SNOW STUDY

THE STORM OF FEBRUARY 6-7, 1980

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ABSTRACT

The offshore explosive deepener of February 6-7, 1980 is examined. Occurring on the second anniversary of the Great Northeast Blizzard of 1978, the 1980 storm ironically was similar in several respects to the record blizzard. The 1980 storm dumped 20" of snow over portions of the Mid-Atlantic region but unlike the big blizzard spared all but extreme southeastern New England.

The storm was very poorly forecast by the LFM. Probable reasons are discussed, and possible ways to remedy the problem are suggested.

1. INTRODUCTION

The blizzard of February 6-8, 1978, was one storm the northeastern U.S. will never forget, with up to 4 feet of snow driven to paralyzing drifts by gale force winds. Amazingly enough, on the second anniversary of that great blizzard, a storm developed that resembled the blizzard's initial stages.

At 1200Z February 4, 1980, a strong upper level trough west of Alaska was throwing warm air into an upper level ridge just off of the west coast of North America. As a result, the ridge amplified as it moved onto the Pacific Coast by 1200Z on February 5th (Figure 1a). A short wave trough in the Northern Plains then began to dig southeastward out of the ridge into the next downstream long wave trough positioned near 80 degrees west. A weak surface low (1020 mb) over northern Iowa was the first surface response to this digging trough.

This sequence was similar to that of the blizzard of 1978. The record-breaking 1978 storm began with a short wave digging southeastward out of a building ridge (Figure 1b). The 500 mb patterns for the two storms were similar, but there were important differences too. The upstream western ridge with the blizzard of '78 was stronger and positioned a bit further east and the eastern trough was sharper than in the 1980 storm. Thus, although the general flow patterns were similar, the 1980 storm did not quite possess the upper level dynamics that the blizzard of '78 had.

At 0000Z on February 6, 1980, height falls and positive vorticity advection associated with the driving short wave reached the coast. A surface low (1015 mb) developed on the Georgia coast while the original center weakened inland.

The following 15 hours brought a rapid deepening of the coastal storm. By 0000Z on February 7, the central pressure fell to 1002 mb. During the 6th, heavy snow fell over parts of the Carolinas and Virginia. Residents of South Carolina had to dig out from as much as six inches of snow, while portions of North Carolina received up to 20 inches from the storm. Norfolk, Virginia, had more than a foot of snow; for them, it was the worst snowstorm in nearly a century. By the morning of the 7th of February the storm, feeding on the warm Gulf Stream, deepened into an intense 986 mb low approximately 300 miles east of Salisbury, Maryland.

Unlike the 1978 blizzard, this storm was a fast mover, being "kicked" rapidly to the northeast by another short wave trough moving southeastward from the Northern Plains. Before the storm sped into the open waters of the North Atlantic, it pounded Nantucket Island with heavy snows and 50 knot winds. Nantucket officially recorded 6 inches of snow; however, gale force winds made the snow measurement difficult. The rest of the northeastern U.S. escaped the storm's wrath with only light snow and gusty winds.

If the storm had tracked only 100 miles closer to the coast, the coastal northeast would have found itself snowbound again on the anniversary of the snowstorm of the century. Forecasting this storm proved to be a problem due to inconsistent computer prognoses.

2. THE LFM FORECAST

First focusing our attention on the height/vorticity forecast panels for the run of 1200Z February 5th (Figure 2 and 3) we noted the LFM's 500 mb height and vorticity prognoses verified well. Height verification for the 24-hour forecast valid 1200Z February 6 indicated errors of less than 30 meters in the eastern half of the nation (Figure 4). Although by 48 hours the error in the height field grew to over 60 meters, the overall upper level forecast by the LFM was not bad considering some of the height verifications that are witnessed at times.

Unfortunately the LFM surface/thickness panels could not be claimed accurate (Figure 5 through 8). This was especially true after 24 hours. The surface storm was forecast to move east-northeast at a leisurely pace. Slow deepening was also indicated with surface pressure forecast to be 1008 mb at the center of the storm by 1200Z February 7th. At that verifying time, the storm center was actually about 400 miles northeast of the forecast position with a central pressure of 986 mb, which was 22 mb deeper than forecast (Figure 7 and 8).

Relative humidity forecasts likewise verified very poorly. The 48-hour forecast valid 1200Z February 7th had a very small area of 90% relative humidity well inland with relative humidity offshore everywhere less than 70% (Figure 9). Six hours after that verifying time, satellite photographs showed a very large area of thick cloudiness in a well-developed cyclonic circulation over the open ocean (Figure 10).

Thus, while the LFM's upper level forecasts verified reasonably well, on the same four-panel product the surface and integrated relative humidity panels were grossly inaccurate. The discrepancies were too significant to overlook.

3. PETTERSSEN'S DEVELOPMENT EQUATION

To better understand why the LFM surface forecasts were in error, we took a qualitative look at the development factors isolated by Petterssen's Development Equation (3).

$$\frac{\partial \eta_0}{\partial t} = -\mathbb{V}_5 \cdot \nabla \eta_5 - \frac{g}{f} \nabla^2 \int_{1000}^{500} \mathbb{V} \cdot \nabla \left(\frac{\partial z}{\partial p}\right) dp$$

$$- \frac{1}{f} \nabla^2 \int_{1000}^{500} \sigma \omega dp - \frac{R}{f C_p} \nabla^2 \int_{1000}^{500} \frac{Q}{p} dp$$

In this equation, development is measured in terms of the change of surface vorticity. The terms are explained below.

$$\partial \eta_0 / \partial t$$

Time rate of change of surface vorticity or cyclonic development. Intensification of storm results in an increase of surface vorticity, while weakening brings about a decrease.

The terms on the right side of the equation are factors that will produce or destroy surface vorticity by causing an intensification or weakening of a surface pressure system. The first term is a measure of the contribution to surface development by the upper level dynamics.

$$-\mathbb{V}_5 \cdot \nabla \eta_5$$

Advection of vorticity at the 500 mb level by the 500 mb wind. Positive vorticity advection (PVA) contributes to cyclonic development. PVA is associated with divergence. The consequent evacuation of mass will bring about a reduction of pressure (increase of vorticity) at the surface if not offset by other factors (like cold advection).

The other terms can be called the thermal (density) factors. In general, a lowering of the density (warming) of an atmospheric column without a compensating increase in depth will result in surface pressure decreases (surface vorticity increases). It should be noted from the equation that it is the laplacian (configuration) of these heating terms that is important, not simply their magnitude.

$$-\frac{g}{f} \nabla^2 \int_{1000}^{500} \mathbb{V} \cdot \nabla \left(\frac{\partial z}{\partial p}\right) dp$$

Thermal advection term. Concentrated warm advection out ahead of a storm contributes positively to cyclonic development. Warm advection into an atmospheric column will lower density and without a compensating increase in depth of that column, will decrease the pressure at the surface. Cold advection has the opposite effect.

$$-\frac{1}{f} \nabla^2 \int_{1000}^{500} \sigma \omega dp$$

Stability term. In unstable air undergoing upward vertical motion within a developing storm, there is a net heat flux upwards. This term is then positive and contributes to development. On the other hand, in stable air, even when saturated, upward vertical motion produces a cooling of the atmospheric column and acts to retard development.

