" NORLUN INSTABILITY TROUGH "

AN EXPLANATION OF TWO COASTAL NEW ENGLAND UNEXPECTED SNOWSTORMS WHICH PRODUCED OVER A FOOT OF SNOW

Weir Lundstedt
National Weather Service
Center Weather Service Unit
Nashua, New Hampshire

INTRODUCTION

On March 21st, 1992 the southwest coast of Maine received the largest snowstorm for that year. Nearly 1 to 2 feet of snow fell in an 8 hour period from just after midnight to 8 o'clock in the morning. What made this storm unique was that it was a total surprise and snowfall rates at the height of the storm where some 3 to 4 inches per hour.

Nearly one year later on February 19, a similar storm occurred over parts of Cape Cod. Snowfall rates reached 3 to 4 inches per hour, blizzard conditions were experienced, and snow amounts ranged from 12 to 20 inches, most of which occurred in a 6 hour period. Again this storm was generally a surprise with some local media calling it a "freak" snowstorm.

This paper will give a brief overview of both snowstorms and show that these two snow events had many things in common. It will be argued that in each case it was persistent snow squalls which led to the large snowfall rates. These snow squalls were fueled by instability and sufficient moisture in the boundary layer as defined by WINDEX. (Lundstedt, 1993). A special type of trough was identified and named the Nogueira / Lundstedt or " NORLUN " instability trough for its ability to focus and lift the moisture in an unstable atmosphere to form the intense and persistent snow squalls over a given area. Criteria for this trough will be established for future use by forecasters.

1. DISCUSSION

Lake effect snowstorms have always been a part of life for those people who live in areas downwind of the Great Lakes. The reason for the snowstorms and ways to forecast their occurrence have been well documented, especially by Niziol (1987).

This paper deals with a similar type of snowstorm that effects New England, especially coastal sections. It results when moisture is advected from off the ocean into a nearly stationary convergent zone. This moist air is then lifted into an environment which is favorable for the formation of snow squalls as determined by WINDEX. These snow squalls then move very little, or traverse the same area over a given period of time resulting in a significant accumulation of snow.

Although this type of snowstorm does not occur nearly as often as those experienced downwind of the great lakes, it certainly has the same impact on both public and aviation interests. The convergent zone in which persistent snow squalls occurred was named the NOgueiRa/LUNdstedt or NORLUN instability trough. Five criteria were found necessary for this trough to have the potential to produce significant snowfall. They are as follows:

1) NGM T1-T5 temperature difference is ~~14~~10°C or greater.
2) NGM boundary layer relative humidity (R1) > 50% with a wind component from off the ocean on one side of trough.
3) 500 mb positive vorticity advection is observed with associated NGM positive 700 mb vertical velocity values.
4) Trough axis is expected to be nearly stationary for at least 6 hours.
5) 850 mb flow is very weak or is parallel to surface trough.

2. THE NORLUN INSTABILITY TROUGH

In brief, the NORLUN instability trough acts to focus atlantic moisture into a nearly stationary convergent boundary which is then lifted into the low level instability to form snow squalls. 500 mb positive vorticity advection (PVA) with associated NGM positive vertical velocity values enhance upward motion and likely increases the depth of the unstable layer. The 850 mb winds are important as a steering current for the snow squalls. A very weak flow or a flow which is parallel to the surface trough both act to ensure that the snow squalls persist over a given area which result in a mesoscale snowstorm. The five criteria set forth to establish the NORLUN instability trough each contribute in formulating this event.

2.1 Criteria 1: NGM T1-T5 temperature difference is ~~14~~10°C or greater.

The difference in the NGM model layer 1 and layer 5 temperature is a measure of instability in the lower levels of the atmosphere as defined by WINDEX. A difference of ~~14~~10°C was found to be unstable for the formation of snow squalls.

2.2 Criteria 2: NGM boundary layer relative humidity (R1) of greater than 50% with a wind component from off the ocean on one side of trough.

This criteria establishes the minimum amount of moisture necessary in the boundary layer for the formation of snow squalls as established by the WINDEX study. The wind component from off the ocean is necessary to continually feed a rich reservoir of moisture into the trough from off the ocean. It can usually be assumed that if there is a wind component from off the ocean than R1 will most likely be greater than 50%.

2.3 Criteria 3: 500 mb positive vorticity advection is observed with associated NGM positive 700 mb vertical velocity values.

This criteria appears to enhance upward vertical motion and increase the depth of the unstable layer. Both factors help to contribute to the snowfall rates of 2 to 4 inches per hour observed with the snow squalls in the NORLUN instability trough.

2.4 Criteria 4: Trough axis is expected to be nearly stationary for at least six hours.
Criteria 5: 850 mb flow is very weak or is parallel to surface trough.

The nearly stationary trough ensures a semi-permanent breeding ground for the formation of snow squalls. When the 850 mb flow is very weak the snow squalls are slow moving and thus have the potential of producing larger accumulations over a given area. Likewise a 850 mb flow which is parallel to the surface trough has a "train echo" effect which enables the snow squalls to continually traverse the same area. Finally, a trough that is nearly stationary for at least six hours has the potential to produce 12 or more inches of snow if all the other criteria are met.

3. ATMOSPHERIC CONDITIONS AND SCENARIO OF THE SOUTHWEST MAINE SNOWSTORM OF MARCH 21ST, 1992.

3.1 ATMOSPHERIC CONDITIONS

The surprise snowstorm in southwest Maine on March 21st, 1992 was the result of a NORLUN instability trough. The synoptic pattern for this event was very benign looking. At the surface an inverted trough was forecast to move across New England and become nearly stationary along the coast during the early morning hours of the 21st (Fig 1,2). There was some 500 mb PVA (Fig 3,4), but no measurable precipitation was forecast by the models. In addition, the 1000-500MB mean RH was between 30-60% (Fig 5,6) and this was below the threshold values most forecasters use for precipitation.

Of more importance during this period was what was happening in the boundary layer. The low levels over southwest Maine were forecast to be very unstable with T1-T5 temperature differences of 14 to 16°C (Fig 7). Although the boundary layer relative humidity (R1) forecast to be initially dry, a persistent south to southeast wind was slowly bringing moisture in from off the ocean and this was reflected in rising dewpoints during the late afternoon and evening hours. At 850 mb, winds were to become light and variable (Fig 8,9) and 500 mb PVA and positive 700 mb vertical velocity values were both forecasted by the NGM. All criteria were in place for a significant outbreak of snow squalls.

3.2 SCENARIO

By 0000 UTC on the 21st, the inverted trough was well defined by a wind shift line near western New England. As mentioned earlier, the initially dry atmosphere which existed over much of southern and central New Hampshire and southwest Maine during the early afternoon had now been moistened by a persistent south to southeast wind from off the ocean. Between 0000 and 0200 UTC, the inverted trough moved across New Hampshire. It touched off flurries over southern sections of the state and a period of snow over central New Hampshire just south of an associated 500 mb vorticity maximum. Behind the trough, winds turned to the north and northwest as dryer air and partial clearing took place.

