2.7 Using lagged average forecasts and model trends to Identify initialization errors

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1. INTRODUCTION

Model trends, referred to as ***dProg/dt***, are used to compare differences between model runs of the position and intensity of key features or parameters. Lagged average forecasts (LAFs) are often referred to as ***dProg/dt.*** The true LAF is a consensus of all forecast members from a single model initialized at different times (Hoffman and Kalnay 1983). LAF techniques are a cheap and easy ensemble consisting of members of the same model, initialized at different times. Implicitly, they contain different initial conditions. The most recent member is typically considered to be the single most accurate member (Hoffman and Kalnay 1983).

In an age of ensembles (Sivillo et al. 1997) and multi-model ensembles we do not advocate using LAFs to issue a forecast. However, when evaluating forecasts from a single model, LAFs and dProg/dt can provide useful insights into the impact of initial conditions on the performance of the model being examined. For example, the trends of a stronger surface cyclone may indicate that the short wave associated with the system may be more intense than previous model initializations.

For an optimal forecast with a high probability outcome forecasters should use ensembles. These ensemble members should be from the most recent set of initial conditions available. As demonstrated by Toth et al. (1997), LAF techniques should only be used when evaluating the problem with a single model or ensemble member.

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In this paper, we present two East Coast snowstorms. Each event had a significant initialization problem that led to erroneous forecasts. Select images will be used to show how forecasters could have used LAF and dProg/dt to improve upon the forecast and identify potential errors.

2. METHOD

The gridded model data from the National Centers for Environmental Prediction Centers (NCEP) aviation run (AVN) of the global spectral model and stepped terrain Eta model were archived in real-time. A few missing files were retrieved from COMET to make the data sets complete.

All data were displayed using GRADS. (http://grads.iges.org/grads/) GRADS' was used to compute the mean forecasts, the dispersion about the mean, and the 4 panel model trend graphics. For each model, 4 model initializations and their forecasts, valid at the same time, were summed and averaged to compute LAF. The dispersion of each member about this mean was then computed. These graphics are referred to as LAFs throughout the text.

Graphics of model trends were computed using and displayed in a four-panel mode for easy comparison. These graphics are available in real-time at http://eyewall.met.psu.edu and are referred to as dProg/dt throughout the text.

3. RESULTS

3.1 East Storm of 25 January 2000

During the late evening and early morning

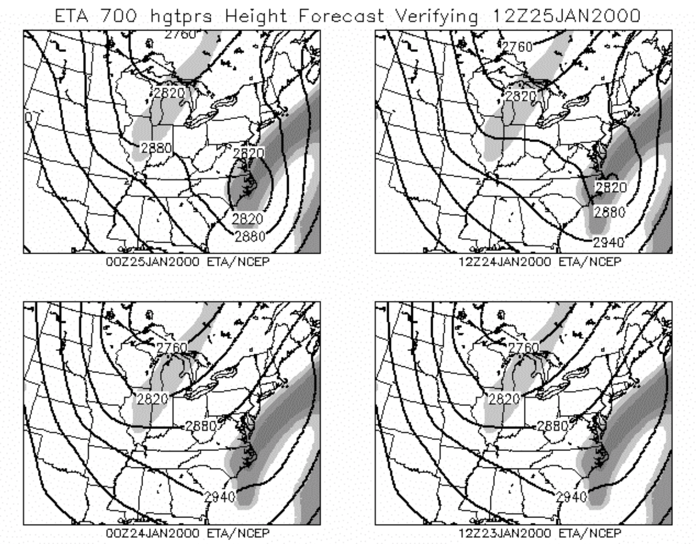

Figure 1. Eta 700 hPa heights (m) and relative humidity (percent) forecasts valid at 1200 UTC 25 January 2000 from the Eta initialized at a) 0000 UTC 25, b) 1200 UTC 24, c) 0000 UTC 24, and d) 1200 UTC 23 January 2000. Heights are every 60 meters and relative humidity is shaded every 10 percent beginning at 70%.

