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REGIONAL SCALE ENSEMBLE FORECAST OF THE LAKE EFFECT SNOW EVENT OF 7 FEBRUARY 2007

Justin Arnott and Michael Evans
NOAA National Weather Service, Binghamton, NY

Richard Grumm
NOAA National Weather Service, State College, PA

1. INTRODUCTION

The resolution and sophistication of today's mesoscale numerical weather prediction models has advanced to where explicit simulation of mesoscale weather events is becoming possible. One example of an event that poses a challenge to National Weather Service (NWS) forecasters over the northeastern United States and can have a substantial impact on the public is lake effect snowfall.

The operational 12 km North American Mesoscale (NAM) model from NCEP has shown the ability to simulate banded precipitation off of the eastern Great Lakes when bands are organized parallel to the long axis of the lake. In these scenarios, the typical band width (length) is 20-50 km (50-200 km) (Hill 1971), which begins to come within the resolvable range of a 12 km simulation. While these banded structures are forecast by the model, forecasters have noted problems in their timing, strength, and inland extent.

Their fixed forcing (e.g. orographic vs. free atmospheric forcing) nature makes lake effect bands an ideal phenomena to study with regional high resolution models. Each NWS office has the ability to run a local workstation version of the Weather Research and Forecast (WRF; Michalakes at al. 1998) model over their forecast area. This enables offices to generate forecasts over common areas and compare results. These various WRF simulations, combined with the operational NAM run, can essentially create a "poor-man's" ensemble.

The ability of an ensemble forecast system to anticipate regions most likely to be affected by high-impact weather has been shown in the literature (e.g. Stuart and Grumm 2006). This research, however, has been limited to models that do not have the horizontal grid spacing necessary to explicitly simulate lake effect snow bands.

While other regional ensemble forecast systems have been developed (Jones et al. 2007; Eckel and Mass 2005), the authors are unaware of any published literature examining the ability of a mesoscale ensemble prediction system to increase forecast skill during lake effect snow events by explicitly forecasting the timing, location, and movement of lake effect bands.

This study presents the first step in the development of a prototype operational regional ensemble forecasting system over the northeastern United States. The initial goal of this regional ensemble is to improve forecasts of the timing, location, and movement of lake effect snow bands.

2. DATA AND METHODOLOGY

In the fall of 2006, a group of NWS offices surrounding the eastern Great Lakes began an effort to ensemble output from their regional workstation WRF simulations. The goal of this endeavor was to test the efficacy of such an ensemble in anticipating the timing and location of lake effect snow bands. The participating offices along with the common simulation domain are shown in Fig. 1.

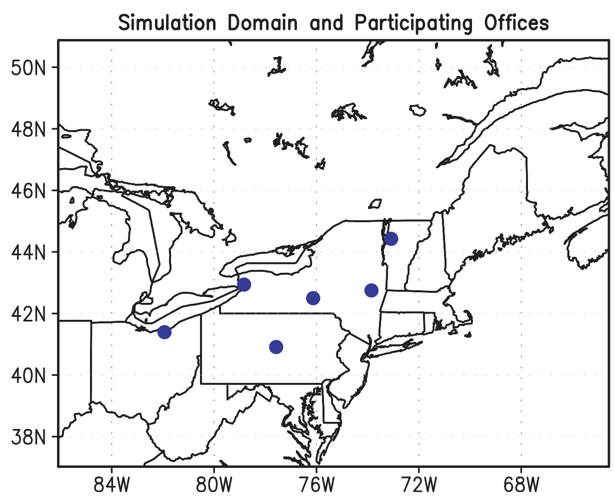

Fig. 1. Map of ensemble forecast domain along with NWS offices participating in the ensemble.

The simulation domain and horizontal grid spacing (12 km) are identical for all members. The use of 12 km horizontal grid spacing allows for rapid simulation times, as well as for direct comparison with the 12 km operational NAM.