By 0600 UTC, the trough was along the Maine and New Hampshire coast (Fig 10). North winds were observed at Portsmouth, southeast at Portland. At this time the convergence zone had run into a rich reservoir of moisture. Between 0600 and 1200 UTC on the 21st, the trough slowed its progress due to in part to the large ocean storm well to the southeast in the open Atlantic ocean (Fig 11). The maximum snowfall occurred during this time period within 10 miles of the southwest coast of Maine, mainly from Kennebunkport to Falmouth. The light and variable 850 mb winds resulted in slow and erratic movement of the squalls with some snowfall rates of 3 to 4 inches per hour. Total accumulations from the event ranged up to 2 feet!

After 1200 UTC on the 21st, the circulation around the intensifying low in the Atlantic was now beginning to shift the squalls more southwest and south, with first coastal New Hampshire getting a glancing blow, then coastal Massachusetts and Cape Cod.

4. ATMOSPHERIC CONDITIONS AND SCENARIO OF THE CAPE COD SNOWSTORM OF FEBRUARY 19TH, 1993

4.1 ATMOSPHERIC CONDITIONS

A remarkably similar situation to the southwest Maine snowstorm occurred over parts of Cape Cod on February 19th, 1993. Again, the synoptic pattern was benign looking with an inverted trough moving across New England (Fig 12,13). The NGM did indicate some 500 mb PVA (Fig 14,15) and less than a tenth of an inch /.10/ of precipitation with this trough, but the mean 1000-500 mb (R2) relative humidity was forecast to be 70% or less (Not Shown).

However, as was the case with the southwest Maine snowstorm, all criteria were forecast to come together for a NORLUN instability trough. The low levels of the atmosphere were expected to be unstable with a T1-T5 temperature difference of 14°C or greater (Fig 16). The boundary layer relative humidity (R1) was greater than 50% (Fig 17,18) with a wind component from off the ocean. Both 500 mb PVA and 700 mb vertical velocity values were forecasted to be present as the trough was to become nearly stationary along the coast during the morning of the 19th. Finally, the 850 mb winds were expected to be light and variable over southern New England during the evening of the 18th, then become more north to northeast and aligned with the surface trough during the morning of the 19th (Fig 19,20). Thus the snow squalls that formed on the 19th would be directed toward the southern New England coast or Cape Cod.

4.2 SCENARIO

During the late afternoon hours on the 18th, flurries and some heavier snow showers began to develop in the unstable and increasingly moist atmosphere across parts of southern New England. Those flurries and snow showers became heavier and more widespread during the evening hours as the trough began to develop. By midnight, 1 to 5 inches of snow had fallen roughly in an area along and near the trough axis. This included Rhode Island, eastern Connecticut, central Massachusetts and even extending northward into New Hampshire. Keep in mind, the afternoon forecast for these areas indicated little about accumulating snow.

After midnight, the trough was beginning to shift to the coast. Correspondingly, the snow showers had come to an end across much of the interior. Between 0800 and 1600 UTC on the morning of February 19th, the trough became stationary just off the coast of southern New England and intense heavy snow squalls developed. The area hardest hit during this time was the outer part of Cape Cod from Provincetown to Chatham. Snowfall rates reached 4 inches per hour with white out conditions and accumulations ranged from 12 to 20 inches. Elsewhere over the cape and along the southern New England coast much lower snowfall accumulation of 1 to 4 inches were noted. The heaviest snow squall activity began to move east of the area by late in the morning as winds aloft began to shift northwest and offshore.

5. SUMMARY AND CONCLUSIONS

Non-lake effect snow squalls occur many times during the winter across New England. On occasion these snow squalls organize in a way which can produce a localized snowstorm. The more significant localized snowstorms occur within what has been named the NORLUN instability trough. Five criteria were established in this paper to identify a NORLUN instability trough, they are as followed:

1. NGM T1-T5 temperature difference is ~~14~~ 10°C or greater.
2. NGM boundary layer relative humidity (R1) > 50% with a wind component from off the ocean on one side of trough.
3. 500 mb positive vorticity advection is observed with associated NGM positive 700 mb vertical velocity values.
4. Trough axis is expected to be nearly stationary for at least 6 hours.

5. 850 mb flow is very weak or is parallel to surface trough.

The two events presented in this paper were excellent examples of the significant snow that can fall in a short time period within a NORLUN instability trough. It must be emphasized that the heaviest snowfall occurs in a narrow band near the trough axis with accumulation decreasing rapidly away from this axis.

Once a NORLUN instability trough is expected to evolve, the two most important decisions a forecaster must make is; where will the axis of the trough become stationary and just how much snow will fall in the persistent squalls. It would be best to address these uncertainties to the public in a special weather statement and refine the forecast as the event begins to unfold.

Remember the squalls along the axis of the trough are capable of snowfall rates of 2 to 4 inches per hour, thus a trough that is expected to remain nearly stationary for 6 hours would have the potential of 12+ inches of snow over a given area.

ACKNOWLEDGMENTS

The NORLUN instability trough was partly named after Steve Noguiera. Steve is a meteorlogist intern at the Weather Service Office in Concord NH and has added invaluable insight to this study.

REFERENCES

Lundstedt, W.,1993 : WINDEX

Niziol, T.A.,1987: Operational Forecasting of Lake Effect Snowfall in Western and Central New York. Weather and Forecasting 2, 310-321.

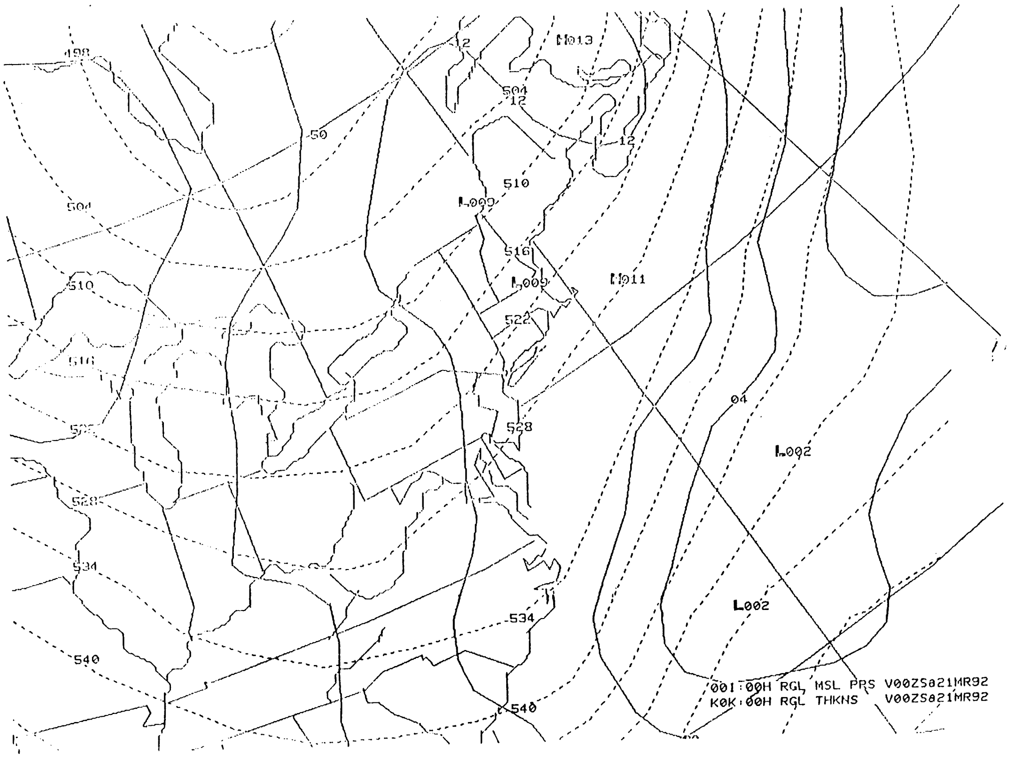

Figure 1. 0000 UTC, March 21, 1992. NGM MSL pressure analysis and 1000-500 mb thickness.