Diabatic heating term. The heating of air diabatically brings about a density decrease and can result in surface pressure falls. In contrast, diabatic cooling processes cause a density increase and pressure rises. If the configuration of this heating pattern is favorable, the result can be an increase in surface vorticity (development). A favorable configuration for coastal storm development by diabatic heating is produced off the east coast both to the north and to the south of Cape Hatteras due to the concave curvature of the coastline there: the coast confines the oceanic sensible and latent heat transfers. It is not surprising that cyclogenesis frequency relative maxima are actually found offshore north and south of Cape Hatteras and not abreast of the Cape.

In summary, storm development or intensification is favored in a region where divergence aloft associated with strong mid-level positive vorticity advection is evacuating mass, where the density of the air column is decreasing due to pre-storm warm advection, and where there is a core of rising unstable air with convective releases of sensible and latent heats. The more of these terms that act in a positive sense and the greater their magnitude, the greater the potential development (4).

$$-\frac{R}{fC_p}\nabla^2\int_{1000}^{500}\frac{Q}{P}\,dp$$

In this situation, recall that the LFM did a good job with the dynamics on the 500 mb panels, especially during the early development stages. However, it seriously underestimated the strength of the storm at the surface. Consequently, the LFM may have had problems quantifying the other (thermal) factors that led to storm development.

Prior to this storm and as we have observed in most offshore explosive deepeners, very cold, dry air poured off the mid-Atlantic coast. As this cold air moved over the warm waters just off the coast, heating at the surface rapidly destabilized the lower atmosphere and initiated convection cells. However, with strong subsidence aloft associated with the anticyclonic system to the west, convection and cloud growth was arrested. A stratification of the low cloud layer followed (stratocumulus formation) (Figure 11a). This is typical in the offshore region when cold air moves in an anticyclonic fashion offshore over warmer ocean water.

Convection is an efficient method of transferring both sensible heat and moisture into the air. It should be remembered that, even while capped, the low-level convection process is moistening and heating the cloud and cloud layers.

Usually, however, in these pre-storm stages, negative vorticity advection and cold thermal advection act to inhibit surface low development. Typically, it is only after the upper ridge line passes and both positive vorticity advection and warm advection begin that surface low development occurs.

On occasion, when the instability has been particularly great, surface low formation and development has preceded the arrival of the upper support (storm of 18-19 February, 1979). Even then, however, significant deepening usually doesn't occur until conditions improve aloft.

In this 1980 case, when PVA reached the coast (by 1200Z February 6th) the lid on convection was effectively removed (Figure 11b). Deep penetrative convection was allowed and, with divergence aloft, actually encouraged. Radar at 1135Z on the 6th showed Cb towers topping 19,000 feet.

Strong production of surface vorticity (surface low intensification) by the instability and diabatic heating term likely followed. The stronger resultant flow combined with the rapid, deep convective warming of the air to enhance the warm advection, which in turn hastened storm development (thicknesses were higher than forecast ahead of the storm offshore in 24 hours). Then as the surface cyclone deepened, enhanced thermal advection produced a further deformation of the upper level height field and increased amplitude of the upper trough and downstream ridge system. The increased upper level vorticity advection that resulted led to further intensification (self-development).

As Boasart (5) noticed in the President's Day Storm of 1979, part of the LFM's problem again here no doubt was poor initialization. With interpolation from cold, dry land RAOBS, the warmed, moistened, unstable low level air offshore went initially unrecognized.

Though convective sensible heat transfer is parameterized in the model and would cause a destabilization of low level air with time in the model's forecast, evaporation from the ocean is not included in the model physics. Since this process is maximized during intense convection, this is likely also to have been a serious problem in this storm. Ironically this warming without moistening leads to lowered relative humidity offshore in low layers, and this drying retards both the surface development and the model's integrated RH and precipitation forecasts. Furthermore, by underestimating these convective contributions to development, the LFM also underforecasts the warm advection and vorticity advection contributions which are enhanced by convection deepening.

It should be also remembered that the model was not only not deep enough but also much too slow in its movement of the cyclone through the forecast period. This may be due in part to the fact that earlier, stronger development also implies earlier coupling with the steering flow. Also since the convective and advective warming ahead of the cyclone was far stronger than forecast, pressures would fall faster and the storm would literally redevelop out ahead faster than forecast.

4. SUMMARY

It appears to us that first, more accurate initialization of temperature and moisture profiles in low-levels over the offshore regions are needed to improve model forecasts under these conditions. Also importantly, the model physics must improve. It has been our experience that the LFM has performed most poorly with its RH, precipitation and surface low intensity prognoses when the initial time was prior to the injection of cold air and development of convective cloudiness offshore. Once cold air moves offshore and offshore convective cloud cover forms, the low level moisture field may be initialized better but future changes are still underestimated because of the model physics shortcomings. When the spectral model physics package is completely in place, allowing for evaporation from water surfaces (doing away with the concrete slab ocean), we may find it shows better results, though scale here may be a problem.

Unless or until changes are made, in those storms similar to this one, where very cold, dry air precedes secondary development, the LFM might be expected to underdeepen and at times to seriously undermoisten the storm and its environment. This will be especially true for cases where the approaching primary low does not carry its own supply of tropical moisture. The effects of this storm were mostly limited to the offshore regions, but a track a bit farther west could have made it a memorable storm -- more like the blizzard two years earlier. Under the circumstances illustrated in this paper, forecasters should be aware of the potential problems and adjust the models accordingly.