*Corresponding Author Address: Justin M. Arnott, NOAA/ NWS Binghamton, NY, 32 Dawes Dr. Johnson City, NY 13790 email: justin.arnott@noaa.gov

Office	Model Core	Boundary Conditions	Microphysics	Convective Scheme
Operational	NMM	NAM	Ferrier	Betts-Miller
CTP – 1	NMM	NAM	Lin	Betts-Miller
CTP – 2	ARW	NAM	Lin	Betts-Miller
BGM	ARW	NAM	Lin	Kain-Fritsch
CLE	ARW	GFS	Lin	Kain-Fritsch

Table 1. Description of ensemble members used in the 7 Feb case study.

Ensemble spread is achieved through variation of initial conditions and model physics (Table 1). Note that not all of the members shown in Fig. 1 were available for the case study that follows, although the WFO State College member, which was available, runs 2 unique simulations.

A prolific lake effect snow event occurred during early February, 2007, producing over 100 inches of total snowfall to the lee of Lake Ontario over an extended 7-10 day period. This provided an excellent opportunity to test the ensemble system.

3. PRELIMINARY RESULTS

3.1 Case day summary

At 00 UTC 7 Feb, the northeastern United States was entrenched under cold cyclonic flow aloft with a weak short wave approaching the eastern Great Lakes (Fig. 2).

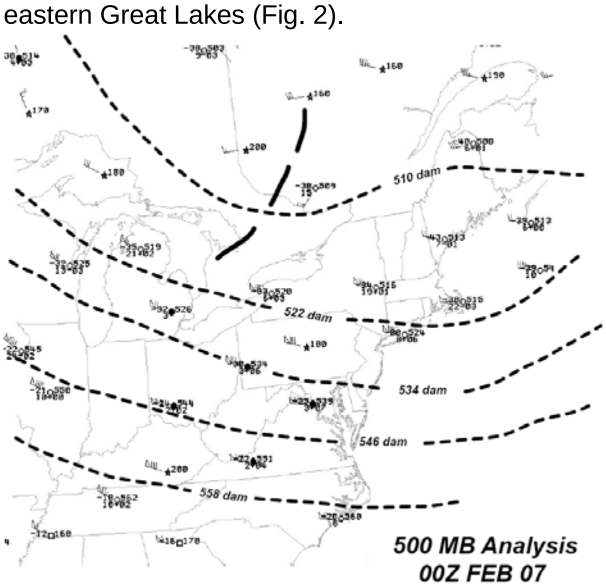

Fig. 2. 500 hPa height analysis for 00 UTC 7 Feb.

Temperatures at 850 hPa were near -20^{o} C (Fig. 3). Lake Ontario water temperatures from that week were 39^{o} F or 4^{o} C. This would make for a surface-850 hPa temperature difference of nearly 25^{o} C, far greater than the 13^{o} C threshold discussed by Niziol (1987) as being necessary for lake effect snow shower development, indicating a high degree of potential instability. At the surface (Fig. 4), a weak trough was approaching the eastern Great Lakes, bringing a subtle wind shift, but little in the way of sensible weather changes.

The 00 UTC Buffalo RAOB (not shown) indicated a surface-800 hPa layer of conditional instability along with substantial low-level moisture, capped by an inversion aloft. All of these features are typically associated with conditions conducive to lake effect snow band development.

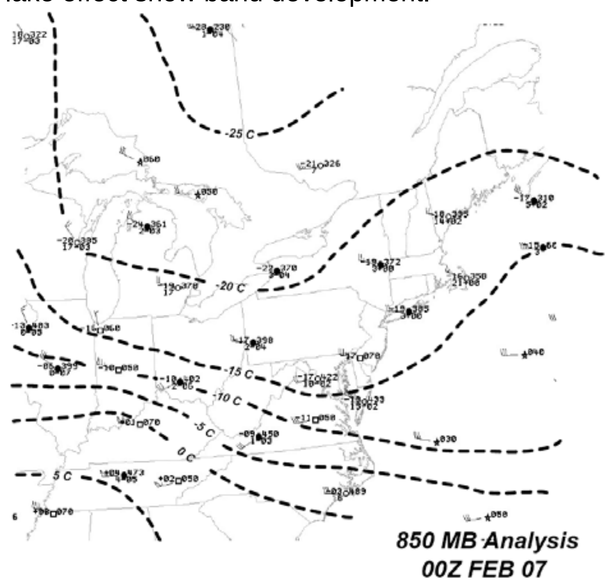

Fig. 3. 850 hPa temperature analysis for 00 UTC 7 Feb.

