EASTERN REGION TECHNICAL ATTACHMENT
NO. 90-10A
NOVEMBER, 1991

THE USE OF VARIOUS FORECAST TECHNIQUES TO PREDICT HEAVY SNOW ON NOVEMBER 1-2, 1988

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Editor's Note: Most of this work was done while Mr. Sniezak was stationed at WSO Burlington, VT.

1. INTRODUCTION

Heavy snow forecasting is a challenging task. This job is further complicated when topographic effects must be accounted for, which is certainly the case in Vermont and northeastern New York. Various snow forecasting techniques have been used across the country with some degree of success. One such technique utilizes 850-700 mb thicknesses to determine where the heaviest snow will fall. This method was successfully used to predict a heavy snow event in southern Minnesota on January 19, 1988 (Naistat 1988).

While the approach has been used in Minnesota and elsewhere, it has yet to be thoroughly tested in a more mountainous region such as the Northeast. For this study, 850-700 mb thickness and 200 mb temperature advection were examined in an attempt to forecast the amount of snow that fell between 0000 and 1200 UTC on Wednesday, November 2, 1988. These forecasting aids were compared with other, more commonly used snow forecasting techniques such as the Magic Chart (Chaston 1989), and model (LFM and NGM) 1000-500 mb thickness.

2. SYNOPTIC SETTING

At 0000 UTC on November 2, 1988, there were two surface lows over the Northeast (Figure 1). One low (993 mb) was well off the Virginia coast, with a weaker low (1009 mb) near Toronto, Ontario. By 0300 UTC, only a single low was analyzed near the eastern tip of Long Island, NY. This low subsequently moved into southeast Connecticut, then passed just east of Boston, MA, by 0900 UTC. By 1200 UTC, the low was located over western Maine.

At 500 mb, a closed low was located over southern Ontario at 0000 UTC, November 2, 1988 (Figure 2a). The main vorticity maximum was co-located with the 500 mb low center, with a secondary maxima over northeast Kentucky. An east-west vorticity axis was also located over eastern Pennsylvania and New Jersey. By 1200 UTC (Figure 2b), the low had moved into northeast Pennsylvania, with a more consolidated vorticity maxima just east of Poughkeepsie, NY. Positive vorticity advection occurred across eastern New York and Vermont between 0000 and 1200 UTC, which supported upward vertical motion over the area during this time.

3. 850-700 mb THICKNESS FORECAST

Previous studies (Naistat 1988; Umpenhoffer 1968) have shown that 850-700 mb thicknesses between 1520 and 1540 m provide an indication of where the heaviest snow will fall, given sufficient dynamic forcing and adequate moisture are available. Naistat (1988) also stated that the 850-700 mb thickness pattern, in many cases, is a feature that changes very little for a given model from one run to another.

The forecast 1530 m thickness line from the successive model runs of the NGM (00-48 hour projections) was compared for the valid times ending at 0000 and 1200 UTC on November 2. This was done to see how much variation occurred, as well as to identify the placement of the line. The NGM was the model used in this study because it is the only model from which forecast 850 mb and 700 mb heights are available to NWS field offices via AFOS.

For the forecasts valid at 0000 UTC on November 2, the 1530 m line only varied 50 to 100 mi across New York state (Figure 3). The 48-hour forecast indicated the 1530 m line would run across central Ohio through northwest Pennsylvania into western New York between Buffalo and Rochester. The 36-hour forecast showed an eastward shift in the line of about 75 miles. The 24-hour forecast depicted the line a little further to the west than the previous cycle. The 12-hour forecast showed more of a southwest tilt, but in a position similar to the 24-hour forecast. The observed 1530 m line was further east than any of the forecasted positions, and extended from near Charleston, WV, to just west of Massena, NY. Hence, the heaviest snow was likely to fall across much of western New York.

In contrast, the forecast 1530 m line valid for 1200 UTC on November 2 varied considerably with each successive model cycle (Figure 4). The 48-hour forecast placed the 1530 m line from Patuxent River, MD, to Philadelphia, then northwest through Wilkes-Barre, to Rochester. The 36-hour forecast depicted the 1530 m line further west and south. Each subsequent model run predicted the line farther east. The observed 1530 m line was a little farther east than any of the forecasts, extending from New York City, north to just east of Massena. This alignment indicated the heaviest snow should fall over eastern New York.

4. THE B.J. COOK TECHNIQUE

By application of the Cook Index (Cook 1980), the average amount of snowfall can be obtained by finding the difference in temperature between the 200 mb warm core and cold core, and dividing by a factor of two. The maximum amount of snowfall is equal to the difference in temperature between the warm and cold core at 200 mb. The warm core and the cold must be no more than 850 nm apart. The Cook Index also assumes that warm advection is occurring at 700 mb.

In this case, the warm core and the cold core were less than 850 nautical miles apart. In addition, warm advection was occurring at 700 mb by 0000 UTC, so the Cook Index could be used without reducing the snow amount as described by Cook (1980). At 0000 UTC, the cold core at 200 mb was located over eastern New England, with a temperature of -61°C. Upstream, the warm core was over the upper Ohio Valley, where the temperature was -47°C. Based on the Cook Index, the average amount of snowfall should have been 7 inches, while the maximum amount of snowfall should have been 14 inches.

5. THE MAGIC CHART

Another snow forecasting technique is based on the so-called "Magic Chart". This technique, described by Chaston (1989), combines the 24-hour, 850 mb temperature forecast with the 12-24 hour, 700 mb net vertical displacement (NVD) forecast derived from the LFM-based trajectory model. (Note, the LFM-based trajectory model was replaced by an NGM-based version in February 1990; National Weather Service 1990.) The Magic Chart technique states that the heaviest snow falls where the greatest NVD coincides with 850 mb temperatures between -3°C and -5°C. The amount of snowfall in this area is forecast with a +10 mb NVD to 1 inch of snow ratio.

