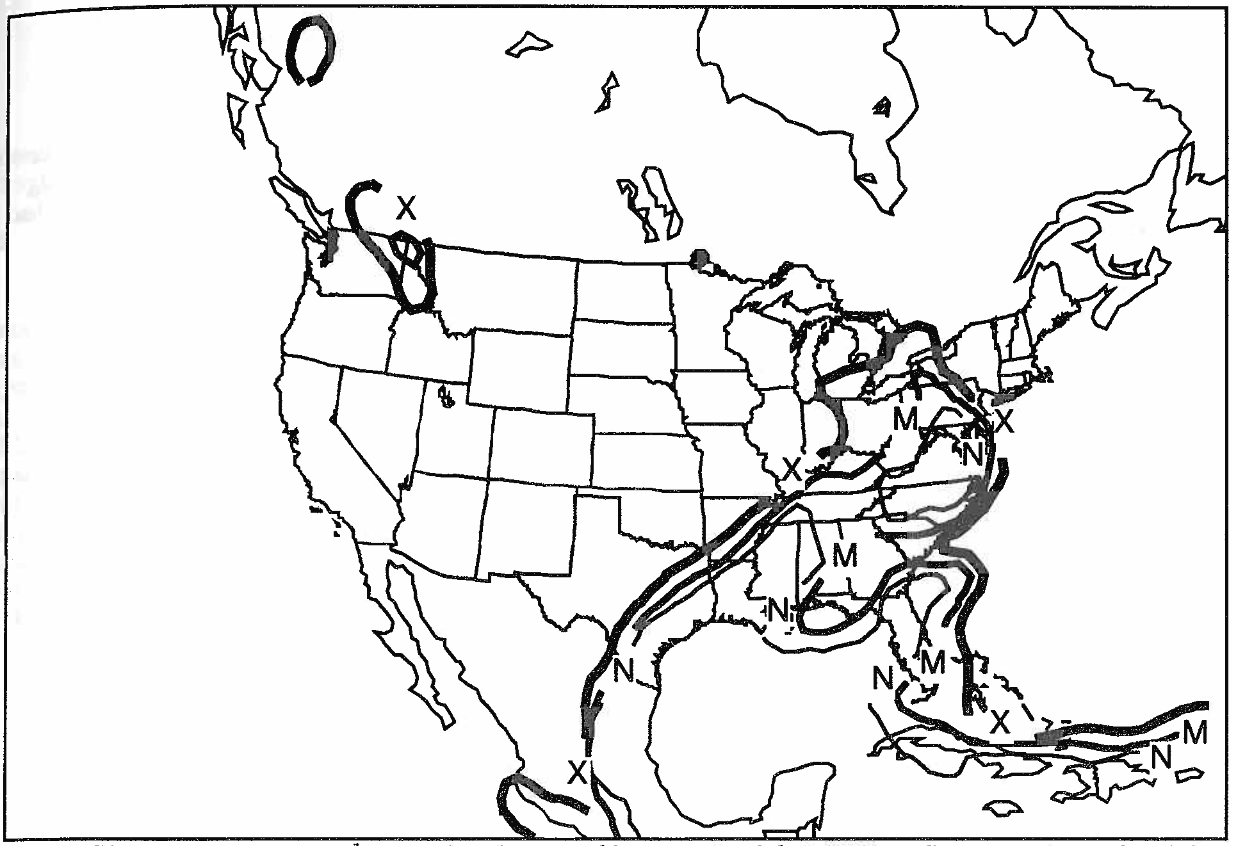

Fig. 1: CAPE value of 800 J kg^{-1} from 36-h Eta ensemble forecast valid at 0000 UTC 11 May. Heavy line (X) indicates maximum area from all members, medium line (M) indicates loation from mean forecast, and light line (N) indicates minimum area. All members had CAPE ≥ 800 J kg^{-1} in the area enclosed by the light line.