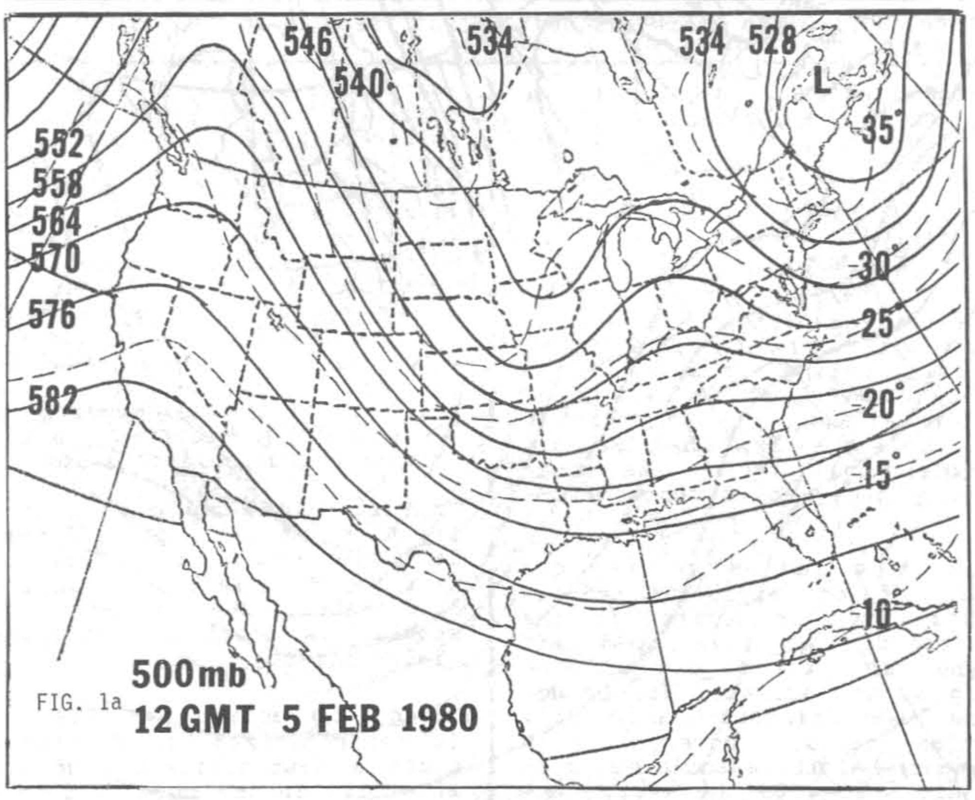

Figure 1a. 500 mb Height/temperature analysis, 1200 GMT 5 Feb 1980.

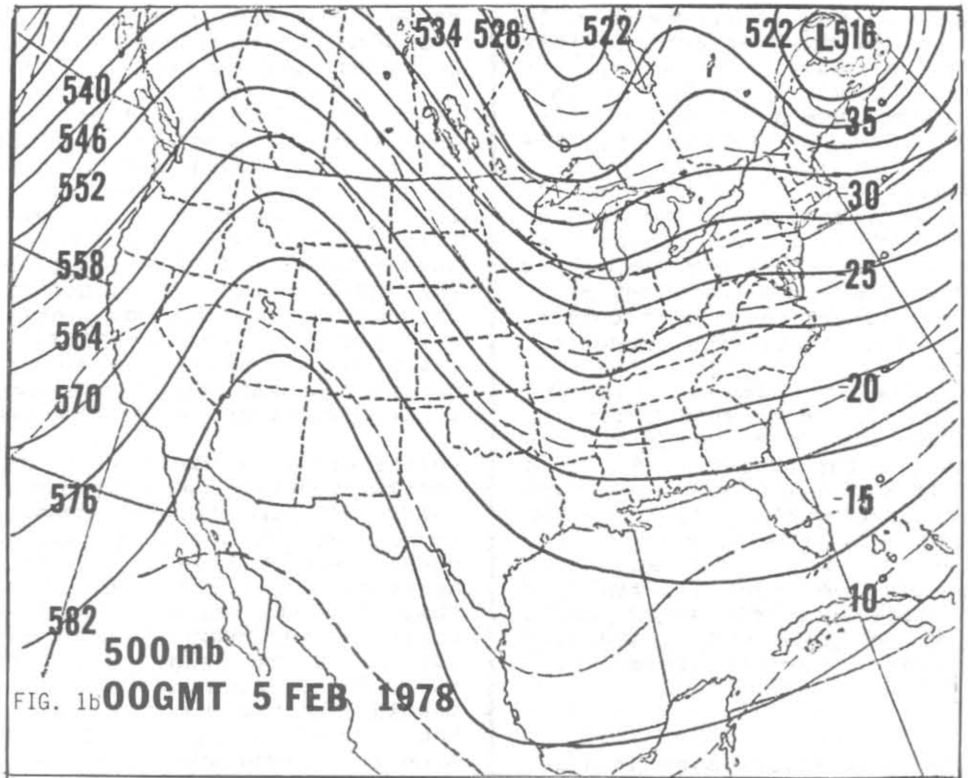

Figure 1b. 500 mb Height/temperature analysis, 0000 GMT 5 Feb 1978.

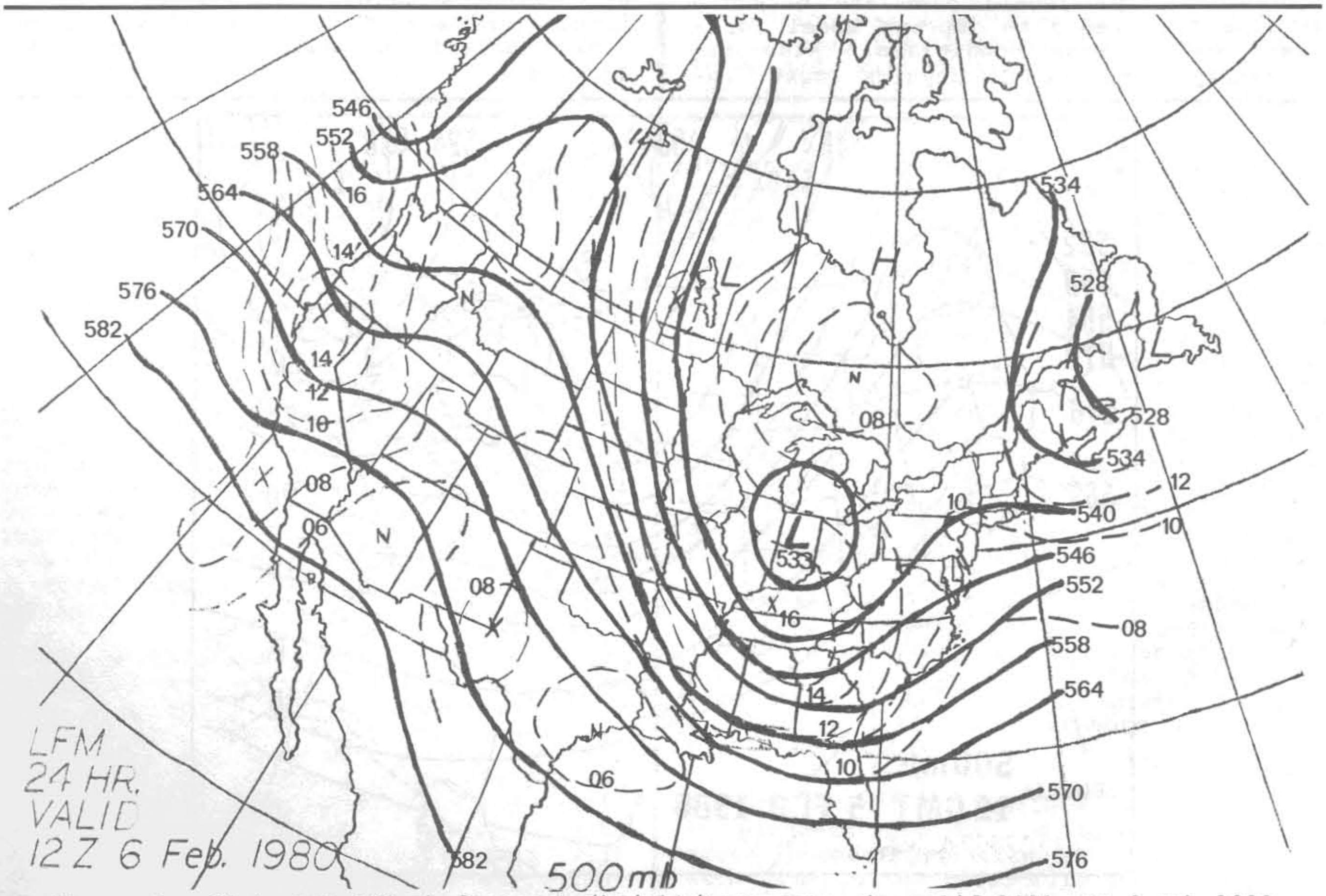

Figure 2. 24 hr LFM 500 mb forecast (height/temperature), valid 1200 GMT 6 Feb 1980.