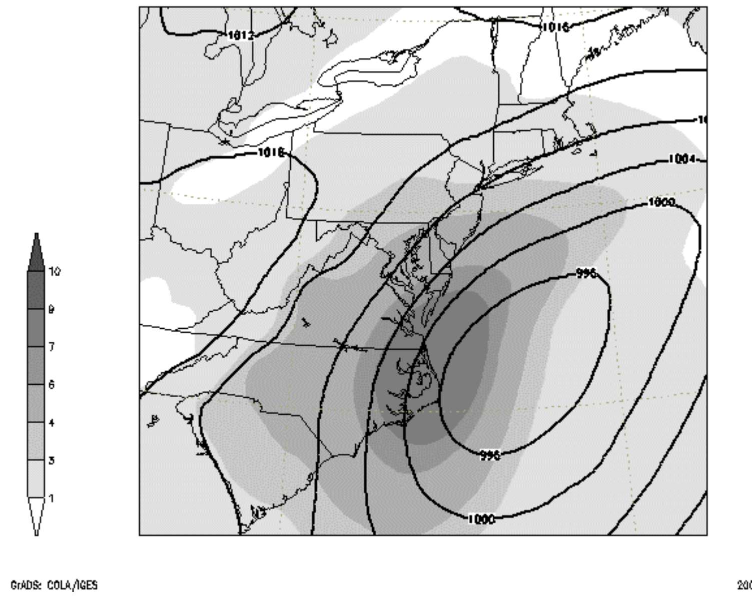

Figure 3. Eta lagged average forecast of MSLP valid at 1200 UTC 25 January. Image shows the mean MSLP forecast from the 4 Eta forecasts valid at this time and the dispersion of these forecasts about the mean. MSLP contours are every 4 hPa. Dispersion (hPa) is shown by the shading as indicated in the scale to the left of the image.

hours of 24 and 25 January 2000, a major East Coast cyclone developed off the Carolina Coast spreading heavy, and in many cases, record snowfall from South Carolina to New England. Particularly hard hit areas include a swath from near Raleigh North Carolina through the Baltimore, MD and Washington, DC areas. At these latter two locations, the heavy snow arrived shortly before the onset of the morning commute to work. Seemingly surprised cities in Virginia and Maryland were nearly paralyzed by the snowstorm. This surprise could be attributed to relatively ***poor model forecasts*** of the event.

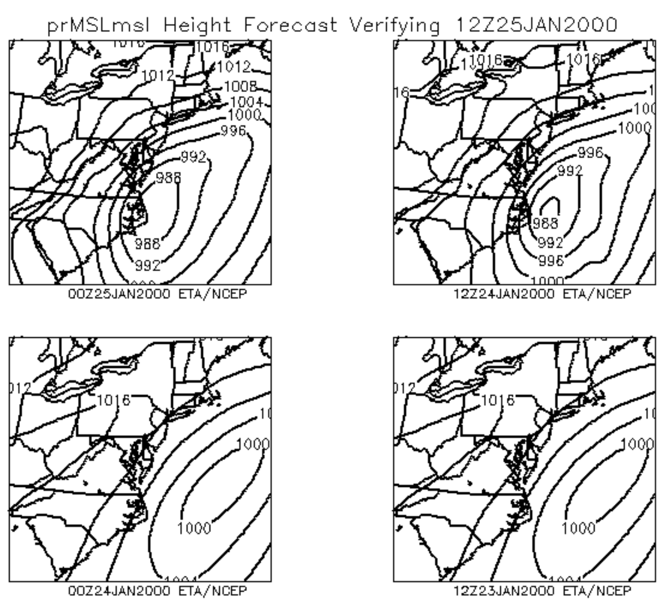

Figure 2. As in Fig. 1 except Eta forecasts of mean sea-level pressure (hPa). Isobars are contoured every 4 hPa**.**

The large scale 700 hPa height and relative humidity forecasts from the operational NCEP Eta model is shown in Figure 1. The forecasts are all valid at 1200 UTC 25 January 2000. The forecasts from 1200 UTC 23 January show a weak, sheared off short wave forecast to move off the East Coast. The associated deep moisture with this system was forecast to remain mainly offshore. Subsequent forecasts showed a trend toward a deeper 700 hPa low farther west with more moisture along the immediate coast.

The Eta Mean-sea level pressure LAF and dProg/dt are shown in Figures 2 and 3 respectively. The LAF (Fig. 2) showed a cyclone off the Carolina coast with large pressure differences, implied by the large dispersion values, to the west of the surface cyclone position. The dProg/dt images showed that subsequent model runs produced a deeper surface cyclone west of earlier forecasts. The combination of the deeper cyclone, and the more westward position lead to the large dispersion west of the LAF cyclone position. The AVN showed a similar LAF and dProg/dt and are not shown.