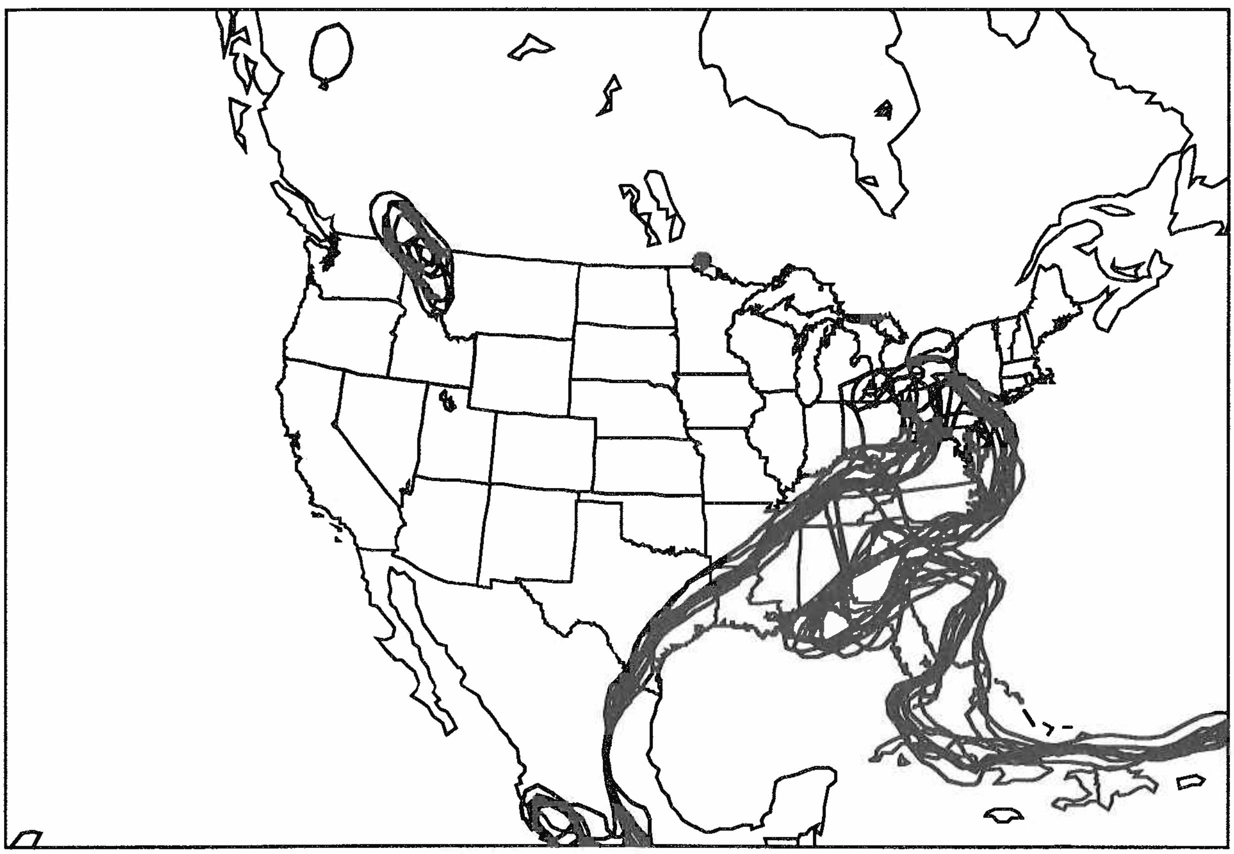

Fig. 2: CAPE value of 800 J kg^{-1} from all ten members of 36-h Eta ensemble forecast valid at 0000 UTC 11 May. Each line represents location from one ensemble member.

Louisiana, and Texas on the 10th. Our concern here is the main body of severe weather on the 10th and we will consider the CAPE as an example of the prediction of environmental conditions and the model forecast convective precipitation for the following period.