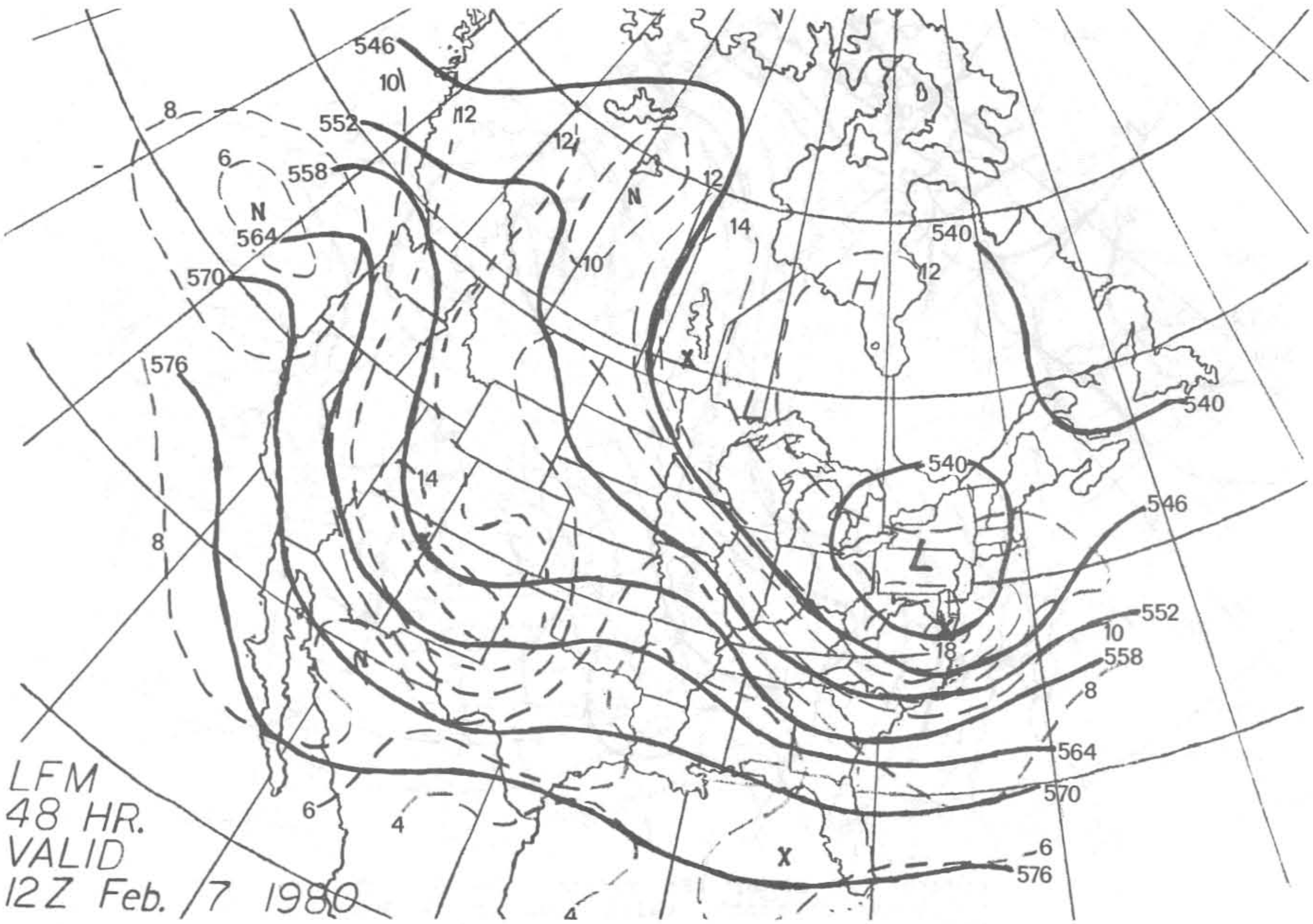

Figure 3. 48 hr LFM 500 mb forecast (height/temperature), valid 1200 GMT 7 Feb 1980.

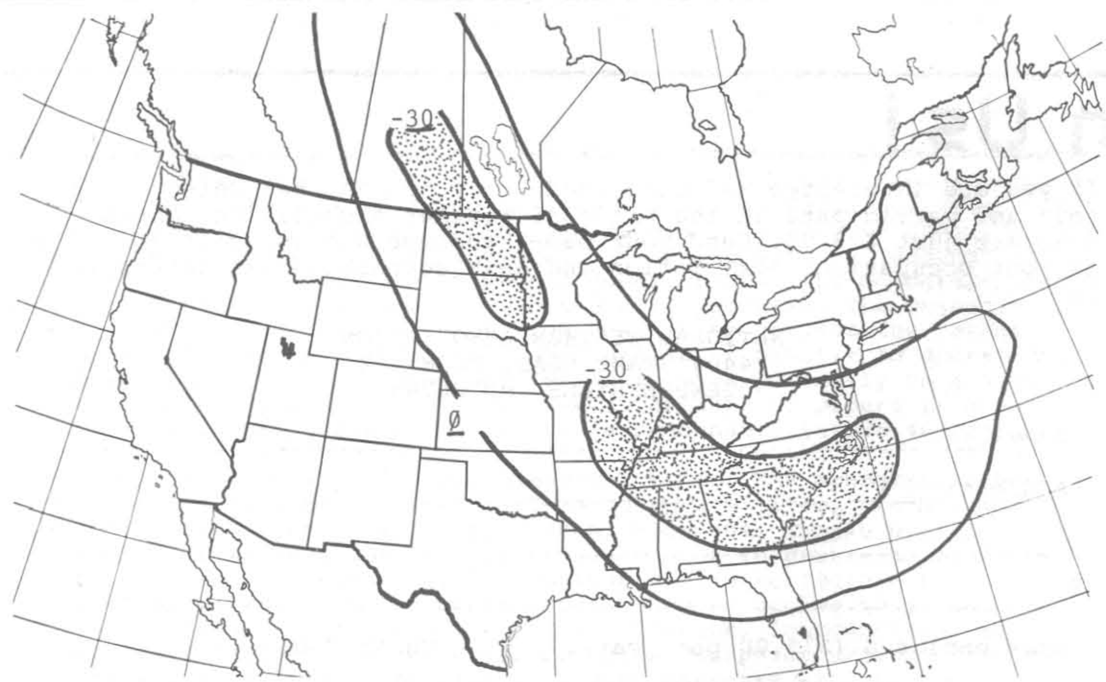

Figure 4. 500 mb Height error field (in meters) for 24 hr LFM forecast, valid 1200 GMT 6 Feb 1980.