In this case, the 850 mb temperatures were never forecast lower than -3°C. Actually, observed 850 mb temperatures at 1200 UTC on November 2, 1988, were around 0°C. As a result, the lower elevation areas in the Champlain Valley received rain, rather than snow. Based on the net vertical displacement alone (e.g., without accounting for the 850 mb temperature), the 10 mb to 1 inch ratio, implied 6 to 12 inches of snow could fall across eastern New York and Vermont through 1200 UTC on November 2, 1988, if temperatures were still cold enough to support snow, despite being warmer than the -3°C upper limit suggested by Chaston (1989).

6. 1000-500 mb THICKNESS FORECAST

One of the most widely used winter forecasting tools is the 1000-500 mb thickness pattern. Most of the time, the 540 dm line is an indicator of where the rain/snow line will be located. The forecast 1000-500 mb thickness patterns from both the LFM and NGM were compared to the observed thickness values valid at both 0000 and 1200 UTC November 2, 1988.

The LFM forecasts valid for 0000 UTC varied considerably (Figure 5) with each model run. The 48-hour forecast indicated that the 540 decameter line would extend from northern Ohio, to near Toronto, Ontario. Each subsequent model run showed an south and eastward shift. By the 12-hour forecast, the 540 decameter line was very close to its observed location, which ran from Roanoke, VA, to Plattsburgh NY.

The NGM forecasts valid the same time were more consistent than the LFM forecasts (Figure 6). The 48 hour forecast indicated the 540 decameter line would extend from near Pittsburgh, PA, to Elmira, NY, to St. Johnsbury, VT. The 36-hour forecast showed a northwest shift of the line across New York of about 75 mi. Both the 12- and 24-hour forecasts changed very little from the 36-hour forecast. The observed position was about 50 mi east of the 12-, 24-, and 36-hour forecast.

The LFM forecast valid for 1200 UTC on November 2 was somewhat inconsistent on the placement of the 540 dm 1000-500 thickness line (Figure 7). The 48-hour forecast indicated the line would extend from northern Virginia to Saranac Lake, NY. The 36-hour forecast indicated a westward shift of the line by about 25 mi. The 24-hour forecast indicated an eastward shift of the line by nearly 40 mi, with even greater shifts evident south of New York. The 12-hour forecast was quite close to the observed location of the 540 dm line, extending from near New Haven, Ct, to Albany, to Massena. This indicated that extreme northeastern New York, and all of Vermont, would be too warm to support snow.

The NGM forecasts were even more erratic with its placement of the 540 dm line than the LFM (Figure 8). The 48-hour forecast position was located from near New York City to Watertown, NY. The 36-hour forecast showed a westward shift in the line by over 150 mi. The 12 and 24-hour forecast resulted in an eastward shift of the line, with the 12-hour forecast just west of the observed location.

7. SEA LEVEL PRESSURE FORECASTS

The LFM and NGM sea level pressure forecasts were compared to see how well each model performed (Figures 9 and 10). The LFM forecasts valid for 0000 UTC consistently forecast the low observed off the mid-Atlantic coast farther west than the actual location, with slight improvements evident in each subsequent model cycle. The LFM did not indicate a low in southern Ontario until 24 hours before valid time.

The NGM forecast for the same time had the position of the mid-Atlantic low farther west than the LFM. While the NGM indicated a low over southern Ontario as early as the 48-hour forecast; there was no low in the 12-hour forecast. Each NGM run forecast this low slightly northwest of the observed position. These position errors are consistent with the findings of Junker et al. (1989), who state that the NGM forecasts of surface lows over the eastern U.S. are, on average, too far northwest.

The LFM forecasts valid at 1200 UTC were somewhat erratic, with positions ranging from south of Buzzards Bay, MA, at 36 hours to central Maine (the closest model forecast to the observed position) at 24 hours. The NGM forecasts were a little more consistent, but all forecasts positions were south or southwest the observed position.

8. OBSERVED SNOWFALL

The storm produced some locally heavy snow in the Adirondacks of northern New York and the Green Mountains of Vermont (Figure 11). Whiteface Mountain, NY, reported 10 inches of snow between 0000 and 1200 UTC. Nine inches of snow was reported at Ray Brook and Tupper Lake in New York. Jay Peak and Waitsfield, VT, as well as Malone, NY, reported 8 inches. Six inches of snow fell on Colton and Ellenburg Depot in New York. Lesser amounts fell over much of northeast New York and along the Green Mountains of Vermont, with only rain in the Champlain Valley.

9. CONCLUSIONS

Based on this case study, the 850-700 mb thickness pattern was not a particularly useful forecasting tool. In contrast to Naistat (1988), there was considerable variation in the location of the 1530 m line from each forecast run, and it did not accurately delineate the location of the snow event until 0000 UTC, just as the event began.

However, none of the other forecast techniques performed much better. It is important to remember that forecast techniques such as those discussed here, which are derived from dynamical model output, can only be as good as the model input they utilize. Techniques that rely on specific positions of features such as thickness contours and isotherms are susceptible to substantial changes with each model cycle. In this case, while the model appeared to handle the overall evolution of this system quite well, variations in location (or timing), when applied in these forecast techniques, give the impression that the models are erratic.

Another probable factor in the less than fully successful results may be that this was an early season storm, which is often more difficult to forecast than a mid-season snow event. The B.J. Cook Index, and the net vertical displacements from the Magic Chart, forecast the snow amounts fairly well, although the heavier amounts were confined to the mountains of northern New York and Vermont. Elevation played a major role in determining precipitation type in this event, and may also have enhanced snowfall totals through orographic lift, although precisely how much is not clear. This case does not imply the 850-700 mb thickness can not be used to forecast snow in the Northeast. However, it does suggest that additional research into the applicability of these forecast techniques in variable terrain is needed. Also, caution should be exercised with the application of these forecast tools, especially during early, or off season, events. Of course, these tools can never replace the careful and detailed analysis of an experienced forecaster with access to the full suite of operational data, both observed and predicted.