Severe reports consisting mostly of hail and high winds marched relatively rapidly across Ohio into western New York and central Pennsylvania from about 2000 UTC to 0000 UTC on the 11th associated with a line of convection. At the same time, the southern end of the convective line moved much more slowly to the south out of eastern Kentucky into Tennessee and western North Carolina. The 36-h ensemble forecast of CAPE valid 0000 UTC 11 May shows a region of at least moderate CAPE (greater than 800 J kg^{-1} extending from the Louisiana Gulf Coast northeast towards Pennsylvania. From the spread between the largest area and smallest area forecast (Fig. 1), it is clear that the ensemble members agree much more about the portion of the forecast domain in Tennessee, where the convective line advanced slowly, than in the northern mid-Atlantic States, where the line moved rapidly. This is also apparent in the "spaghetti" plot, showing the isolines for all ten members (Fig. 2). This implies that the ensemble has greater confidence in the exact location of the high CAPE air in the southern portion of the domain than in the northern. This is not surprising since a large part of the uncertainty in the forecast had to do with the speed of movement of the system.

There are two members of the ensemble (including that from the "early" Eta analysis) that produce a relative minimum in CAPE in eastern Tennessee (see Fig. 2), near where the observed convection occurred after 0000 UTC on the southern part of the convective line. The convective precipitation forecast by the ensemble after 0000 UTC is extremely interesting in this regard. Despite having two members producing little in the way of instability, the maxima in convective precipitation in the ensemble mean occurs in eastern Tennessee (Fig. 3). Maximum precipitation due to the convective parameterization in this region is over 17 mm in the 12 hour period in the *mean* forecast. The maximum from any individual member is over 25 mm, with eight generating a maximum on the order of 20 mm or more in eastern Tennessee. Thus, on the whole, the ensemble forecasts a high probability of significant rainfall associated with convection (and presumably strong convection in eastern Tennessee). Depending on other parameters, such as SREH, a forecaster in that region might be