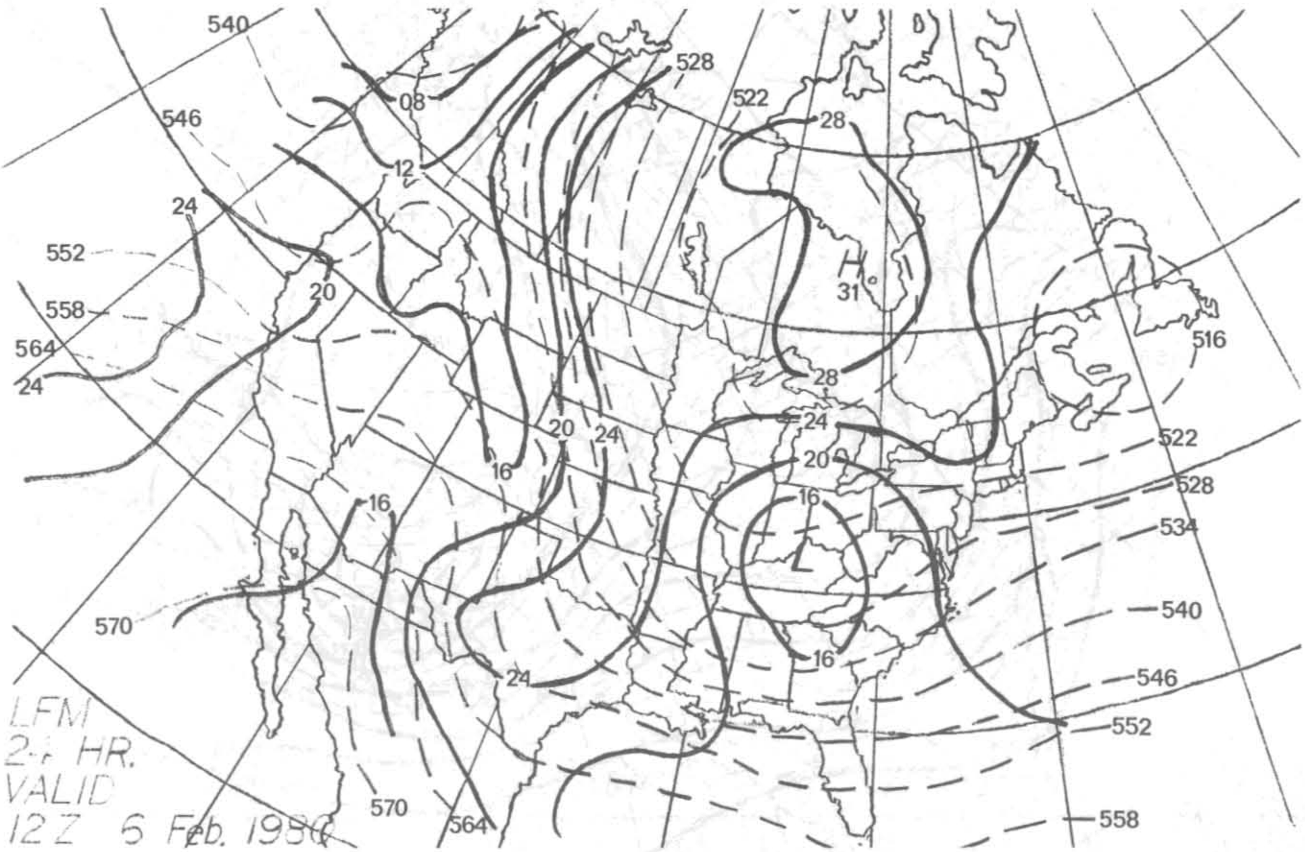

Figure 5. 24 hr LFM surface/1000-500 mb thickness forecast, valid 1200 GMT 6 Feb 1980.

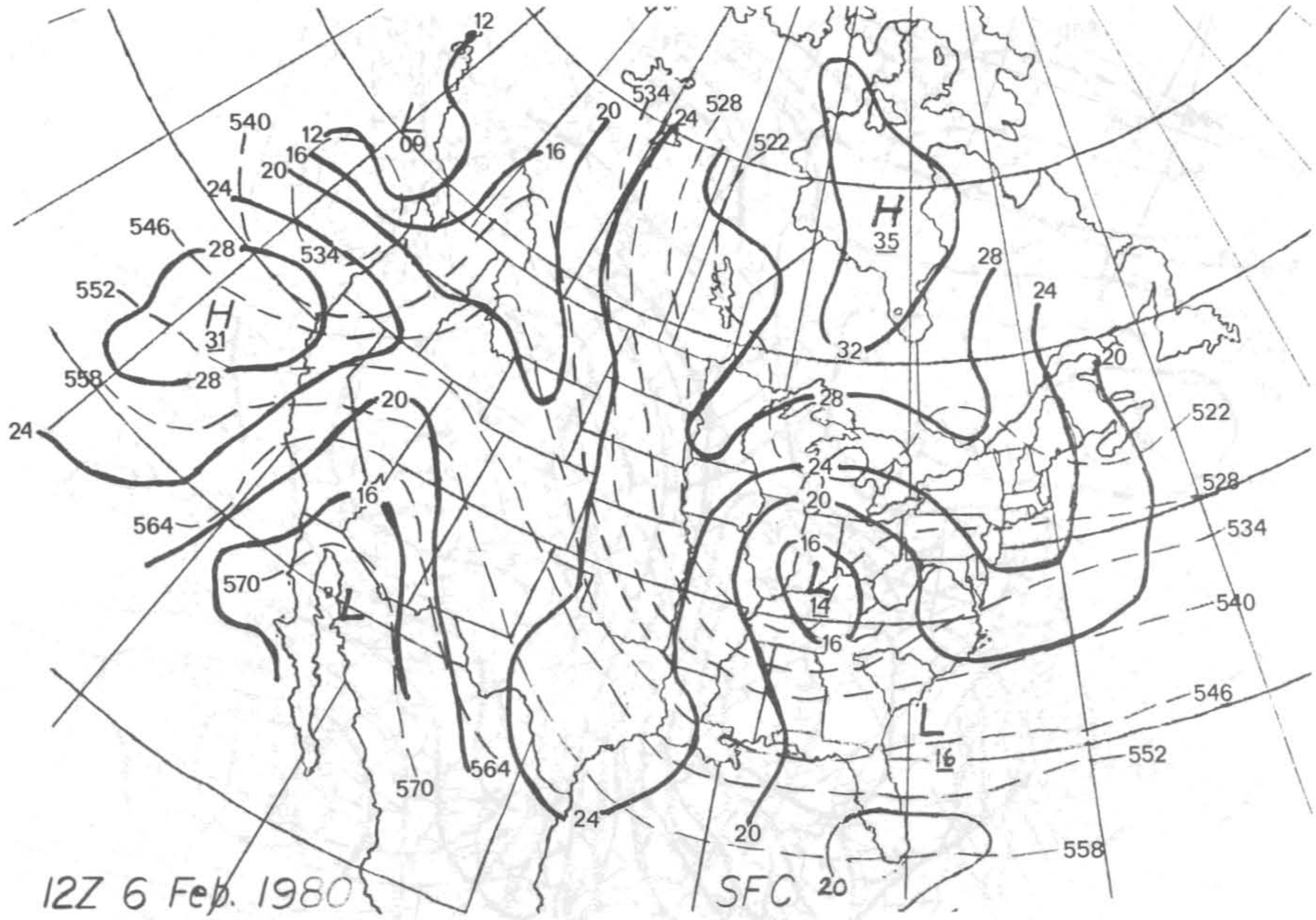

Figure 6. Surface/1000-500 mb thickness analysis, valid 1200 GMT 6 Feb 1980.