10. ACKNOWLEDGEMENTS

Special thanks to Richard Naistat at WSFO Minneapolis, whose paper on 850-700 mb thickness was the basis for this study. Other individuals to be acknowledged include Barry Schwartz (Environmental Research Laboratory/Forecast Systems Laboratory), and Jeff Waldstreicher (Eastern Region Scientific Services Division). Their assistance in retrieving data was invaluable. Thanks also go to the staffs at both WSFO Albany and WSO Burlington for providing constructive comments and suggestions.

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Umpenhoffer, C.M., 1968: Low level thickness charts (Unpublished report). Det. 42, 7th Weather Wing (MAC), Kansas City, MO. [Available from National Severe Storms Forecast Center, Kansas City, MO.]

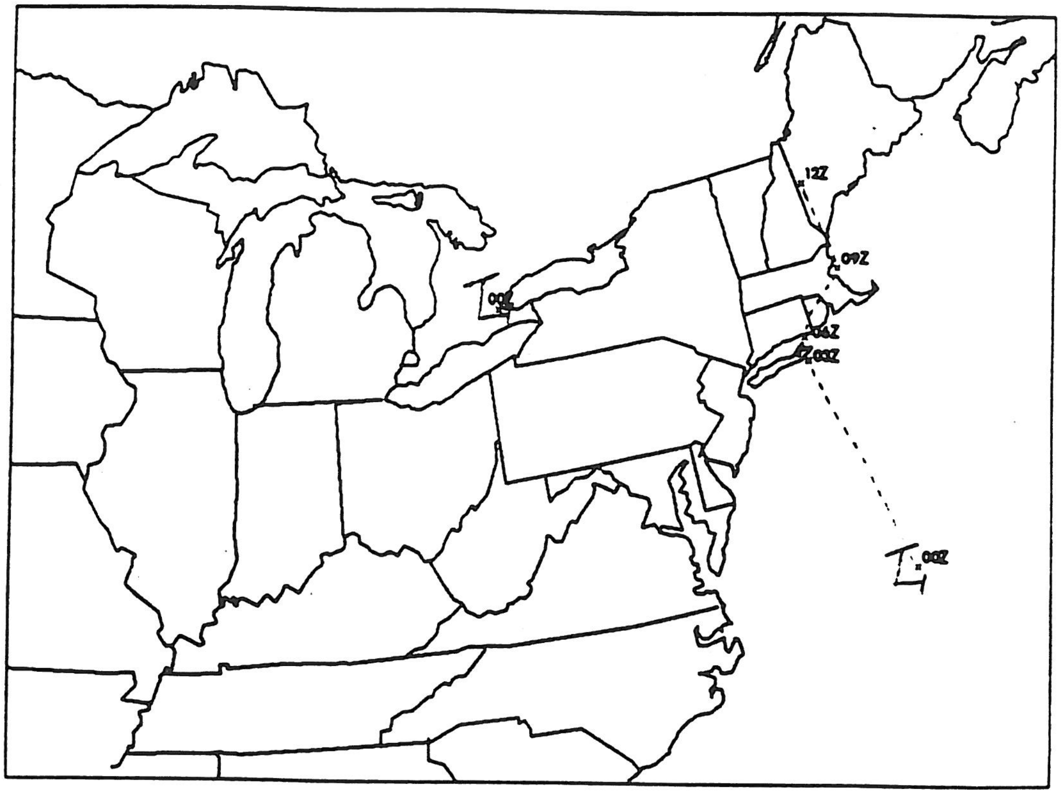

Figure 1. Observed position of surface lows for 0000 to 1200 UTC November 2, 1988.