3.2 Model forecasts and verifying analysis

Reflectivity data from the WSR-88D radar at Montague, NY (KTYX) demonstrate what occurred through the day on 7 Feb. Figure 5 shows 6-hourly reflectivity for the period 00 UTC-18 UTC on 7 Feb. A lake effect snow band east of Lake Ontario is clearly evident through the period. The band sinks southward through 12 UTC while weakening (Fig. 5c). The band then reinvigorates as it returns northward. This type of southward shift, then subsequent reorganization of the snow band is often observed following the passage of a weak short wave such as depicted in Fig. 2.

Figure 6 shows the corresponding 3 hourly (the finest time resolution available) QPF output from the 00 UTC 7 Feb operational NAM. In general, the operational NAM was successful in anticipating the movement of the band (cf Fig. 5), although the core of the band forecast by the NAM never moved south of Rome, NY (shown by a star in Figs. 5c and 6c) while it clearly did in the reflectivity data (cf. Figs. 5c and 6c,d). Another problem the operational NAM has concerns the inland extent of the band,

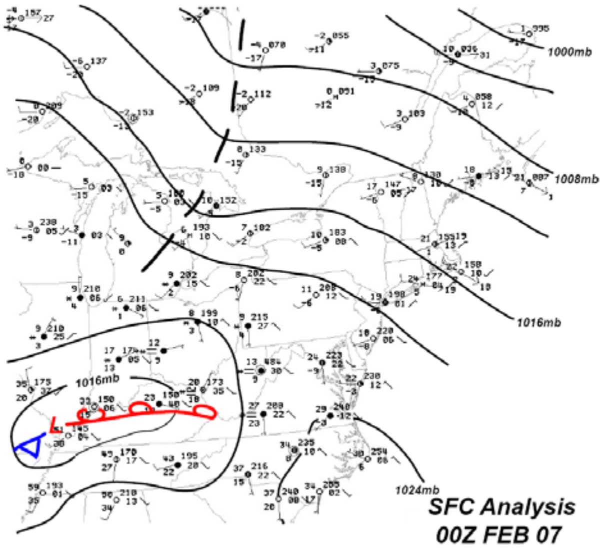

Fig. 4. Surface analysis for 00 UTC 7 Feb.

particularly during its southward shift in the morning. From 12-15 UTC, the operational NAM suggested that the band would have extended well east of Rome, NY. KTYX reflectivity data for the same time period (Fig. 5c) shows a diffuse band whose inland extent is far less than what was anticipated in the operational NAM. This would clearly have large forecast implications for areas from Rome, NY eastward.

QPF probability and spaghetti diagrams from the regional ensemble are shown in Figs. 7-10 for the same time period previously discussed. These plots include five ensemble members, one of which is the operational NAM discussed above. The probability and spaghetti plots show the same trends in forecast band location as demonstrated by the operational NAM and the verifying KTYX radar. Figures 7-10 also demonstrate that while the lower probabilities (<50%) indicate potential impact areas, the higher probabilities more precisely indicate which areas are most at risk at a particular time. Of course, there are limitations to probabilities from such a small ensemble. Additional ensemble members should enhance the robustness and reliability of these probabilities.