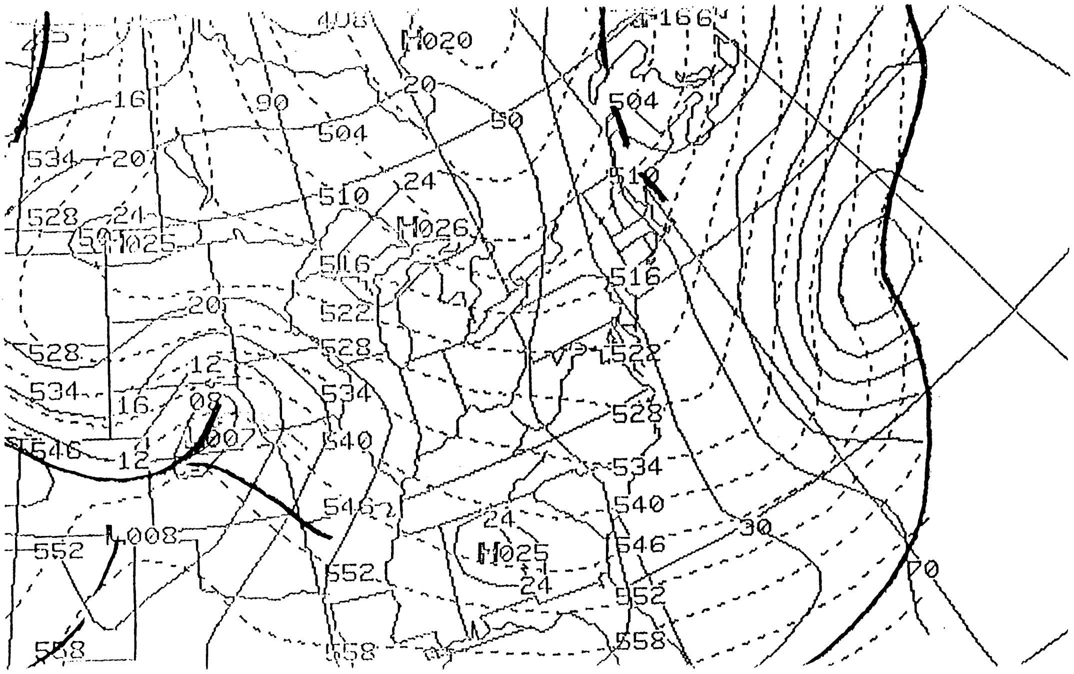

Figure 2. 1200 UTC, March 21, 1992. NGM MSL pressure analysis and 1000-500 mb thickness.

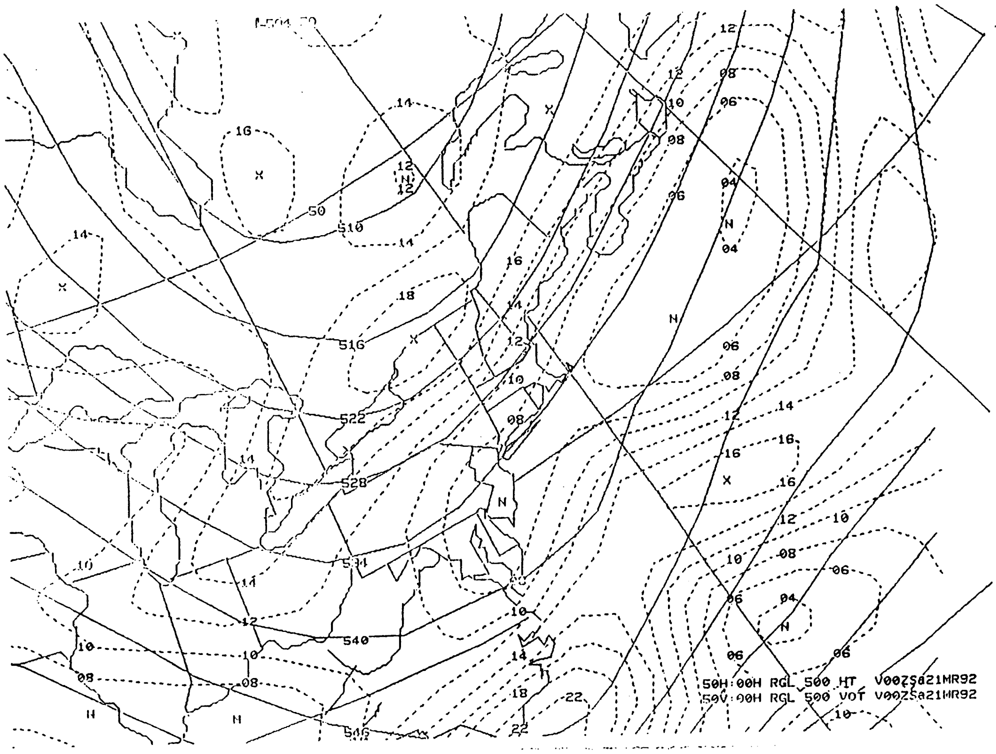

Figure 3. 0000 UTC, March 21, 1992. NGM 500 mb height analysis and vorticity.

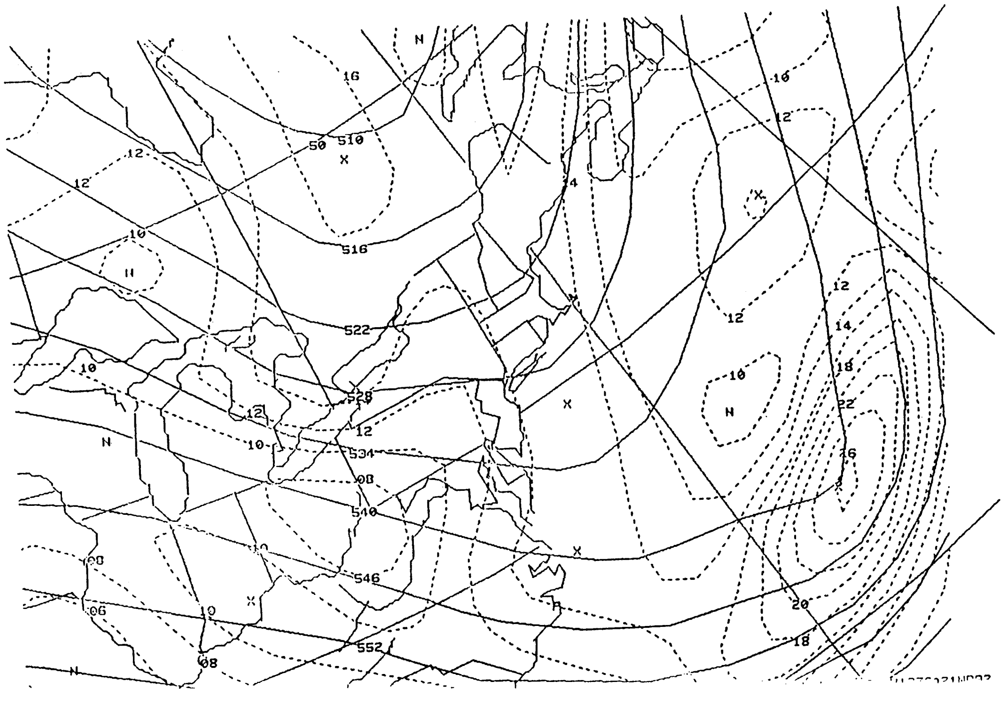

Figure 4. 1200 UTC, March 21, 1992. NGM 500 mb height analysis and vorticity.