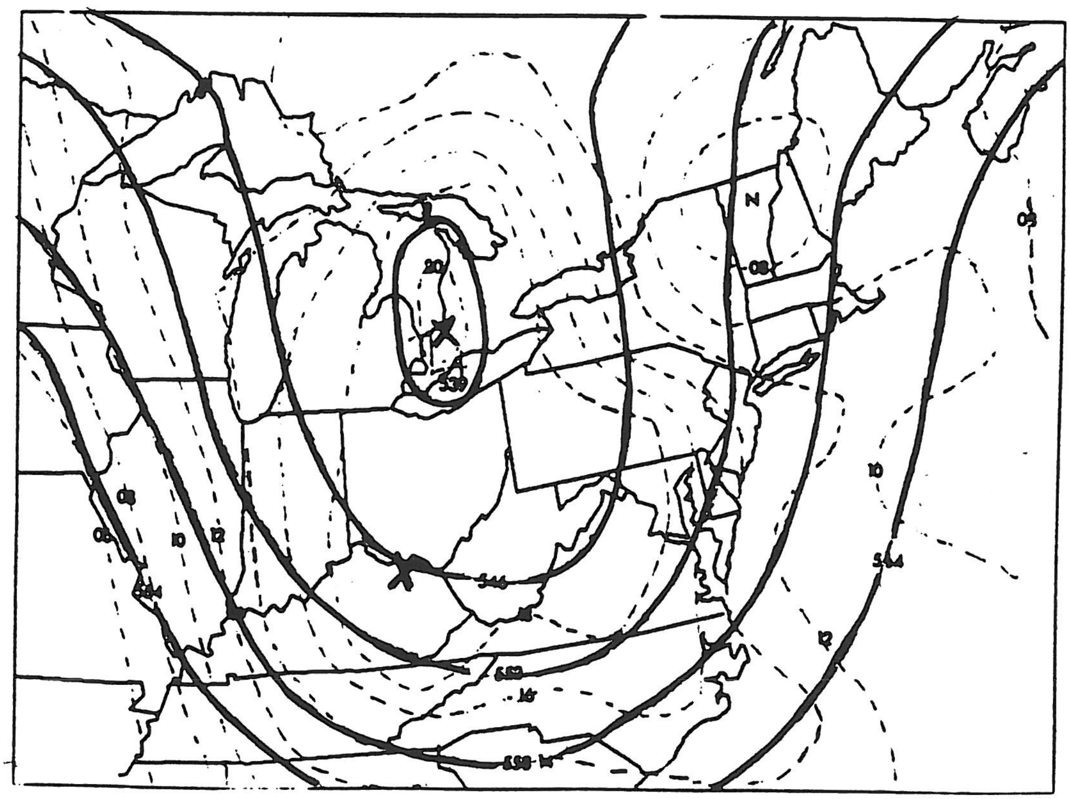

Figure 2a. 500 mb heights (solid) and vorticity (dashed) for 0000 UTC November 2, 1988.

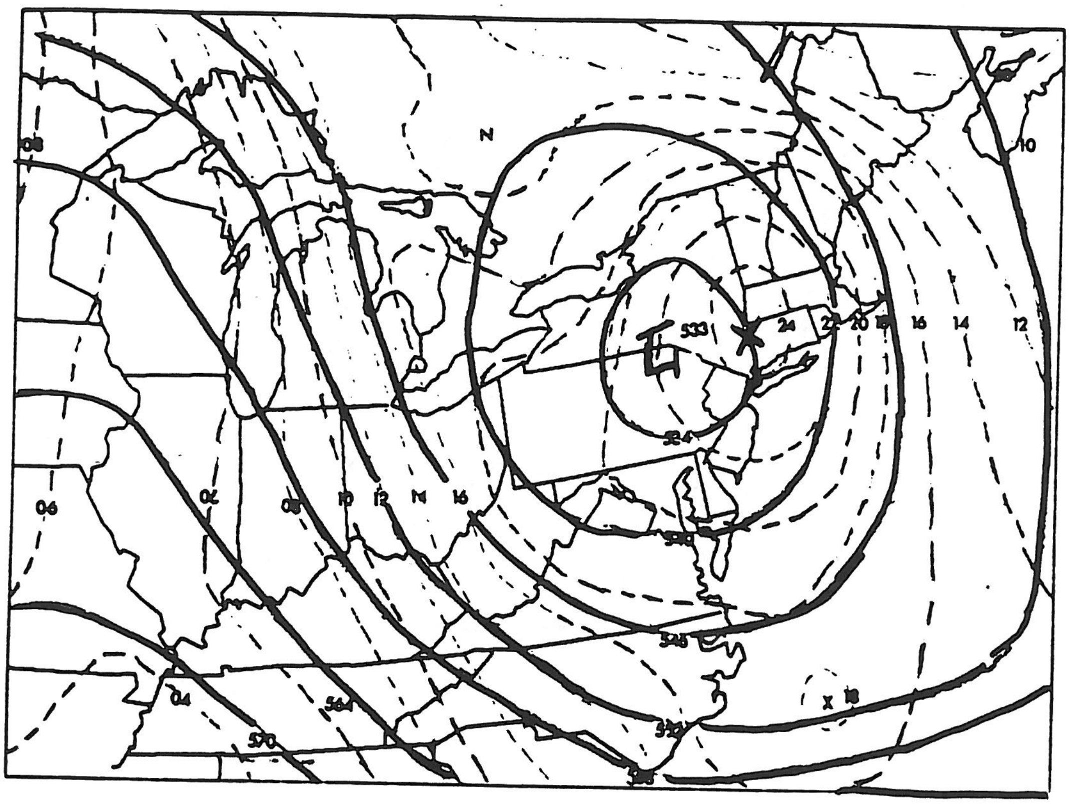

Figure 2b. Same as Figure 2a except for 1200 UTC November 2, 1988.