The trends toward a stronger cyclone, closer to the coast appeared to be related to a poorly initialized short wave. Successive model initializations showed a stronger wave than forecast by each the previous model runs. This implies some impact on the initialization by the first guess.

3.2 East Coast Storm: 30 December 2000

The East Coast storm of 30 December was another example of the utility of using LAFS and dProg/dt to improve upon the forecast. In this event, the model trends were different in Eta and AVN. Ultimately, the observed surface cyclone track and precipitation shield was closer to those forecast by the AVN than by the Eta. However, a forecaster would not have a priori information about which model is going to perform better. Therefore, the LAF and dProg/dt data from the Eta and AVN are provided to show how

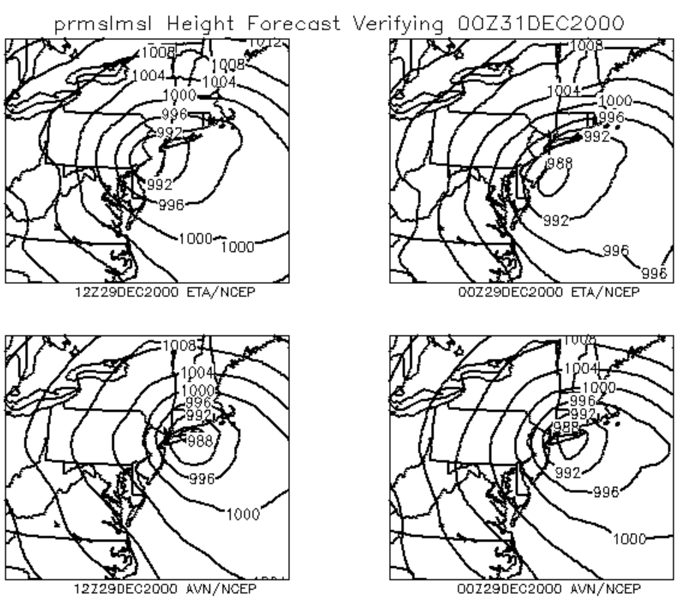

Figure 4. MSLP forecasts (hPa) from the Eta and AVN models valid at 0000 UTC 31 December 2000. Eta and AVN forecasts were initialized at 0000 and 1200 UTC 29 December 2000 as indicated by the labels in each panel. Isobars are contoured every 4 hPa.

these data could provide useful information during a potential winter storm.

The dProg/dt for the AVN and Eta MSLP forecast from the 0000 and 1200 UTC 29 December forecast cycles are shown in Figure 4. These data reveal that the AVN forecast a surface cyclone to move over central Long Island by 0000 UTC 31 December 2000. Unlike the AVN, the Eta forecasts showed a trend toward a deeper cyclone with a more *westward position* with time. The changes in the cyclone track and intensity had large implications on the Eta's quantitative precipitation forecasts.

The LAF from the Eta valid at 0000 UTC 31 December 2000 is shown in Figure 5. This LAF was made from Eta forecasts initialized at 1200 UTC 28, 0000 and 1200 UTC 29, and 0000 UTC 30 December 2000. The mean cyclone was forecast to be around 989 hPa with a 5-hPa dispersion center southwest of the LAF cyclone center. Using the dProg/dt approach (not shown), the large dispersion maximum over Delaware and New Jersey reflects the slower and deeper surface cyclone forecasts from 1200 UTC 28 and 1200 UTC 29 of December. The forecast from 0000 UTC 30 December had a 991 surface cyclone over New York City. This more western track, relative to the AVN forecast, lead to some difficult rain/snow forecast issues along the East Coast.

The AVN MSLP LAF is shown in Figure 6. The LAF showed a 988 hPa surface cyclone over eastern Long Island with a 5 hPa dispersion maximum nearly due south of the surface cyclone position. An examination of the dProg/dt images (not shown) revealed the causes for this error maximum. First, earlier forecasts had a deeper cyclone with a 992 hPa surface cyclone center from the forecast initialized at 1200 UTC 28 December compared to a 991 hPa surface cyclone from the forecasts initialized at 0000 UTC 30 December. Second, earlier forecasts positioned the surface cyclone south of Long Island and the later forecasts placed the surface cyclone over southern Connecticut.

In addition to the surface cyclone forecast differences, these model runs revealed distinct trends in the QPFs. The Eta, with its more westward track, forecast more precipitation to the west than the AVN forecast.