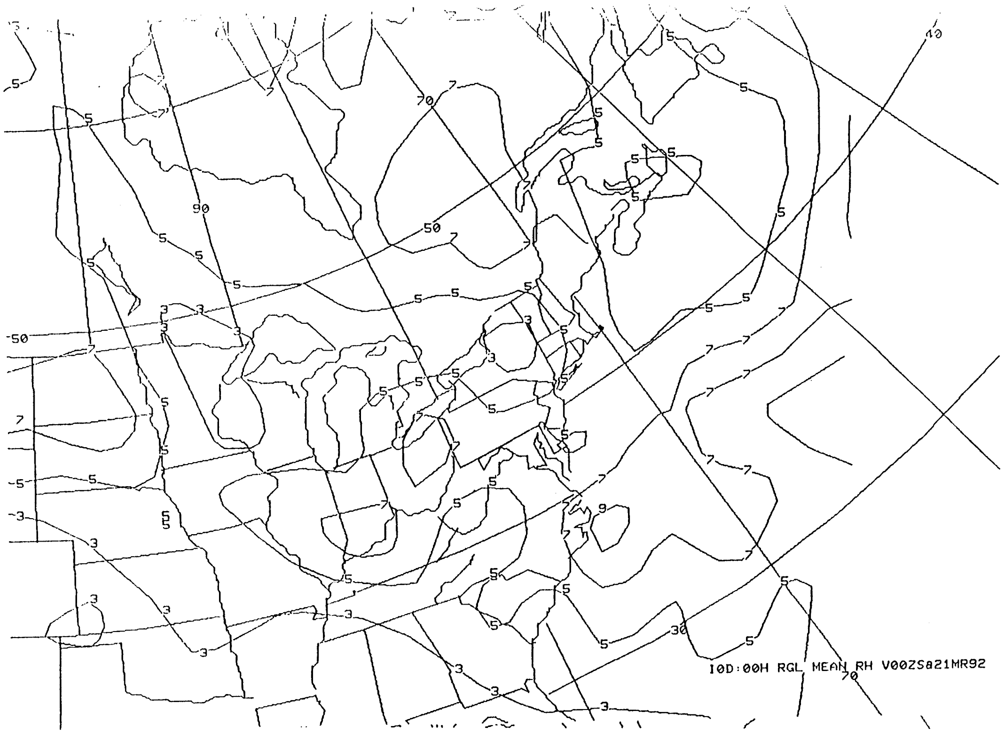

Figure 5. 0000 UTC, March 21, 1992. NGM 1000-500 mb mean relative humidity.

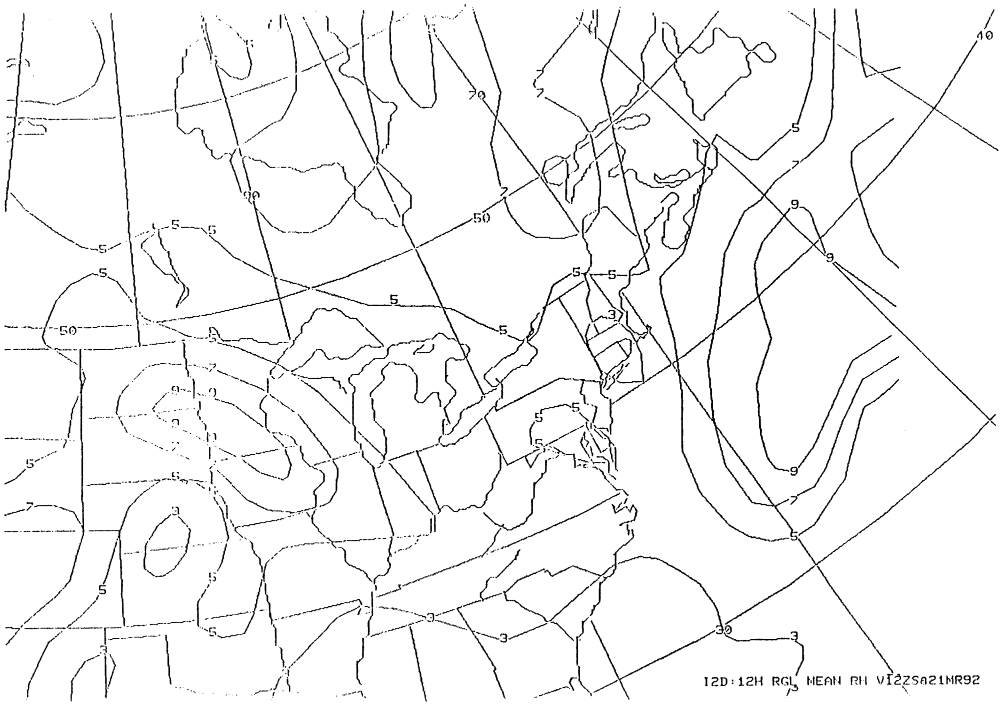

Figure 6. 1200 UTC, March 21, 1992. NGM 1000-500 mb mean relative humidity.

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Figure 7. 0000 UTC, March 21, 1992. NGM FRHT FOUS guidance.