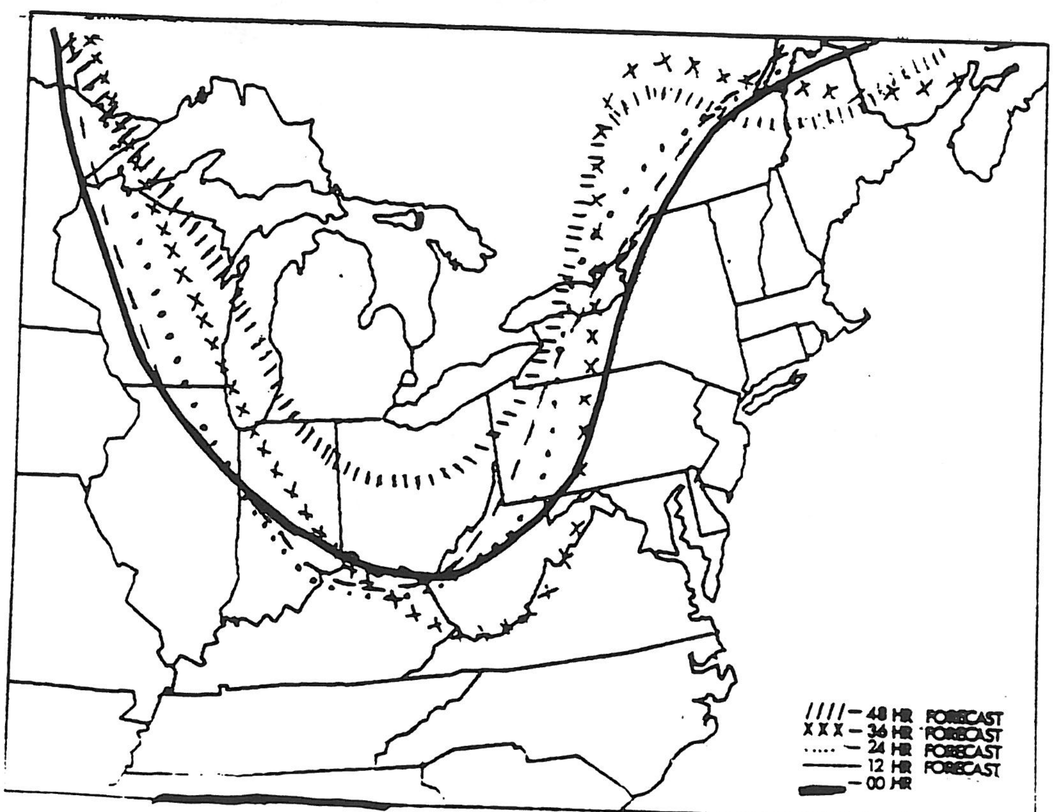

Figure 3. 00-48 hour NGM forecasts of 850-700 mb 1530 m thickness contour for 0000 UTC November 2, 1988.

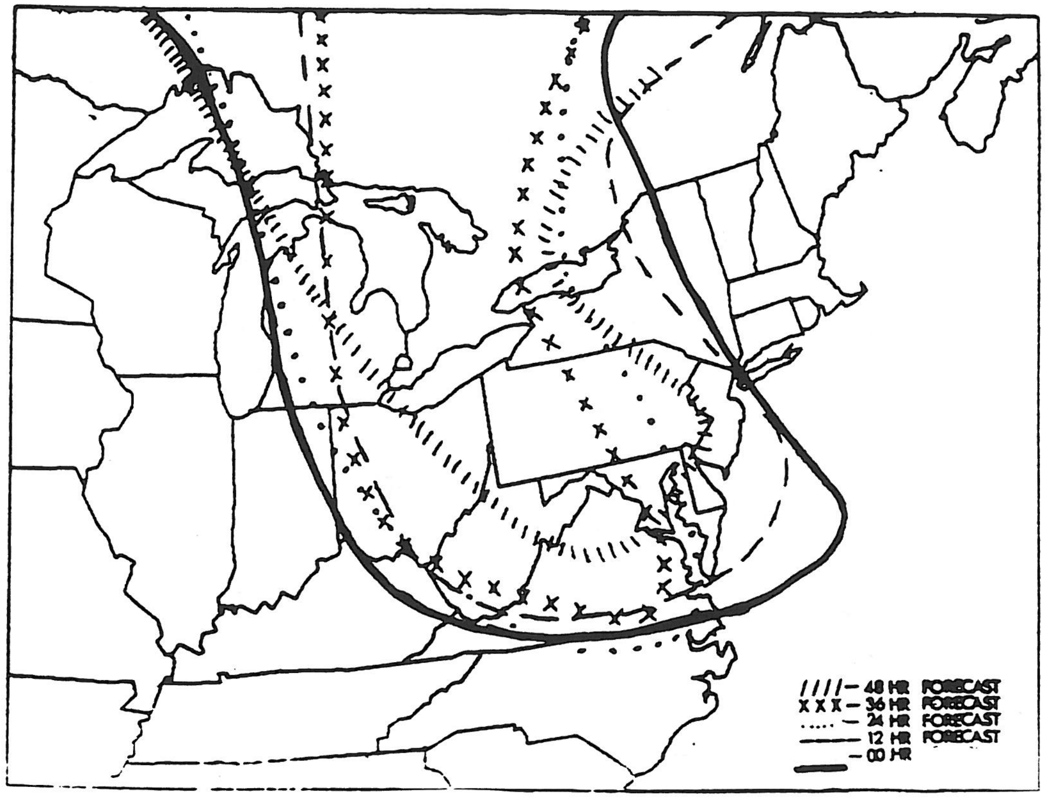

Figure 4. Same as Figure 3 except for 1200 UTC November 2, 1988.