A desired result of the ensemble is that it can help highlight both high and low probability outcomes. The outlier, or low probability outcome, indicates a low-confidence solution. Such an example is shown between 12 and 15 UTC on 7 Feb when the operational NAM (black line in Fig. 9, lower panel) shows a lake effect snow band extending well east of Rome, NY. This solution has no support from the other four members of the ensemble, evidenced by the spaghetti plot (Fig. 9, lower panel). As shown by the KTYX radar, in this case, the regional ensemble highlighted an erroneous outlier and provided a more skillful forecast in the mean during this timeframe.

While much work remains to see whether results of this type are typical of this ensemble system, this case study demonstrates how the utility of such a system can be assessed and what potential forecasting benefits the system may bring.

4. SUMMARY AND FUTURE WORK

A regional-scale ensemble has been developed over the eastern Great Lakes area of the northeastern United States to help improve the skill of forecasting the timing, location, and movement of lake effect snow bands.

While the ensemble was still in the “spin-up” phase during the winter of 2006-2007, results from this research suggest that an expanded deployment of this ensemble for the 2007-2008 lake effect snow season shows promise for improving operational forecasts.

The regional scale ensemble offers detailed forecasts at 12 km resolution while the current NCEP SREF system (Tracton et al. 1998) has horizontal resolution on the order of 32 km. While the SREF system provides important information for assessing uncertainty of the larger scale flow, this regional scale ensemble provides the ability to diagnose local phenomena with greater detail. Additionally, SREF data are available in 3-hour increments. The local WRF runs can be configured to output data with higher temporal resolution.

Future work includes examining additional lake effect case studies (with data from all of the participating members) to continue to further knowledge in the performance of the ensemble system. In addition, displaying ensemble output in ways that are useful to field forecasters is as important as the actual ensemble performance in producing improved forecasts. Therefore, efforts are underway to investigate new visualization techniques to help forecasters condense the plethora of ensemble forecast data into a clear mental picture. Finally, now that this regional ensemble has been created, it is being run operationally year-round and can be used to examine other regional weather phenomena. Software is being tested to use these data to forecast heavy rainfall, convection, and winter storms. Thus, this research will expand as more areas are identified where such an ensemble may prove to be a valuable forecast tool.

5. ACKNOWLEDGEMENTS

The authors would like to thank all offices that are participating in the regional ensemble for their willingness to set up a consistent domain and share model output. In particular, Ron Murphy, ITO at WFO Binghamton provided valuable help in obtaining the data shown in this study. The Lake Ontario surface temperature data were obtained from the Michigan Sea Grant Coastwatch project.

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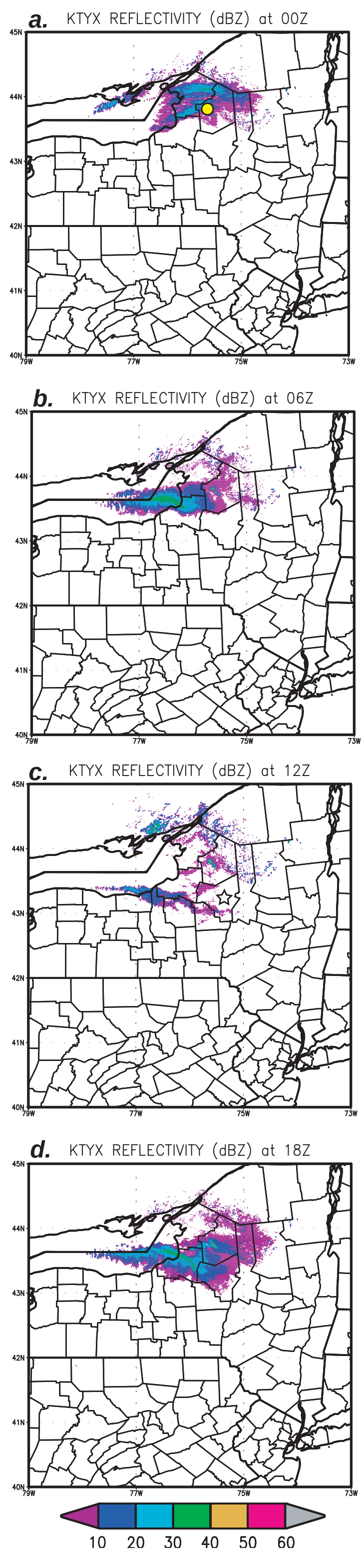

Fig. 5. Reflecitivty (in dBZ) from the KTYX WSR-88D for 00-18 UTC 7 Feb. Yellow circle in panel a. denotes location of KTYX radar. Star in panel c. denotes location of Rome, NY.