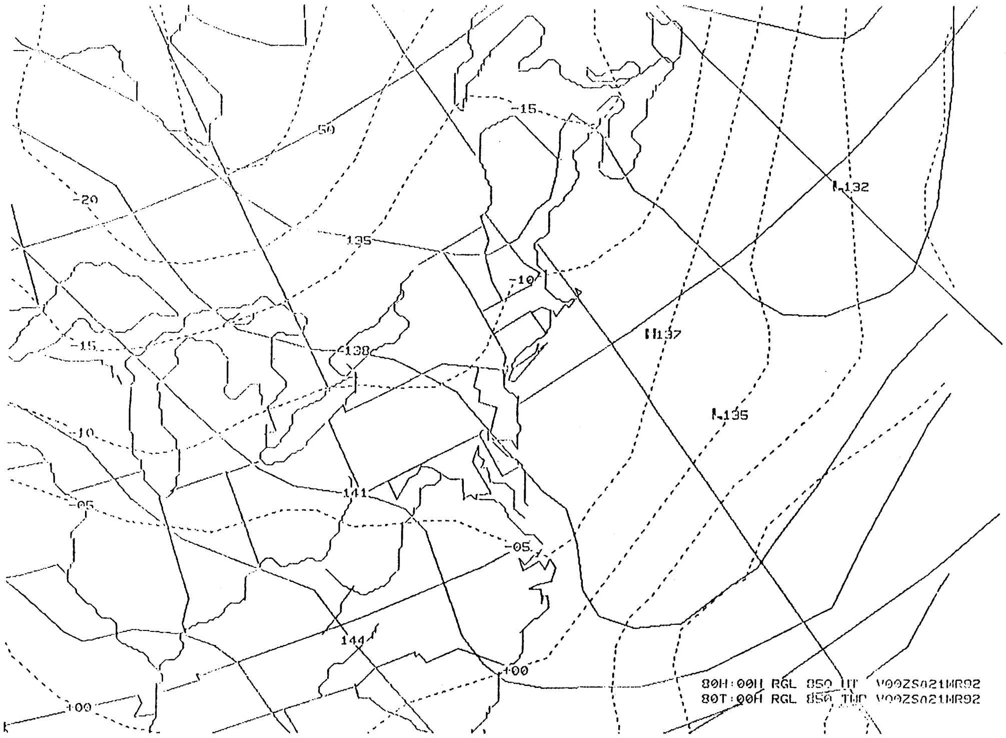

Figure 8. 0000 UTC, March 21, 1992. NGM 850 mb height and temperature analysis.

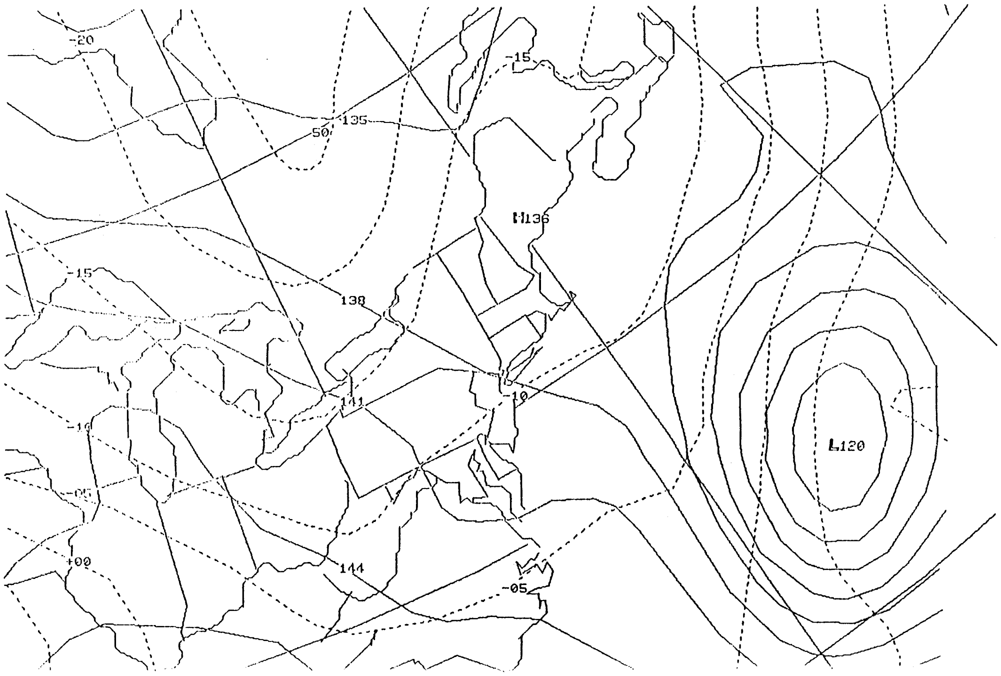

Figure 9. 1200 UTC, March 21, 1992. NGM 850 mb height and temperature analysis.

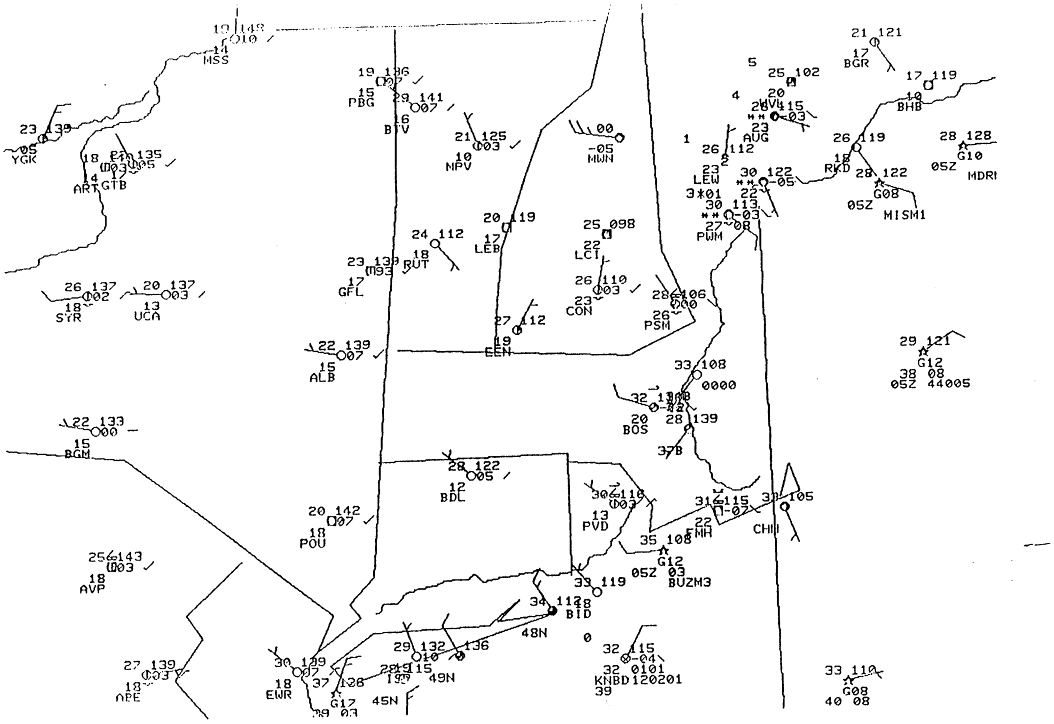

Figure 10. 0600 UTC, March 21, 1992 surface plot.