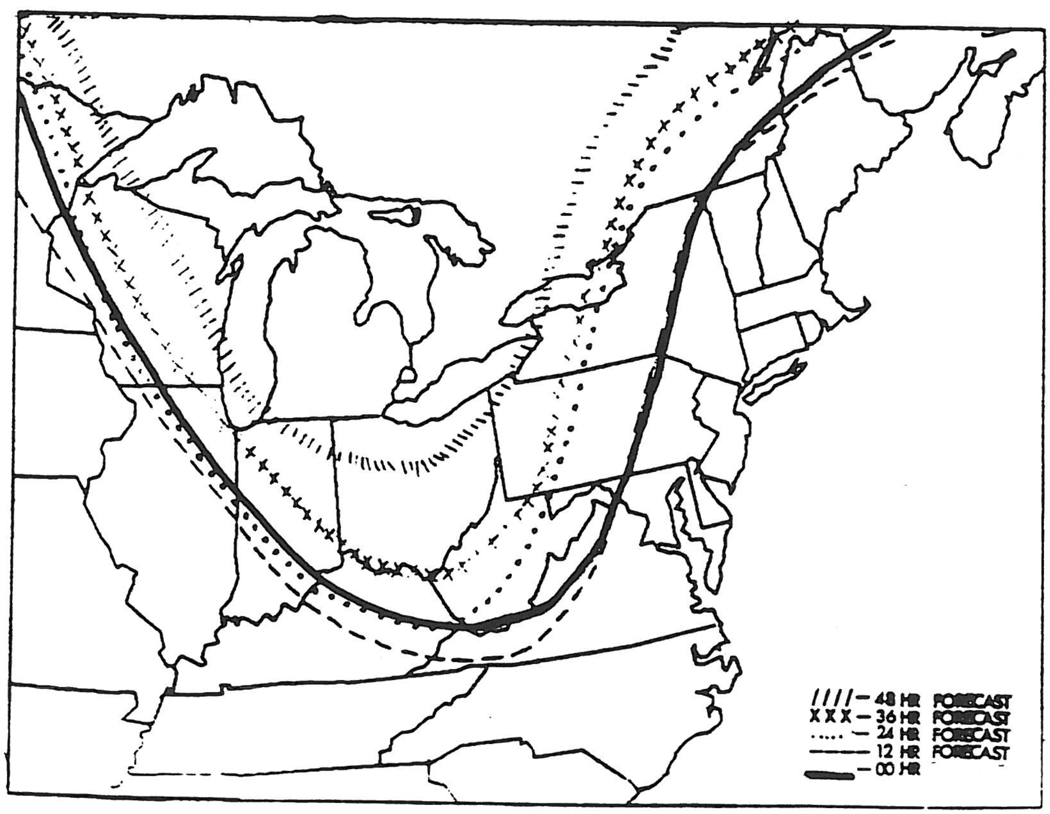

Figure 5. 00-48 hour LFM forecasts of 1000-500 mb 5400 m thickness contour for 0000 UTC November 2, 1988.

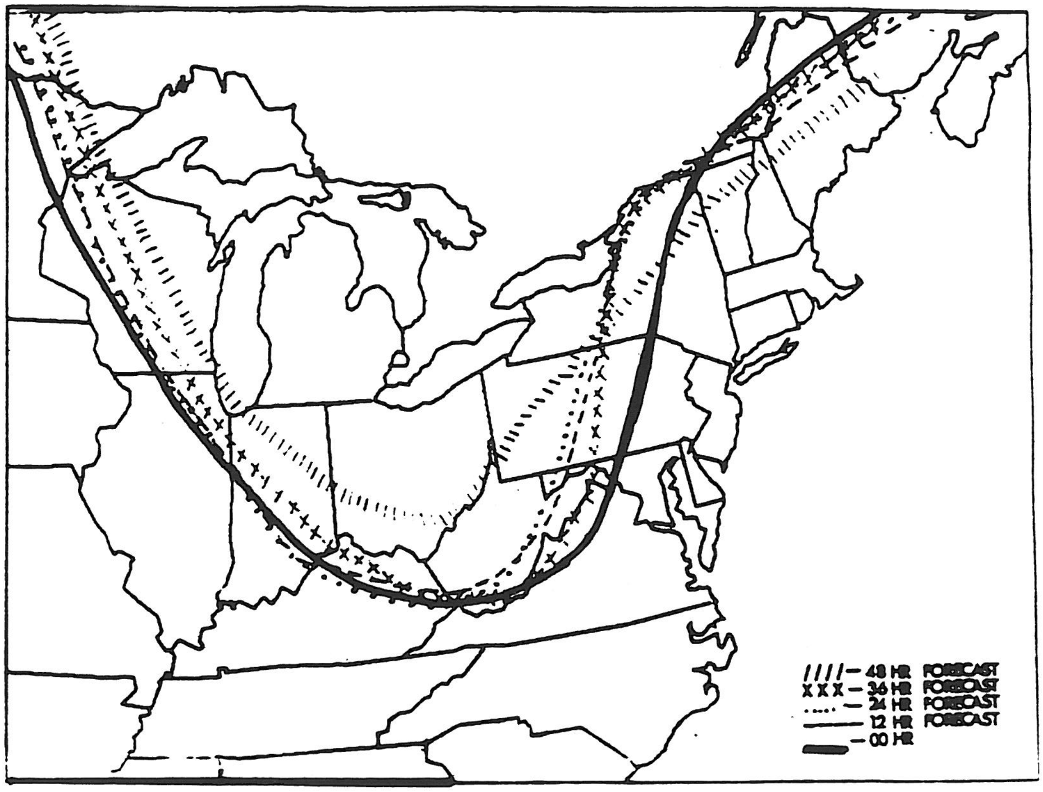

Figure 6. Same as Figure 5 except for NGM forecasts for 0000 UTC November 2, 1988.