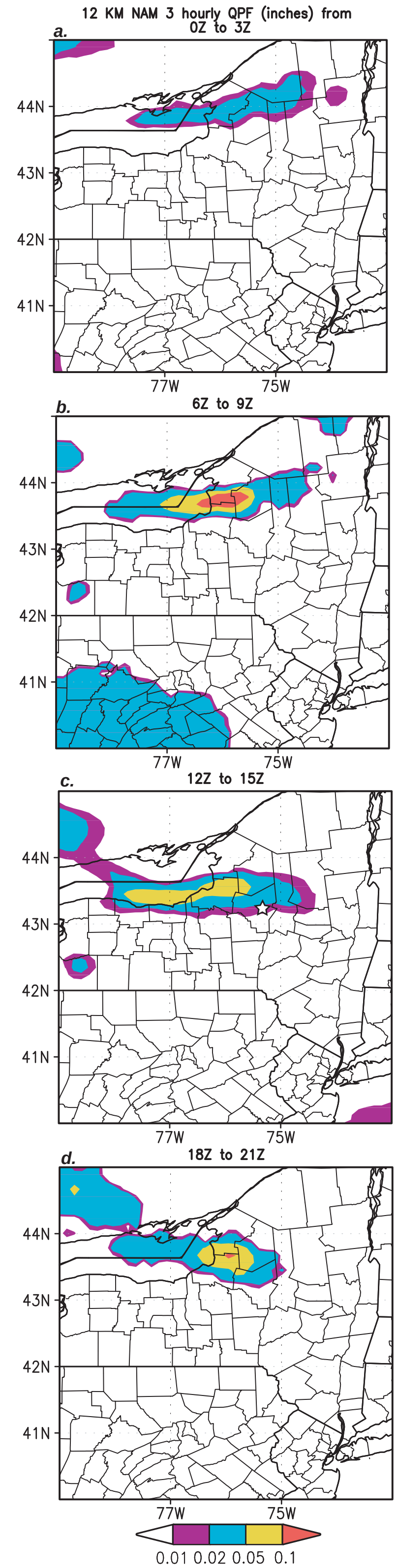

Fig. 6. Three hourly QPF forecast (in inches) from the 00 UTC Feb 7 run of the operational 12 km NAM. Star in panel c. denotes location of Rome, NY.

