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HEAVY SNOWFALL OVER THE SOUTHEAST ATLANTIC COAST ON DECEMBER 22-24, 1989

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1. INTRODUCTION

A very rare heavy snowfall event hit the southeast Atlantic coast on December 22-24, 1989. Snowfall amounts of 2 to 5 inches were reported across coastal Georgia, while amounts of 4 to 15 inches were reported over the coastal areas of North and South Carolina. Snowfall amounts (Figure 1) tapered off rapidly inland, with only a trace reported in Columbia, SC (CAE), and Raleigh, NC (RDU).

This snowfall provided a rare opportunity to examine the performance of the "Magic Chart" (Chaston 1989) during a coastal storm along the southeast Atlantic coast. For the purpose of this study, I will refer to a coastal storm as one located far enough offshore so that it's primary effects extend only about 50 to 75 miles inland.

2. SYNOPTIC SITUATION

A strong arctic cold front pushed through Georgia and the Carolinas during the early morning hours of Friday, December 22. A broad long-wave trough was established over the eastern United States. This feature was not unusual, except for the southward extent of the cold air.

The 546 dm 1000-500 mb thickness line is commonly used as a rain/snow discriminator over coastal South Carolina. The LFM thickness analysis for 1200 UTC, Saturday, December 23 (Figure 2), shows the 546 dm line positioned unusually far south, over northern Florida. Note, the packing of the thickness lines (baroclinic zone) extends from the Florida panhandle, through southeast Georgia, and northeast over the Atlantic Ocean along the Carolina coast. It is rare for such a strong baroclinic zone to be located so far south. Warm advection associated with this baroclinic zone is a key ingredient in determining the track of developing surface lows in the southeastern U.S.

The 500 mb LFM analysis for 1200 UTC, December 22 (Figure 3a) indicates a short wave over southeast Colorado. This short wave intensified as it tracked over Louisiana by 1200 UTC, December 23 (Figure 3b). The short-wave subsequently rotated around the base of the long wave trough, tracking over the thickness gradient that was located along the Carolina and Georgia coasts. Warm air advection associated with this baroclinic zone, coupled with the positive vorticity advection associated with the short wave, resulted in offshore cyclogenesis, providing the necessary lifting mechanism for the resultant heavy snowfall event along the southeast Atlantic coast.

3. DYNAMICAL MODEL PERFORMANCE

The 1200 UTC, December 22 runs of both the LFM and the NGM had problems handling the placement of the surface low.

Both models forecast the surface low too far east off the Florida coast, and too far ahead of the advancing shortwave. This trend was especially evident in the LFM. Despite this problem, the LFM (FRH63), and the NGM (FRHT63) forecast precipitation amounts for the period 1200 UTC, December 22, through 0000 UTC, December 24, for Charleston, SC, (CHS) were quite accurate. Both models forecast around 0.75 inches of liquid precipitation, while 0.80 inches was observed.

The LFM-MOS probability of snow amount (POSA) for CHS, however, forecast only 2", or less, of snowfall for the 0000 to 1200 UTC Saturday time period. This was despite the substantial LFM QPF forecast, the MOS temperature forecasts well below freezing, and a precipitation type forecast (POPT) of all frozen precipitation. Twelve-hour snowfalls in excess of 2 inches are extremely rare in Charleston (there may not have been a case in the developmental sample).

4. THE "MAGIC CHART"

The "Magic Chart" was initially developed at the NWS Forecast Office in Milwaukee, Wisconsin during the 1987-88 snow season. The "Magic Chart" consists of the AFOS chart 7WG (12-24 hr net vertical displacement from the trajectory model), overlaid with AFOS chart 82T (12-hour 850 mb temperature prog from the NGM). The technique utilizes the net vertical displacement (NVD) between the -3 and -5°C isotherms to forecast snowfall by using a 10 mb NVD to 1 inch snowfall ratio. Of course, the technique assumes sufficient moisture (usually defined as 90% 1000-500 mb mean relative humidity (Chaston 1989)) is present to support precipitation. Snowfall guidance for the time-period 12 to 24 hours after initial time based on this technique are listed in Table 1. The -3 and -5°C thermal ribbon is used because warmer temperatures often result in precipitation types other than snow, while air with colder temperatures typically does not contain sufficient moisture to support the 10 to 1 ratio.