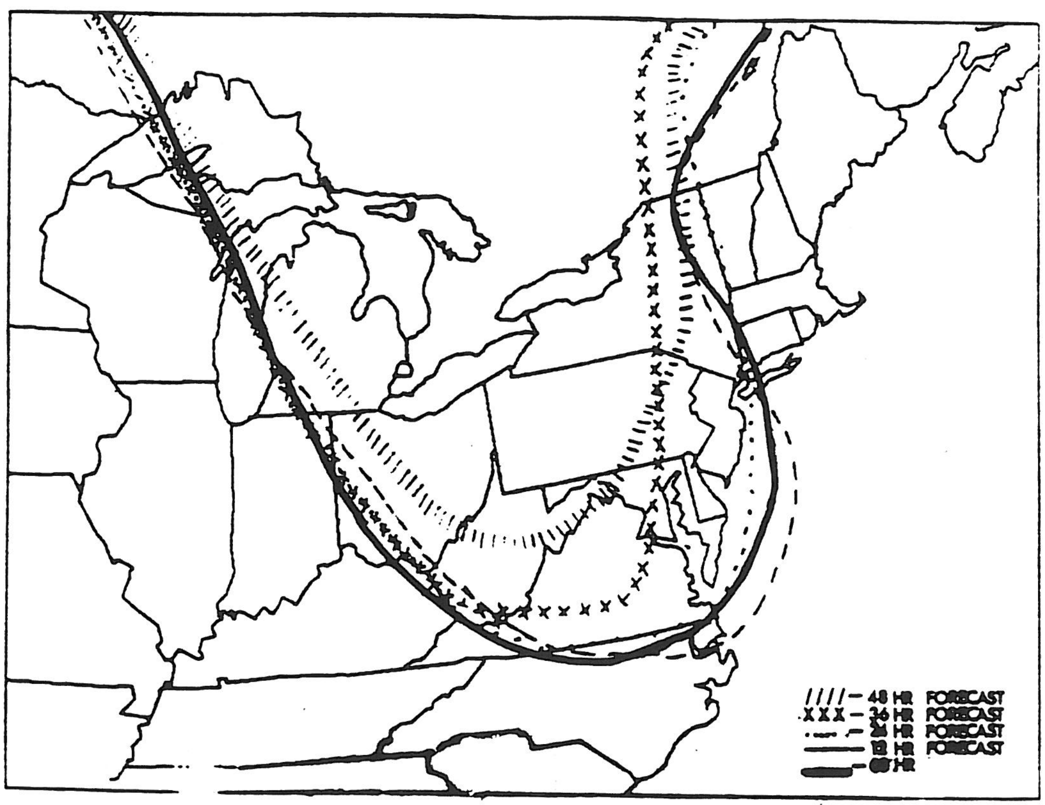

Figure 7. Same as Figure 5 except for 1200 UTC November 2, 1988.

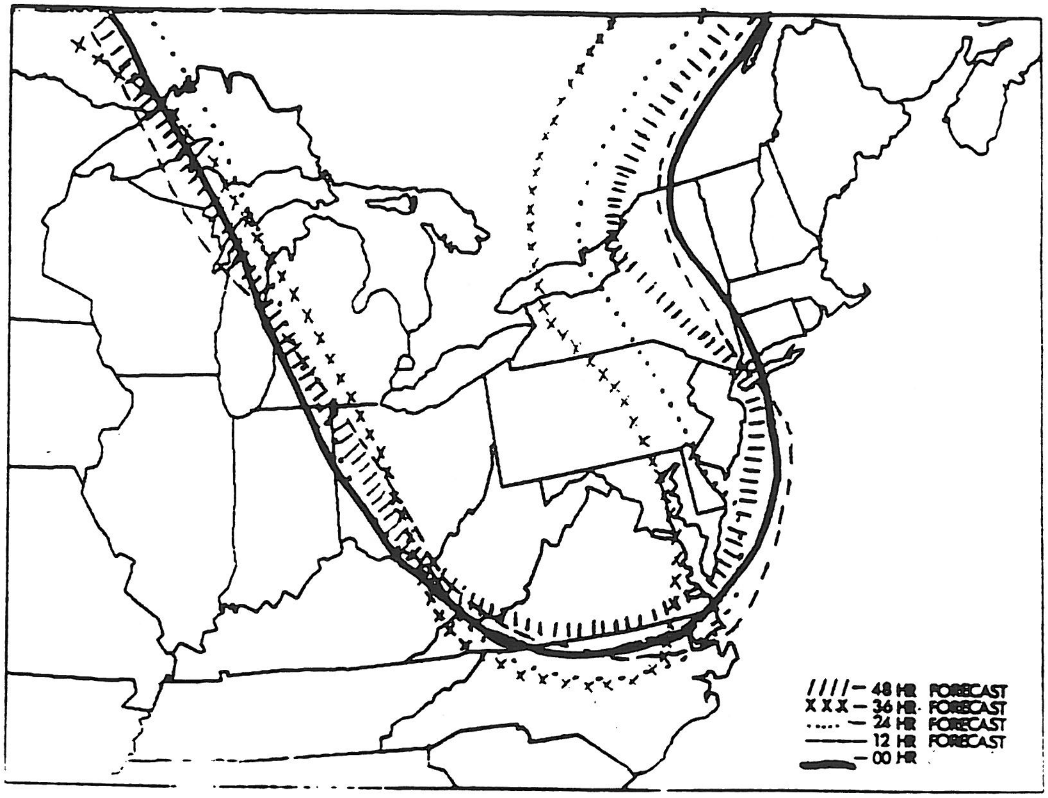

Figure 8. Same as Figure 5 except for NGM forecasts for 1200 UTC November 2, 1988.

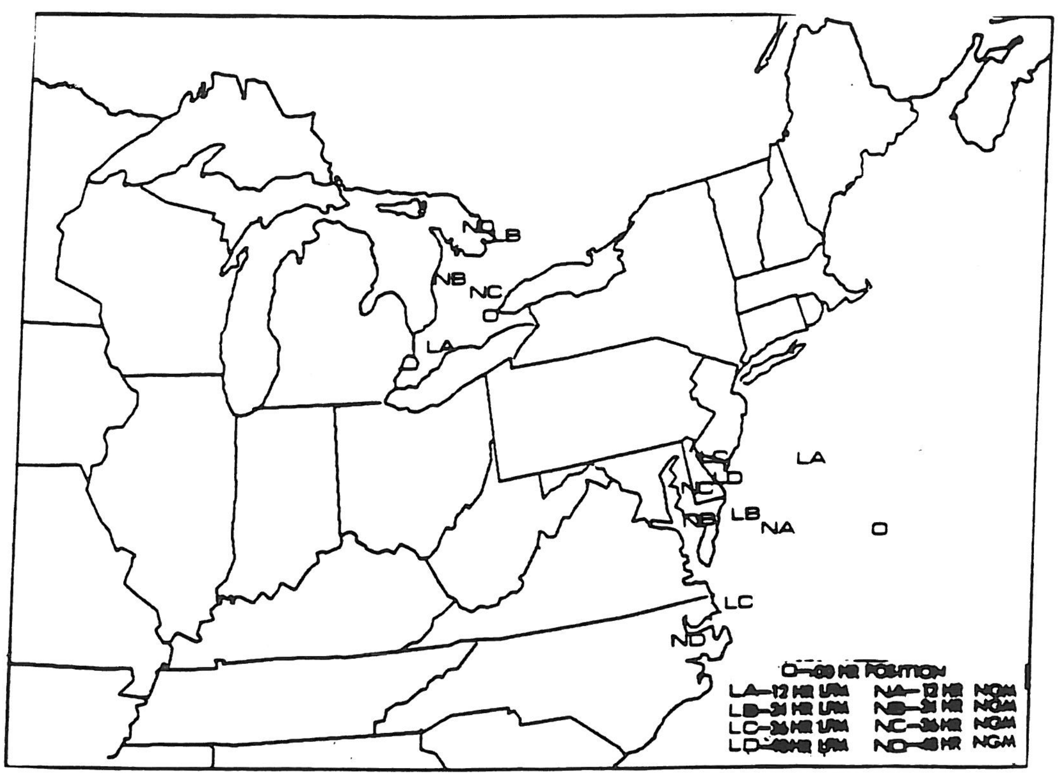

Figure 9. 00-48 hour LFM and NGM forecasts of surface low positions for 0000 UTC November 2, 1988.