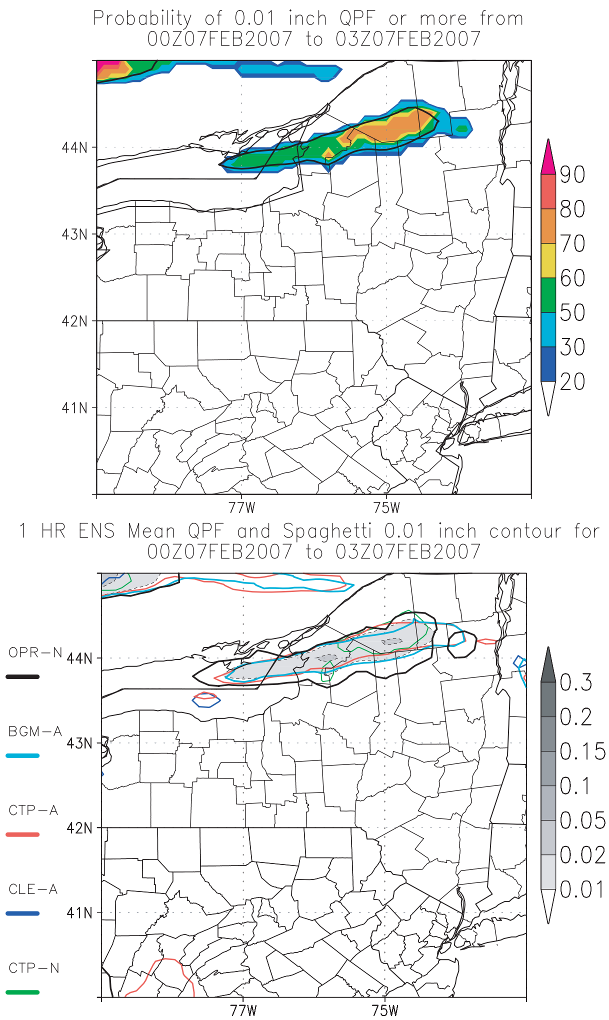

Fig. 7. Probability (top) and spaghetti (bottom) plots for 3 hourly QPF between 00 UTC 7 Feb and 03 UTC 7 Feb. Shading in top panel shows probability of members with at least 0.01" of QPF over the corresponding 3 hour period while shading in bottom panel shows the mean ensemble QPF forecast. Individual members of the spaghetti plot are indicated to the left of the bottom panel.

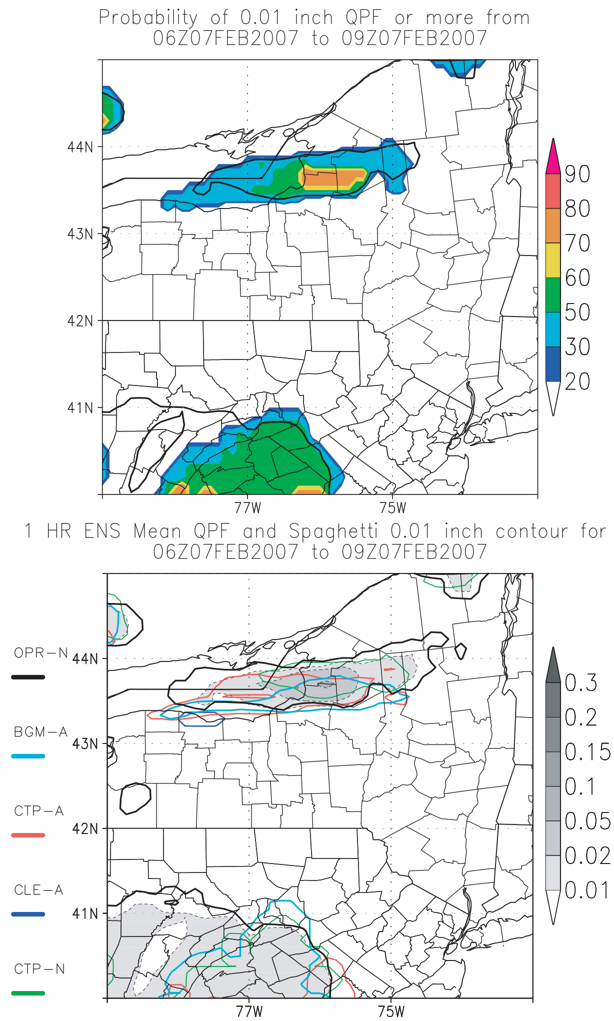

Fig. 8. Same as in Fig. 7 but for the period 6 UTC 7 Feb through 9 UTC 7 Feb.