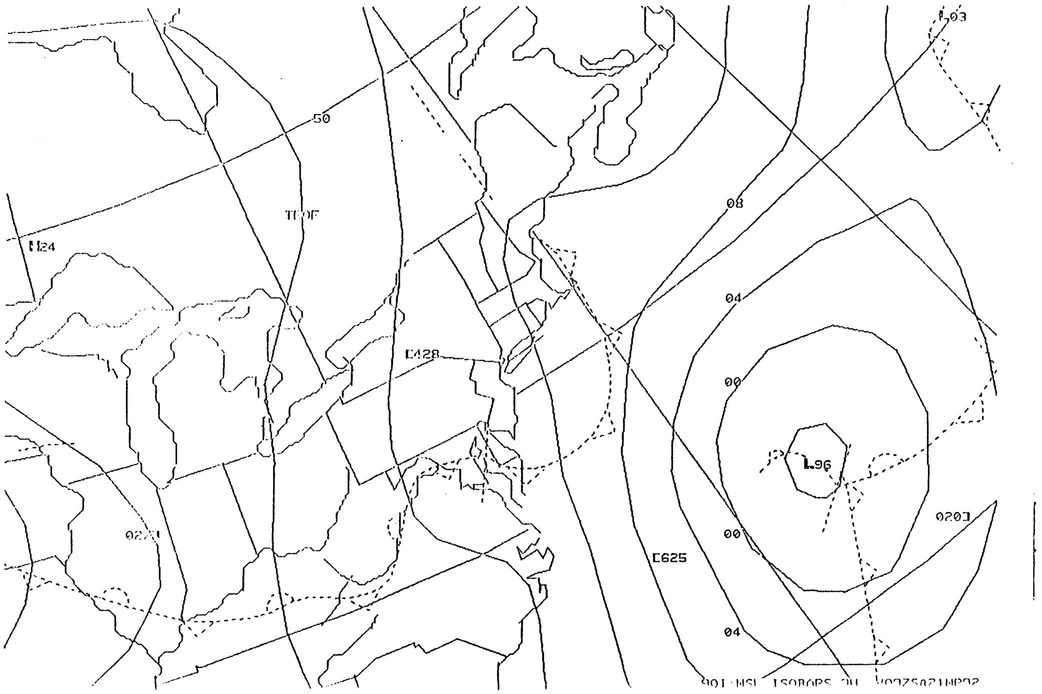

Figure 11. 0900 UTC, March 21, 1992. NMC surface analysis and frontal positions.

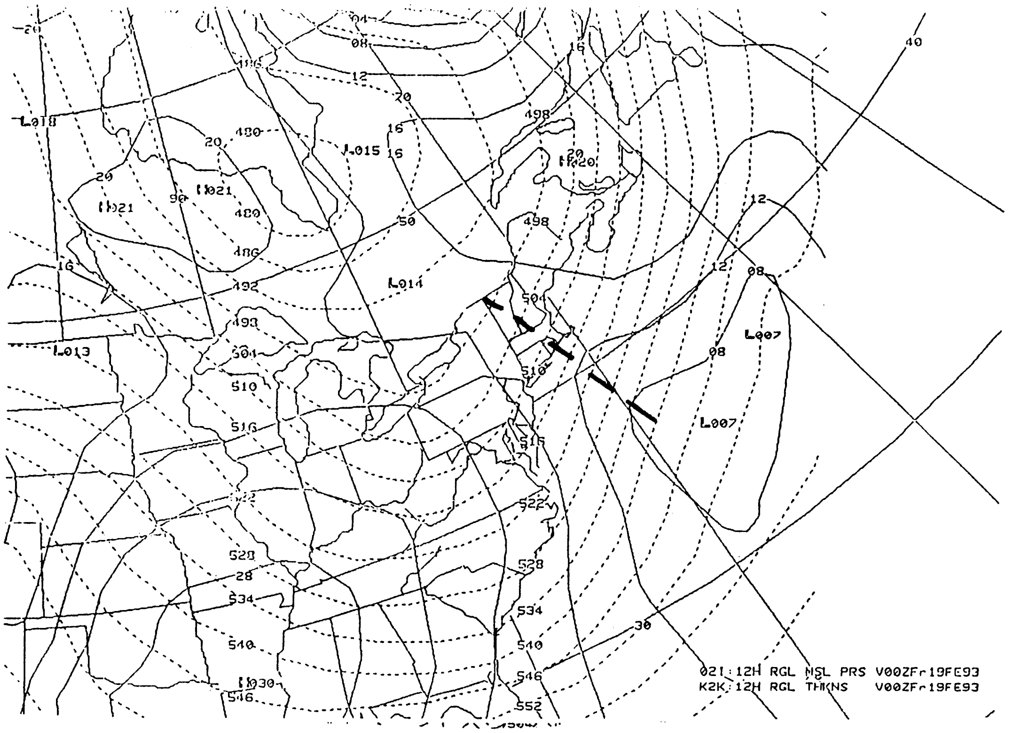

Figure 12. 0000 UTC, February 19, 1993. NGM MSL pressure analysis and 1000-500 mb thickness.

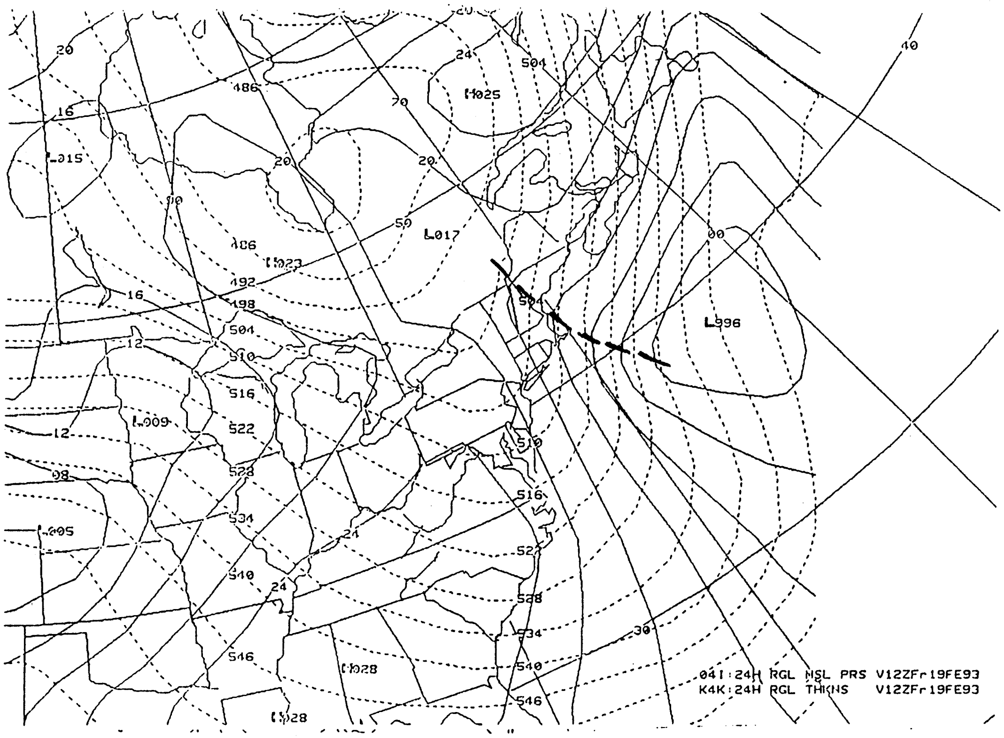

Figure 13. 1200 UTC, February 19, 1993. NGM MSL pressure analysis and 1000-500 mb thickness.