The NGM temperature fields (and moisture fields discussed later) were used because they produced a much better forecast than the LFM. This is due primarily to the NGM's improved physics and better resolution. The NVD fields used in this paper were from the LFM-based trajectory model, since NGM-based trajectory model NVD fields were not available until February of 1990. When using the NGM NVD fields, a small downward adjustment to the 1 inch per 10mb of upward NVD will likely be necessary. This is because the operational NVD fields from the current NGM-based trajectory model have somewhat more amplitude for a given snowfall amount than those from the previously produced LFM-based version. This is a result of the improved physics and the enhanced horizontal resolution of the NGM, relative to the LFM (National Weather Service 1990).

NET 12-HOUR VERTICAL DISPLACEMENT	12-HOUR SNOWFALL
20mb-40mb	2"-4"
40mb	4"
60mb	6"
80mb	8"
100mb	10"
120mb	12"
140mb	14"
>140mb	>14"

Table 1. Snowfall amounts associated with various 12-hour net vertical displacements.

Figures 4a-c show the "Magic Chart" from three successive model runs, for 12-hour periods, beginning 0000 UTC, December 23, thru 1200 UTC, December 24, respectively.

The problem with the "Magic Chart" technique in this case was the excessively cold 850 mb temperatures of -7 to -10°C over the coastal areas. Well inland, it could be assumed that these temperatures would hold much less moisture, preventing utilization of the technique. Moisture content should not be a problem along the coast, however, as the Atlantic can provide more than an ample supply of moisture.

Figure 5 is the total amount of snow forecast from 0000 UTC, December 23, to 12 UTC, December 24, based on the net vertical displacement alone (without respect to temperature, since the entire area was cold enough to support frozen precipitation). Observed snowfall totals in Figure 5 are circled. Note, the substantial improvement in forecast amounts along the immediate coast. However, further inland, the accuracy of the forecast drops off rapidly. Therefore, it appears that if a forecaster can make a determination of the inland extent of Atlantic moisture, the "Magic Chart" can be used more successfully in cases of unusually cold 850 mb temperatures.

5. MOISTURE AVAILABILITY

Observed precipitable water values, and the corresponding percent of the climatologic normals, are shown in Figures 6a-d. Available moisture nearly doubles along the coast at Charleston (CHS) and Cape Hatteras (HAT) from 1200 UTC, December 22, to 0000 UTC, December 24. At the same time, the available moisture at inland stations such as Athens, GA (AHN) and Greensboro, NC (GSO) remained about the same, or decreased. This indicates, that despite 850 mb temperatures below the -5°C level traditionally used in the "Magic Chart" technique, sufficient moisture was supplied to coastal areas. Hence, along the coastal areas the "Magic Chart" temperature criterion was not necessary once frozen precipitation was assured.

The NGM 12-hr forecast of relative humidity (AFOS chart I2D) is used to make initial determinations of the moisture available for snowfall. Note, when using the NGM forecasts of relative humidity, as well as the 850 mb temperature forecasts, one must remember that these are forecasts for a specific time, whereas the NVD is a forecast for a 12-hr period. Therefore, it is often necessary to examine the 24-hour forecasts (AFOS charts I4D and 84T) in addition to the 12-hour charts to account for changes in the temperature and moisture fields throughout the 12-hour period.

The 12-hour NGM 1000-500 mb mean relative humidity forecasts valid for 1200 UTC, December 23, and 0000 UTC, December 24 are shown in Figures 7a and 7b, respectively. An additional isohume, approximating 80% mean relative humidity, has been included. The 80% line closely approximated the inland extent of a trace, or more, of precipitation in this case; while the 90% line closely approximated where the substantial snowfall occurred. The 90% line in Figure 7a extends all the way to the western edge of southern Georgia. Snowfall occurred through much of this area, but the actual amounts were not available for this study.