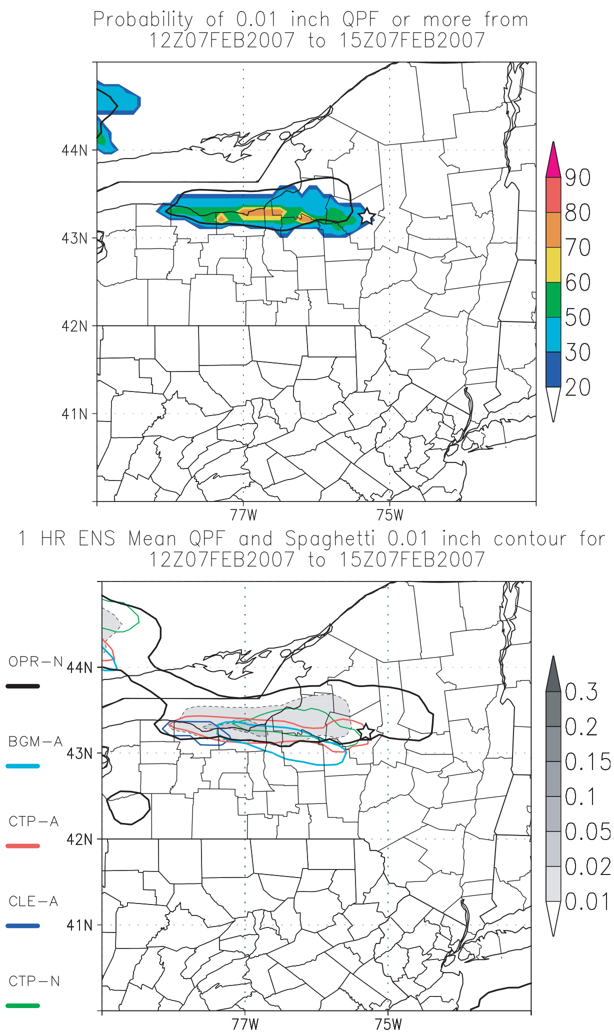

Fig. 9. Same as in Fig. 7 but for the period 12 UTC 7 Feb through 15 UTC 7 Feb. Stars in each panel denote location of Rome, NY.

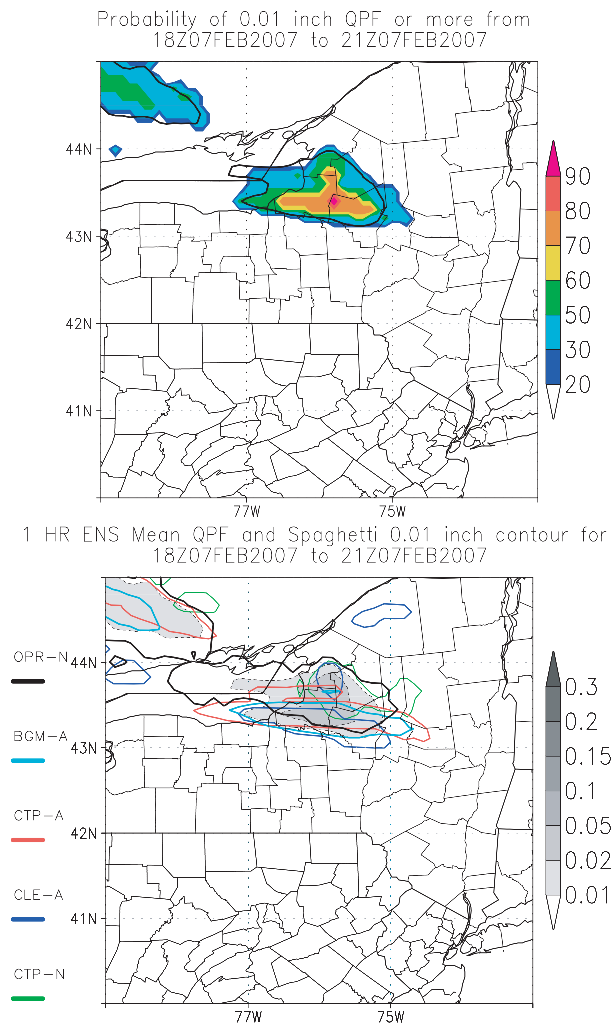

Fig. 10. Same as in Fig. 7 but for the period 18 UTC 7 Feb through 21 UTC 7 Feb.