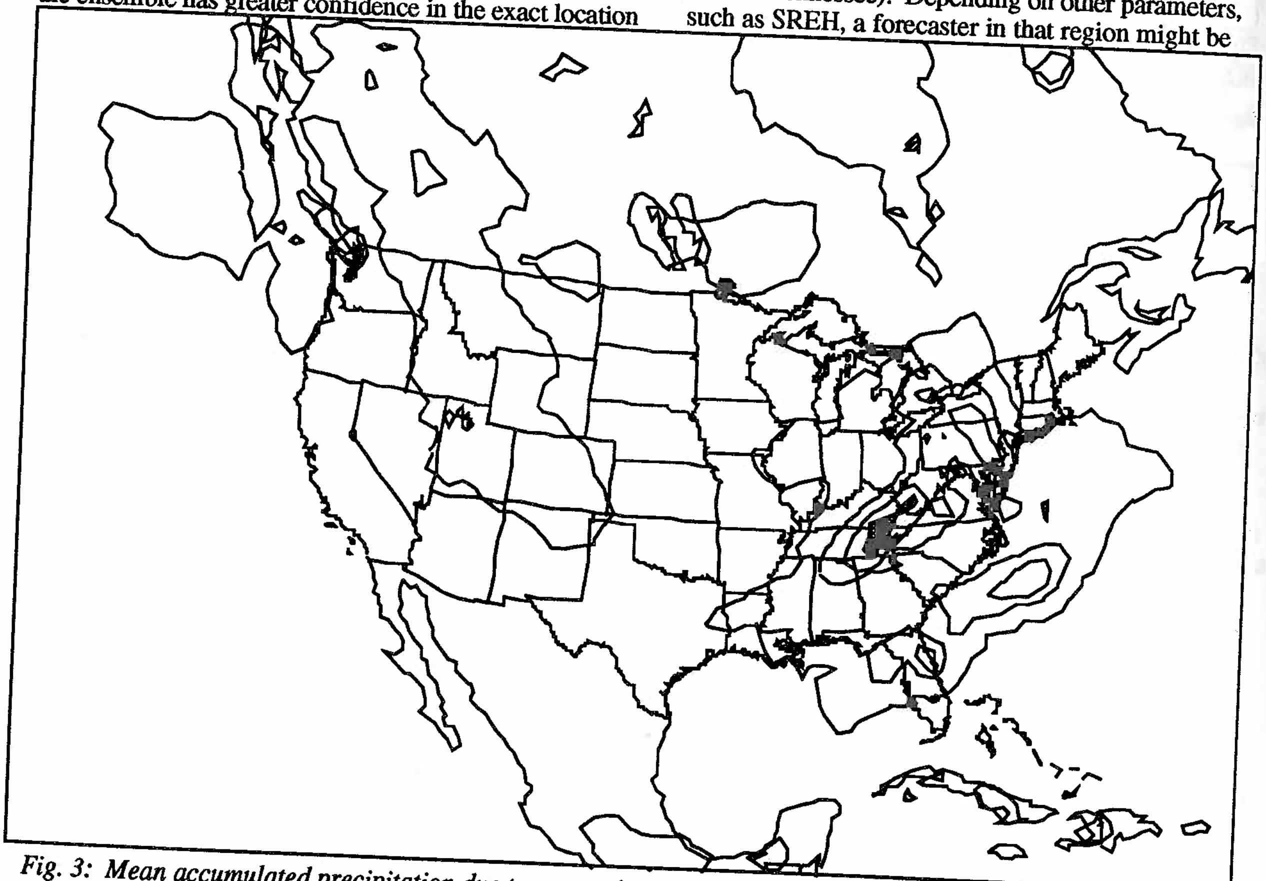

Fig. 3: Mean accumulated precipitation due to convective processes in ensemble from 36 h (0000 UTC 11 May) to 48 h (1200 UTC 11 May). Contours are in mm with outer contour 0 and contour interval of 5 mm. Shaded area indicates accumulations of more than 15 mm.

alerted to the potential for severe weather and flash flooding overnight.

4. DISCUSSION

Forecasting of hazardous weather is becoming a more important part of operational meteorology. It requires a knowledge of atmospheric behavior on all spatial and temporal scales. Ensemble forecasting offers an opportunity to provide significant value in developing guidance for operational forecasting, particularly as we move towards using higher spatial resolution models with more frequent temporal sampling. The ability of high-resolution models generating very *precise*, but potentially *inaccurate* forecasts is a real danger (Brooks and Doswell 1993, Cortinas and Stensrud 1995). Ensembles can provide help in this regard and enable forecasters to assess their confidence in numerical guidance in a particular situation.

Several things must be done for SREF to be consistently useful for forecasting of severe weather. First, we need to understand the predictability of the relevant forecast fields. Much is known, for example, about the model predictability of 500 hPa heights, but little is known about the predictability of CAPE. Second, techniques to group members of the ensemble into clusters of similar atmospheric behavior based on the relevant physical parameters of interest for a given forecast, rather than on large-scale flow similarity, need to be tested. The fact that the parameters of interest may change from day to day makes this more challenging.

Finally, it is likely that the ensemble will have to be expanded greatly (O~100 members) in order to maximize the utility of the forecasting of rare, severe weather. We found clusters of 8 members that forecast heavy precipitation in eastern Tennessee over a 12-hour period, while two other members produced little precipitation. In reality, the sample size is too small to have confidence in the probability of events. Large ensembles are needed if we are going to provide guidance with significant value for forecasters. Related to this point, techniques to monitor the evolution of the ensemble (and cluster) members and the atmosphere are needed, so that the transition from low-probability event to high-probability event characteristic of rare, severe weather can be tracked. For example, suppose that only two or three members of 100-member ensemble produce the right conditions for a major hazardous weather occurrence, but that the "path" the atmosphere must follow to get there, according to the model, is clear. It is unreasonable to assume that a forecaster will be familiar with the evolution of all 100 members of the ensemble. Automated means that alert the forecaster to the fact that what initially appeared to be an unlikely scenario has become more likely, as the atmosphere evolved, would be useful in raising awareness.

5. ACKNOWLEDGMENTS

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<URL: http://antietam.nssl.uoknor.edu/ mosaic_files/sref.html>

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