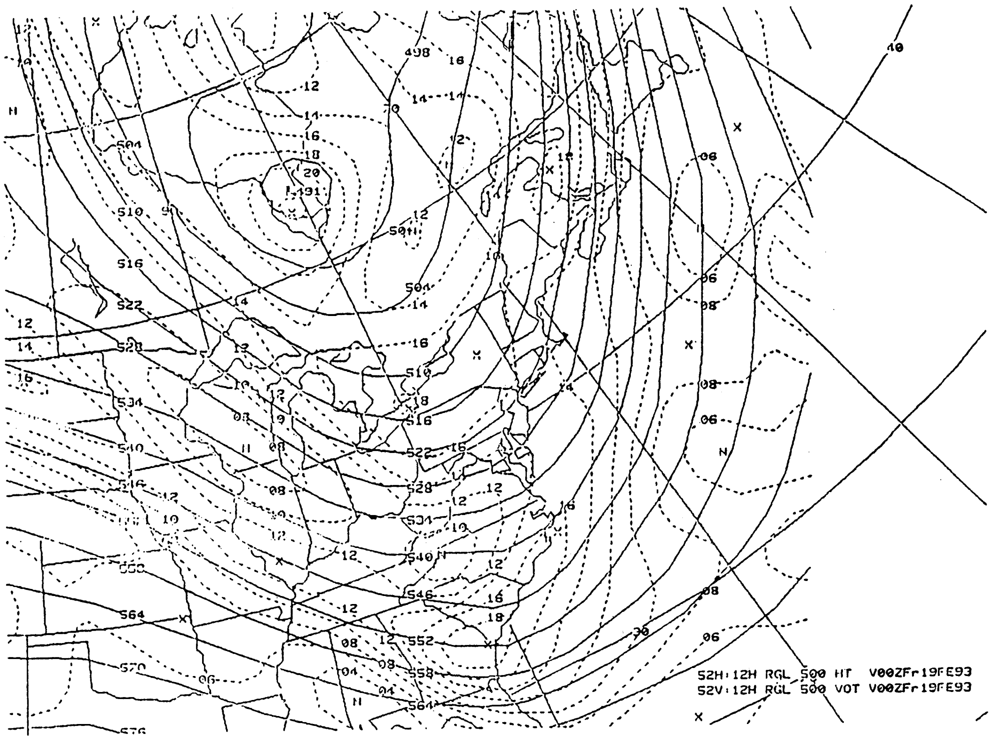

Figure 14. 0000 UTC, February 19, 1993. NGM 500 mb height analysis and vorticity.

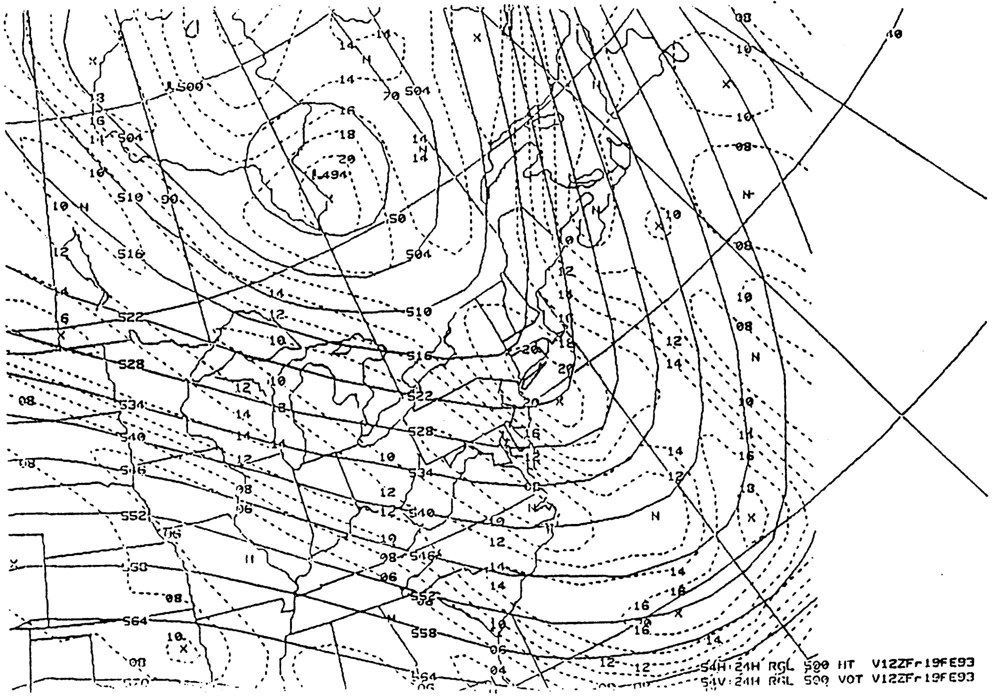

Figure 15. 1200 UTC, February 19, 1993. NGM 500 mb height analysis and vorticity.

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Figure 16. 0000 UTC, February 19, 1993. NGM FRHT FOUS guidance.

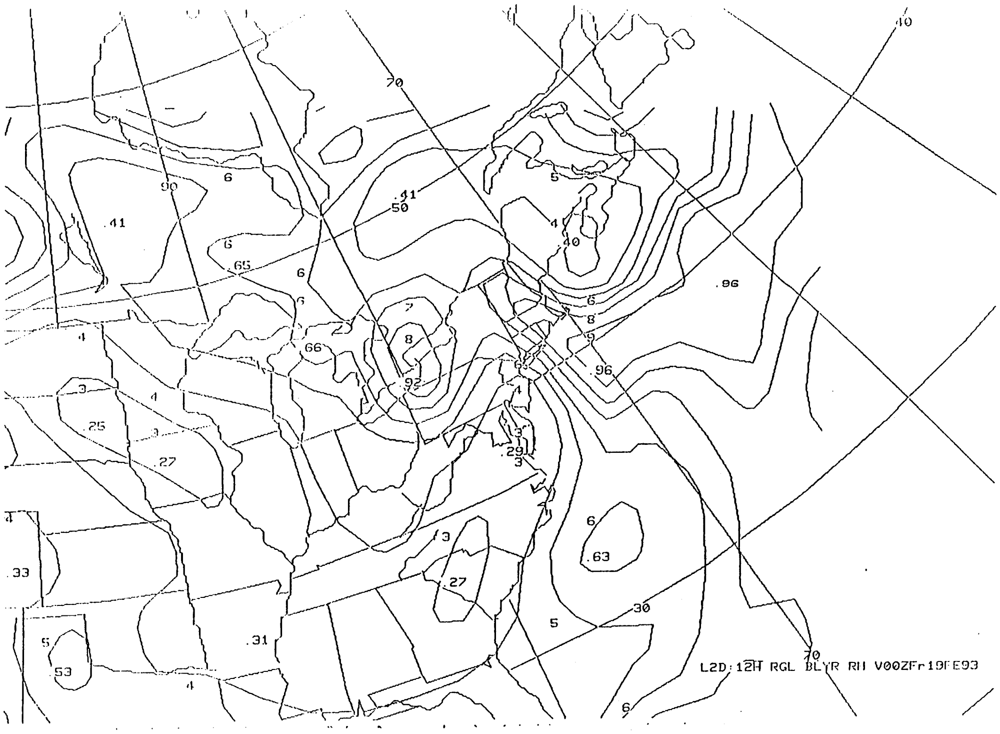

Figure 17. 0000 UTC, February 19, 1993. NGM boundary layer relative humidity analysis.