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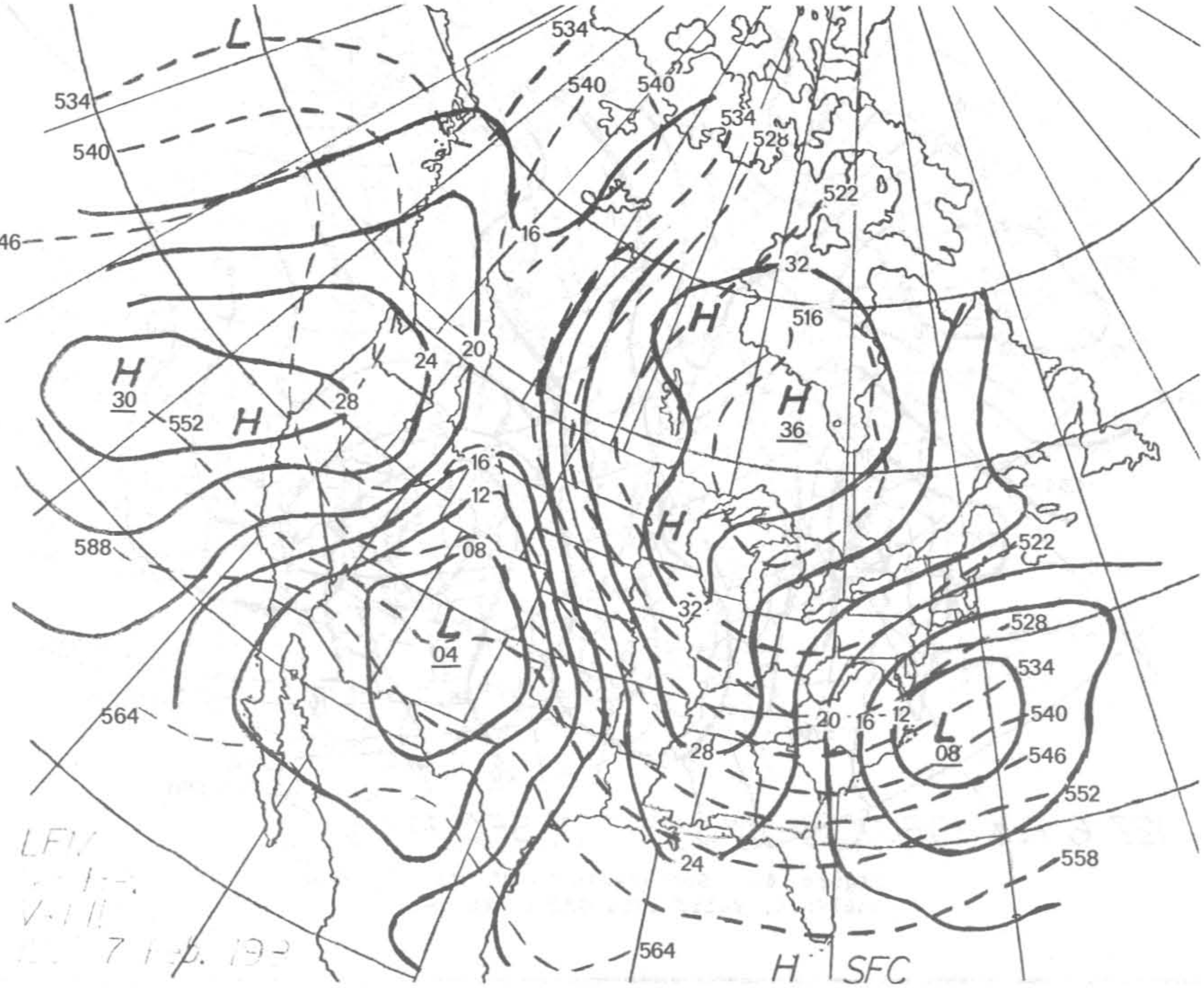

Figure 7. 48 hr LFM surface/1000-500 mb thickness forecast, valid 1200 GMT 7 Feb 1980.