After initially using the net vertical displacement (7WG) to determine snowfall amounts without regard to moisture, the I2D chart was then overlaid onto the forecast snowfall from the 7WG to identify those areas were adequate moisture would be available. In areas with greater than 90% mean relative humidity, the snowfall was forecast according to the NVD (without accounting for the -3 to -5°C 850 mb temperature ribbon). The 90% line has been used in other cases and appears to be a useful "rule of thumb" for snowfall along coastal South Carolina (assuming, of course, that the low level flow is onshore), though no in-depth study has been done to document this guideline. For relative humidities less than 90%, snowfall amounts should be reduced from those suggested by the net vertical displacement.

6. CONCLUSION

While moisture content is always important is assessing snowfall potential, when applying the "Magic Chart" along coastal areas, the inland extent of Atlantic moisture during coastal storms is crucial. The temperatures at 850 mb should be used to determine if it is cold enough to snow. If temperatures are well below the -5°C threshold originally suggested by the "Magic Chart," moisture availability, rather than the -3 to -5°C 850 mb thermal ribbon, should be used to determine if the NVD values are applicable. In these situations, downward adjustments in snowfall forecasts may only be needed well inland, where the moisture content is substantially reduced.

References

Chaston, P. R., 1989: The Magic Chart For Forecasting Snow Amounts, Nat. Wea. Digest, Vol 14, No. 1, 20-22.

National Weather Service, 1990: Forecasting Snow Amounts from Net Vertical Displacements. NWS Technical Procedures Bulletin, No. 389, Silver Spring, MD, 4 pp.