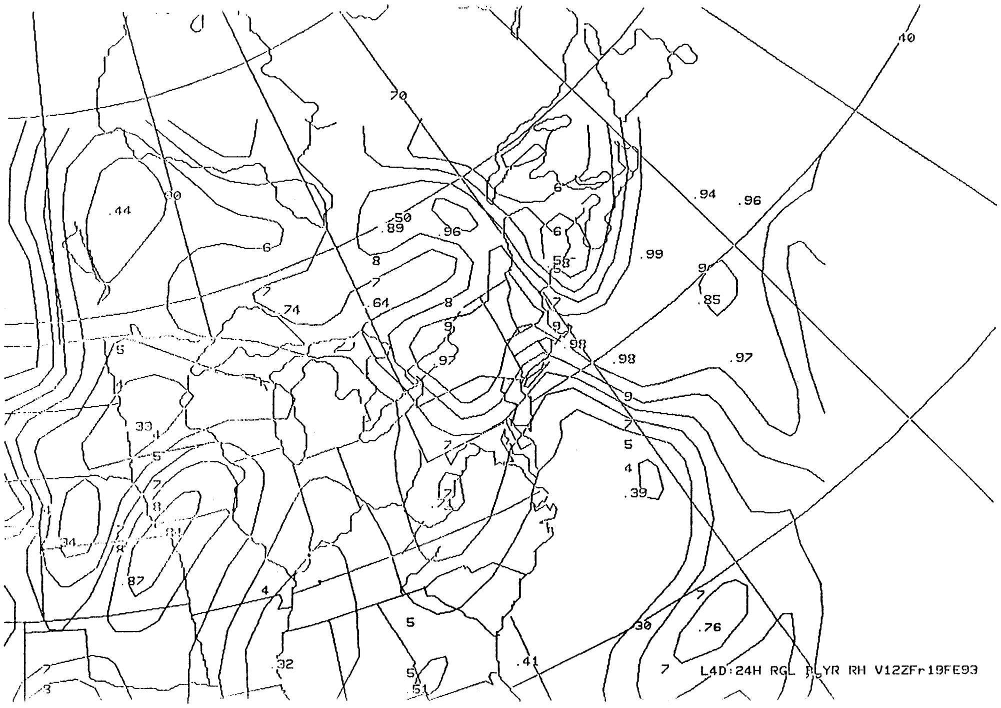

Figure 18. 1200 UTC, February 19, 1993. NGM boundary layer relative humidity analysis.

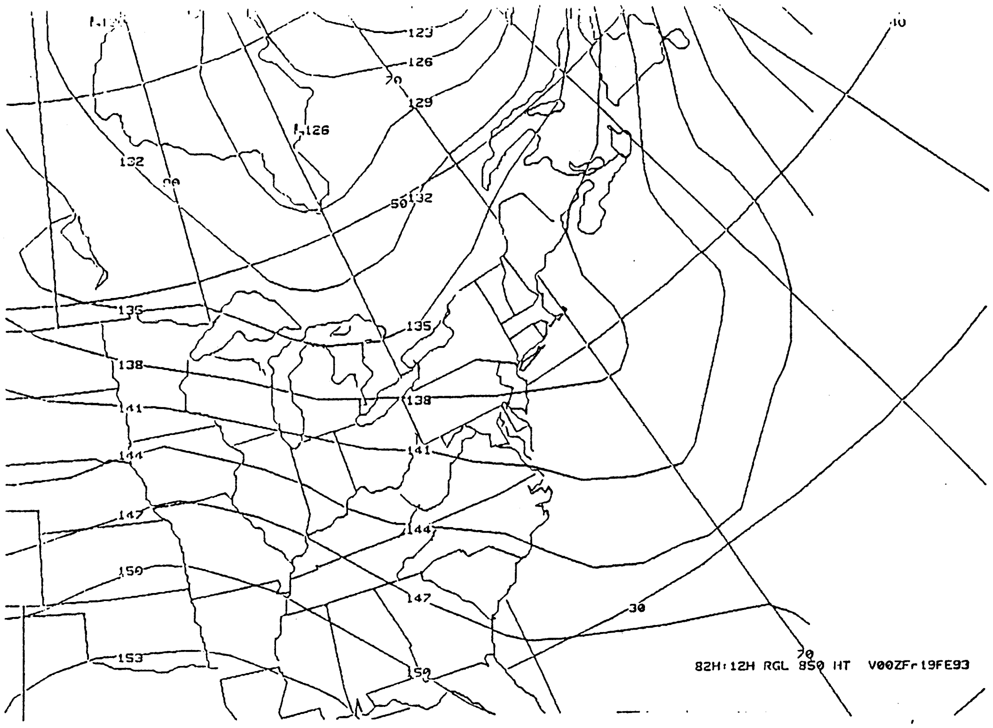

Figure 19. 0000 UTC, February 19, 1993. NGM 850 mb height and temperature analysis.

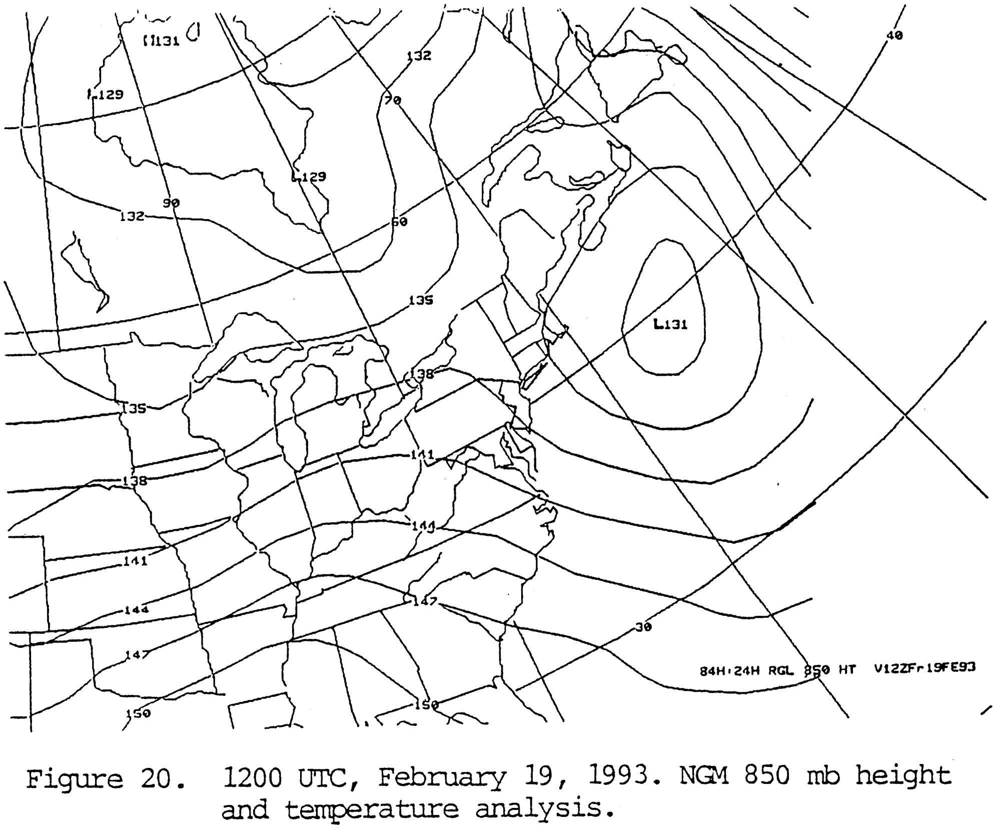

Figure 20. 1200 UTC, February 19, 1993. NGM 850 mb height and temperature analysis.