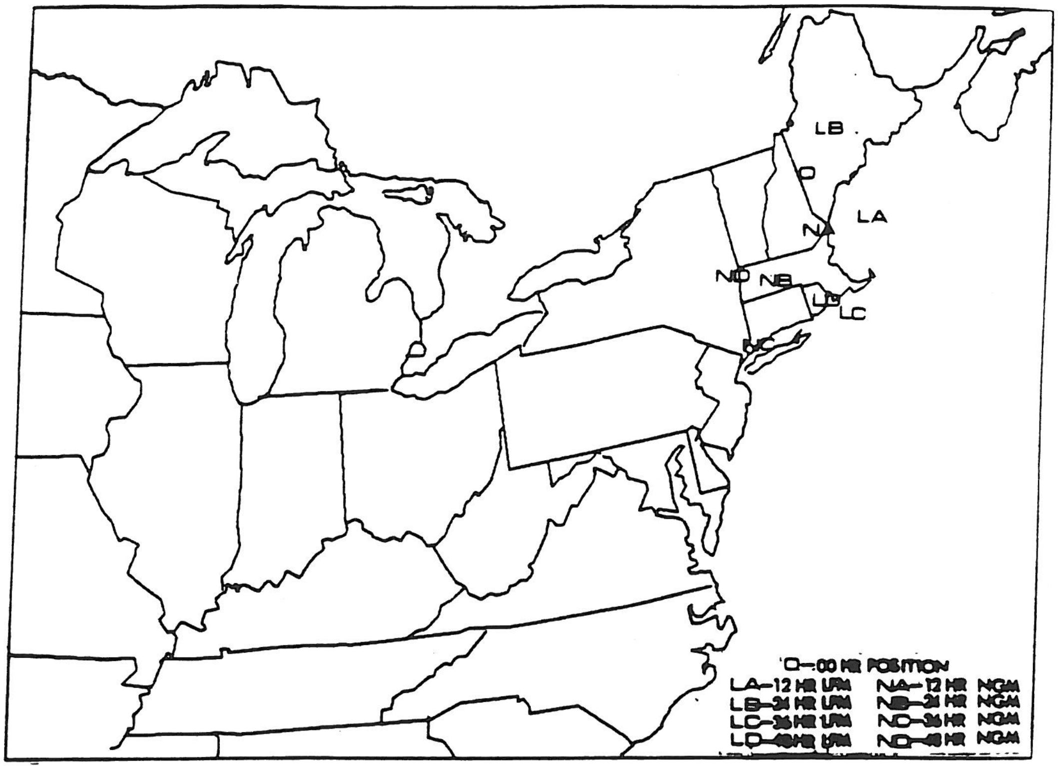

Figure 10. Same as Figure 9 except for 1200 UTC November 2, 1988.

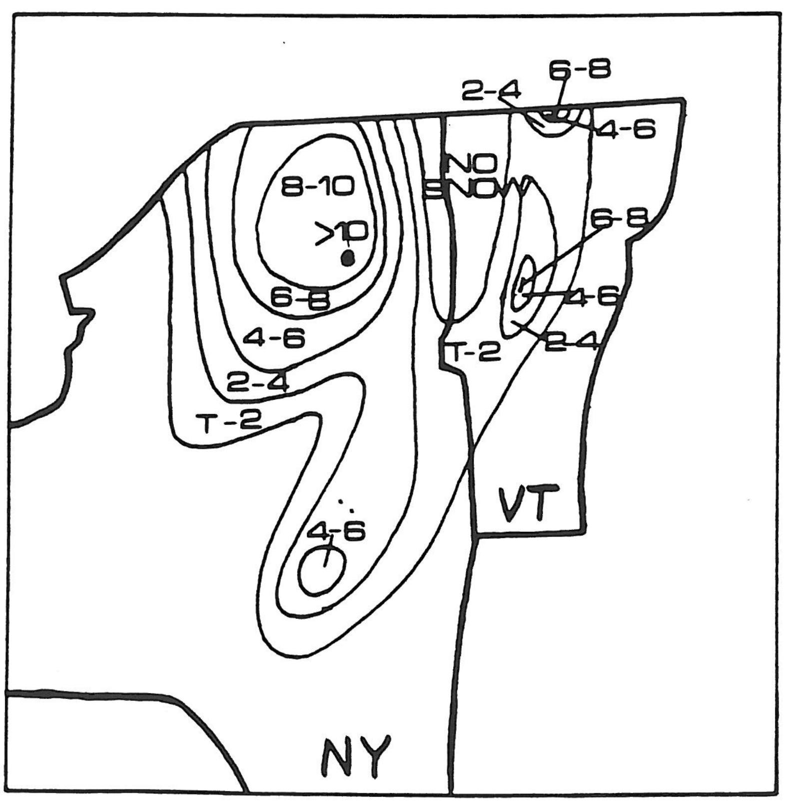

Figure 11. Observed 12-hour snowfall ending 1200 UTC November 2, 1988.