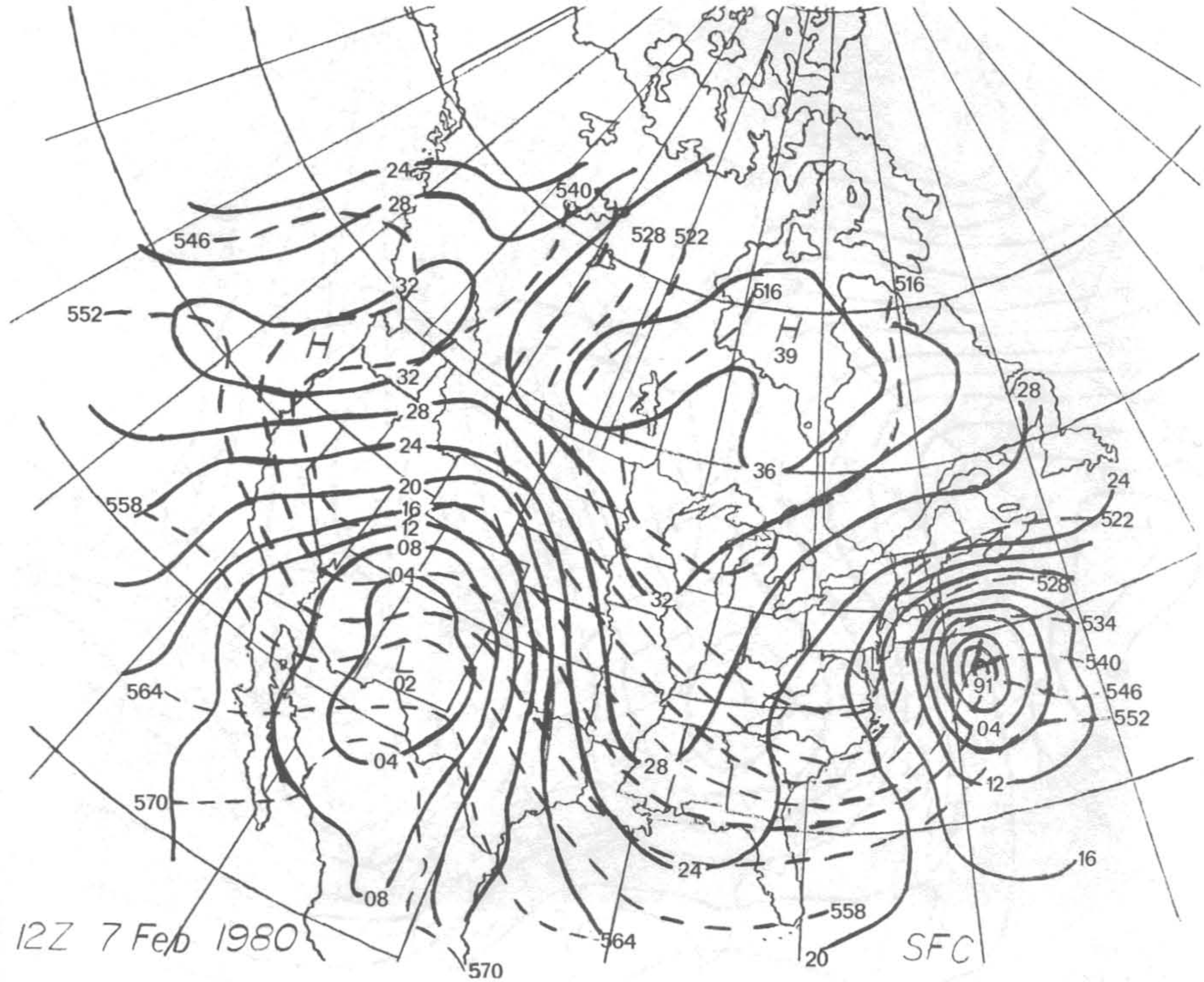

Figure 8. Surface/1000-500 mb thickness analysis, valid 1200 GMT 7 Feb 1980.

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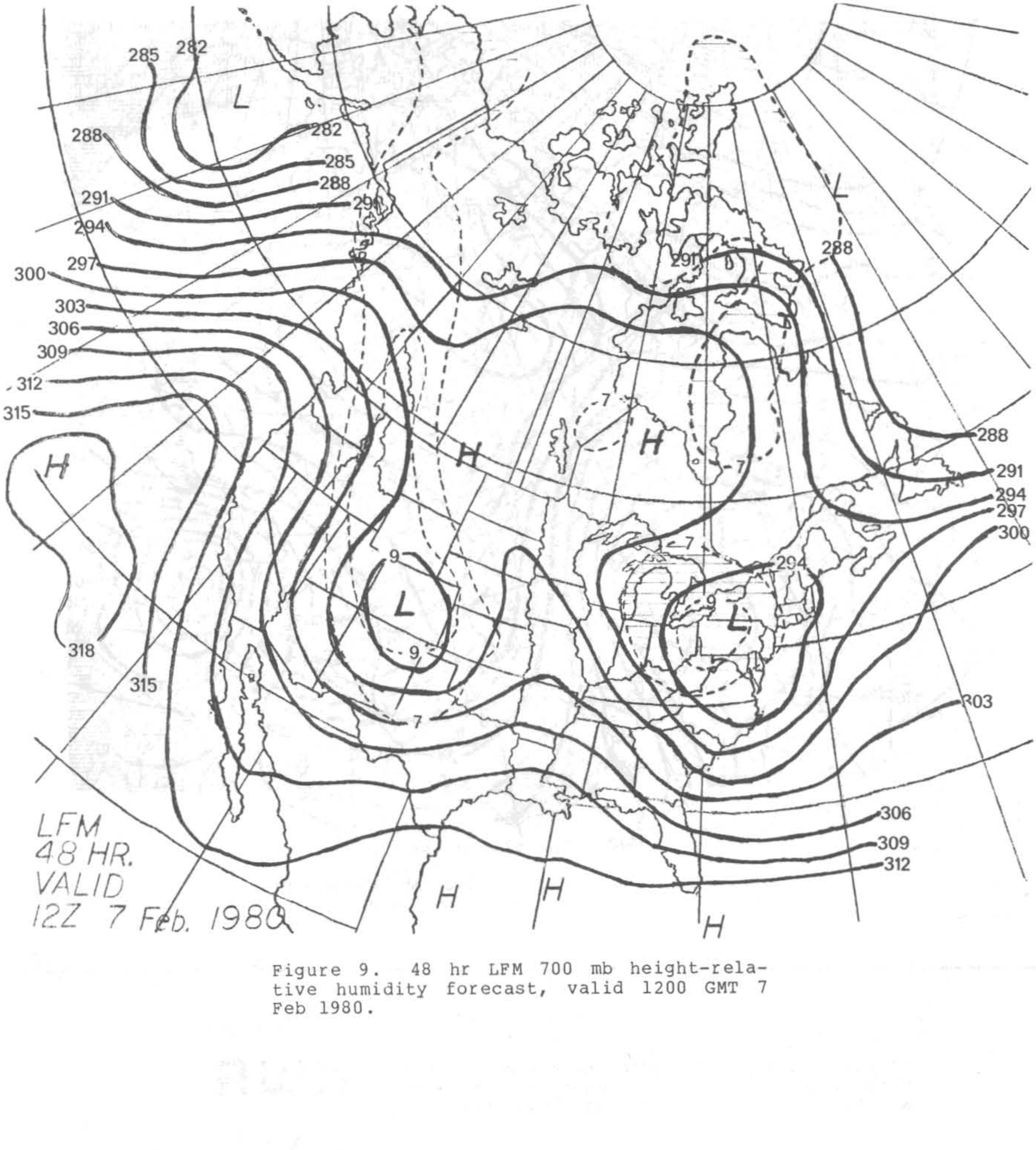

Figure 9. 48 hr LFM 700 mb height-relative humidity forecast, valid 1200 GMT 7 Feb 1980.