4. DISCUSSION

The 25 January case showed similar trends in both the AVN and Eta. This implied a similar feature in the analyses used by both models was responsible for the errors. The LAF dispersion fields of both models showed large pressure differences west of the surface cyclone. Additionally, the dProg/dt images from both models showed deeper cyclone tracking farther to the west with each successive forecast. Using this information, we were able to find an error in the model's initialization of an upper level short wave, which contributed to the errors in both models.

In the December case, the LAF's showed different MSLP dispersion and dProg/dt forecast differences between the Eta and the AVN. These differences imply that both model physics and initial conditions played a significant role in the differences between these forecasts. A version of the Eta, using more detailed sea-surface temperature (SST) data (not shown) revealed trends similar to those displayed by the AVN. This implies the coarse SST data used to initialize the models played a significant role on the internal physics of the Eta.

Mean prmslmsl and dispersion Verifying 00Z31DEC2000

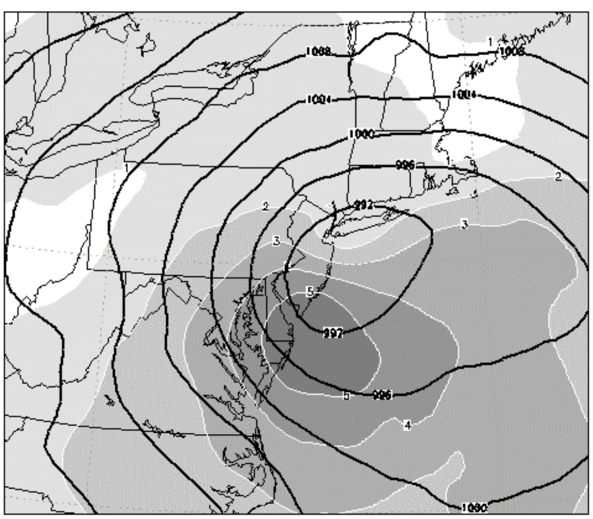

Figure 5 As in Figure 3, except Eta LAF and dispersion valid at 0000 UTC 31 December. Forecast members include forecasts from 1200 UTC 28 December, 0000 and 1200 UTC 29 December and 0000 UTC 30 December 2000

LAFs and dprog/dt are great tools to assist the forecaster in locating potential problems. Using these techniques on different models can be more instructive then using them on a single model. In the first event shown, the similar LAF and dProg/dt revealed that both models were having trouble initializing the intensity of the same short wave feature. In the second case, differences in the LAFs and dProg/dt between the models revealed the impact of SST data on the finer scale Eta's internal model physics. The premise here being that relying on a single model or the trends in a single model may produce a singularly bad forecast. Ultimately, using dProg/dt to evaluate an ensemble of ensemble members may help forecasters determine what features have low predictability.

5. References:

Hoffman, R.N. and E. Kalnay, 1983: Lagged average forecasting, an alternative to Monte Carlo forecasting. *Tellus,* **35a**, 100-118.

Sivillo, J.K and J.E. Ahlquist and Z. Toth, 1997: An ensemble forecasting primer. *Wea. Forecasting* .,**12**, 809-818.

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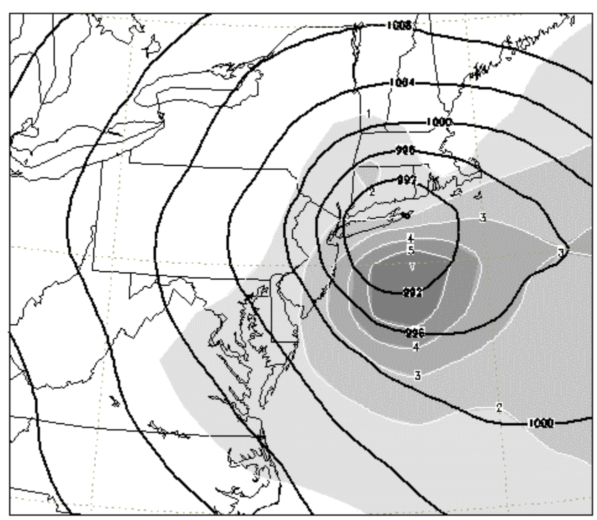

Figure 6 As in Figure 5, except AVN LAF and dispersion valid at 0000 UTC 31 December.