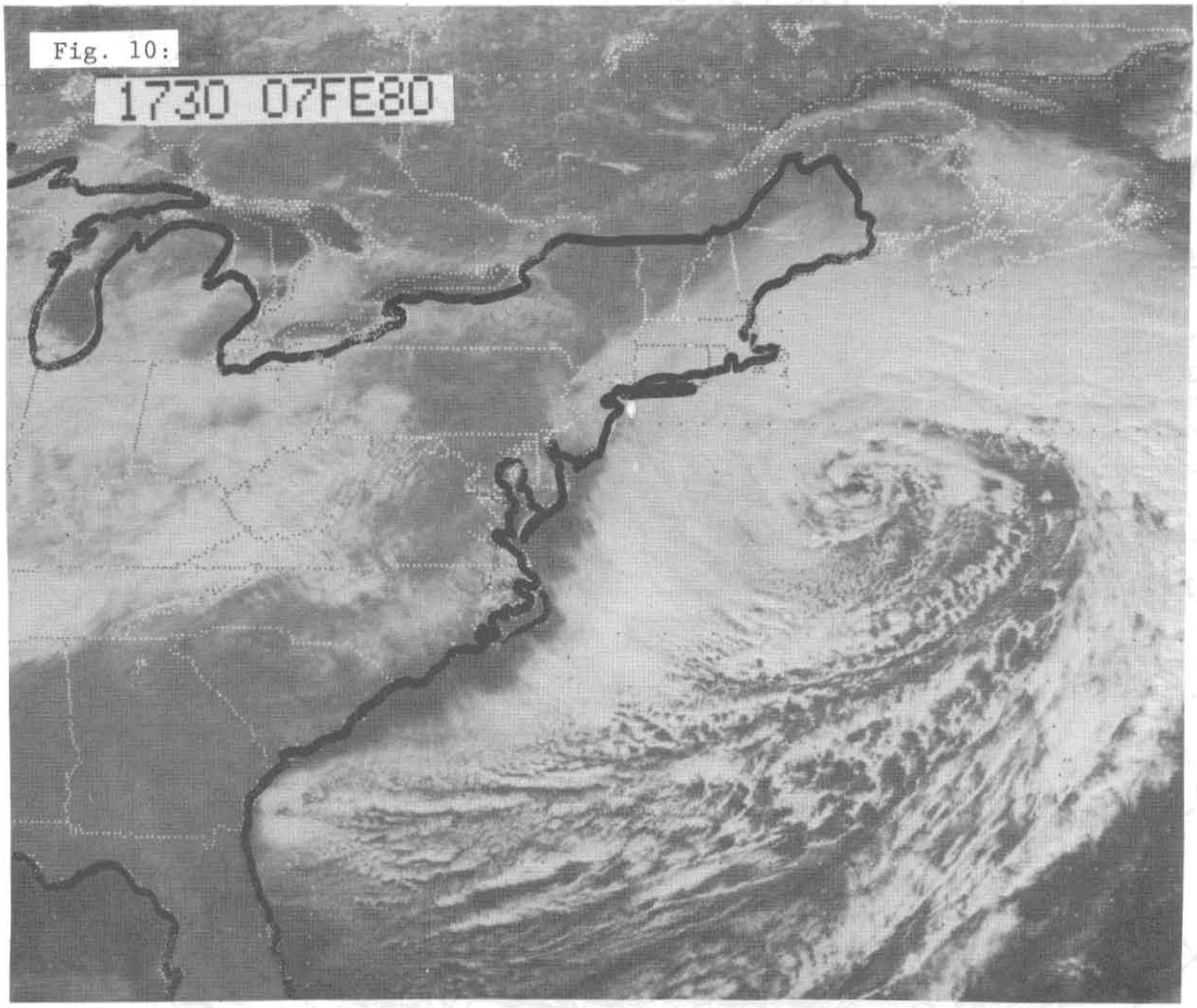

Figure 10. Satellite observed cloud cover valid 1730 GMT 7 Feb 1980.

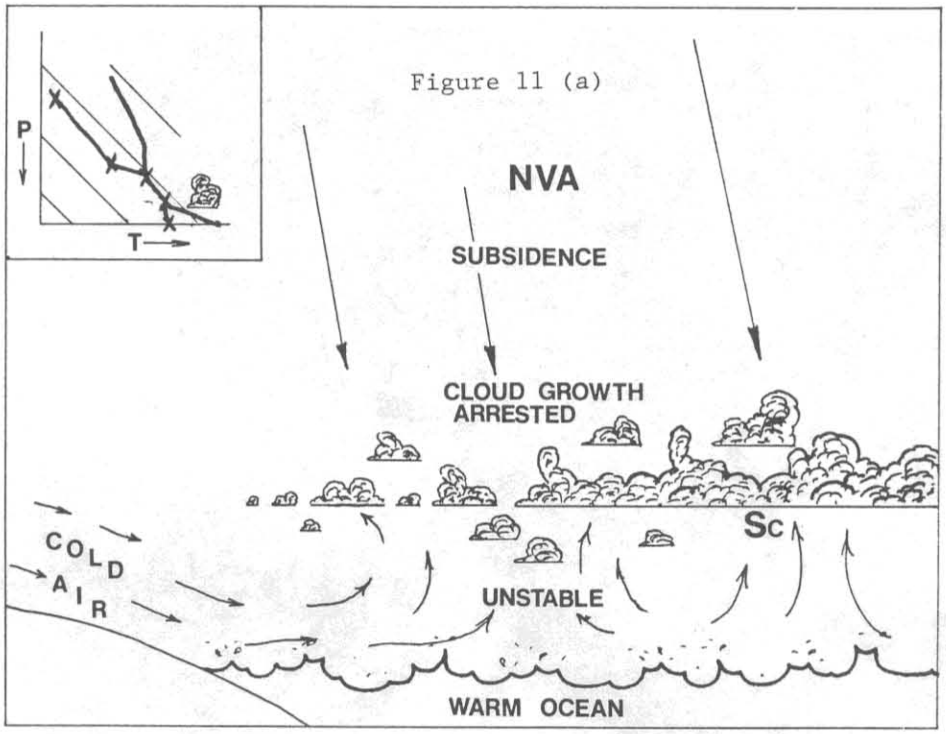

Figure 11(a). East coast prior to secondary development.

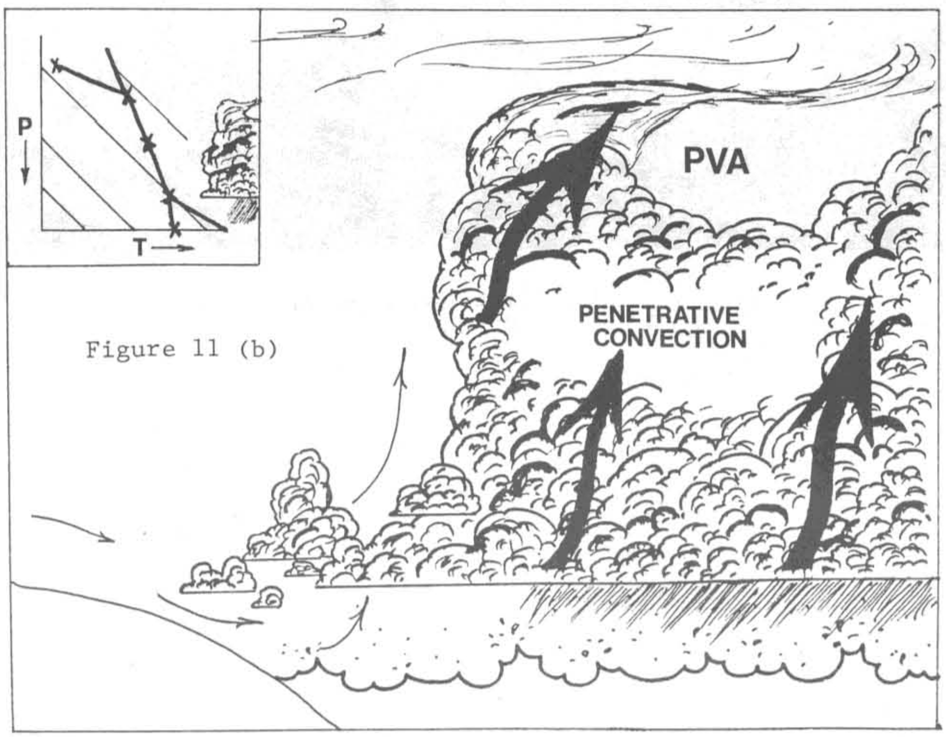

Figure 11(b). East coast after subsidence lid is removed.

REFERENCES AND FOOTNOTES

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