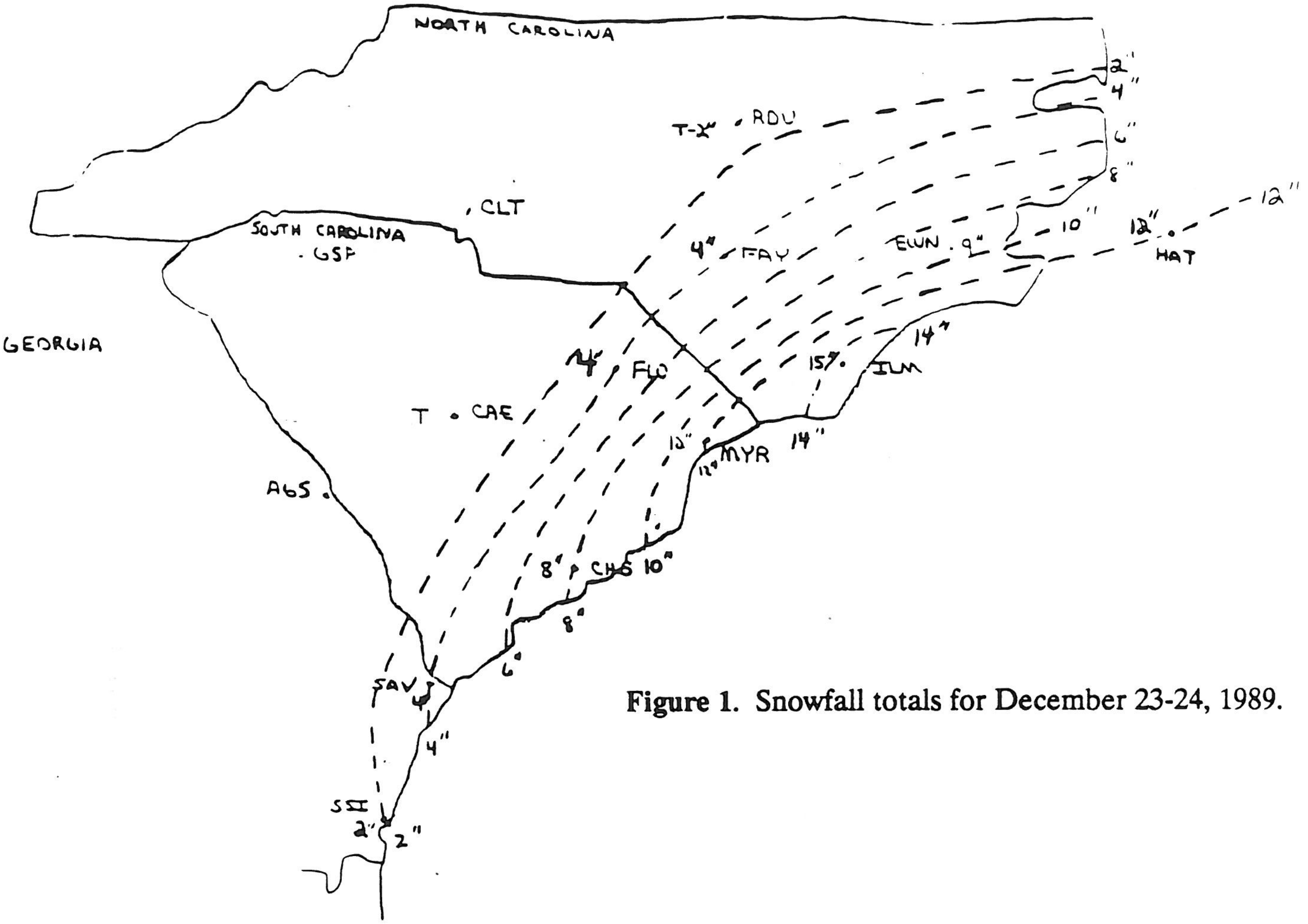
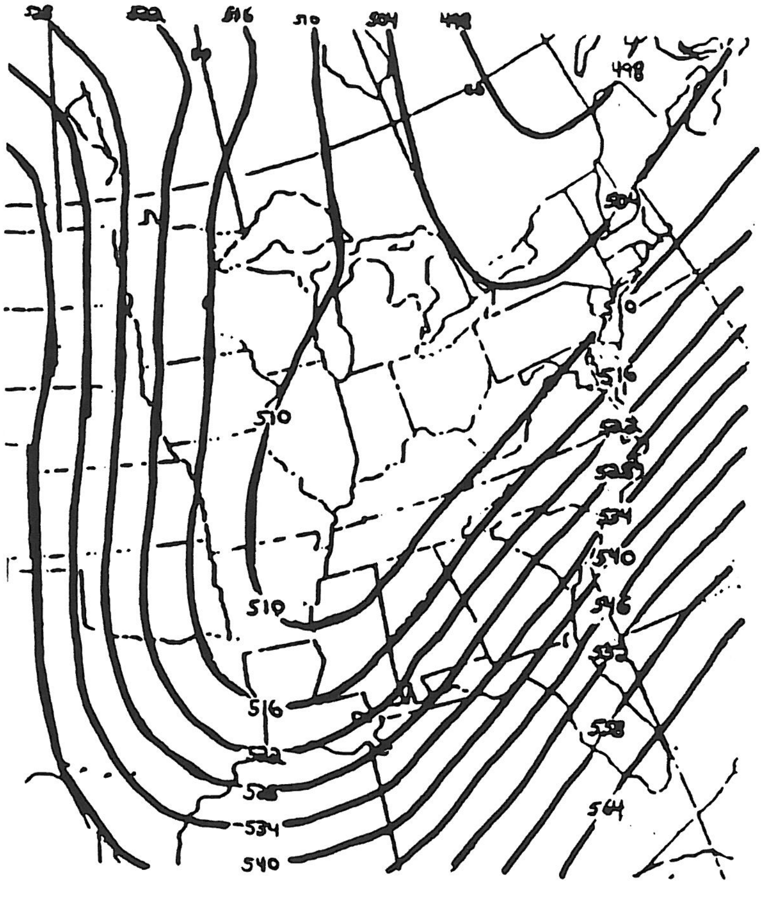


Figure 1. Snowfall totals for December 23-24, 1989.

Figure 2. LFM 1000-500 mb thickness analysis for 1200 UTC, December 23, 1989.



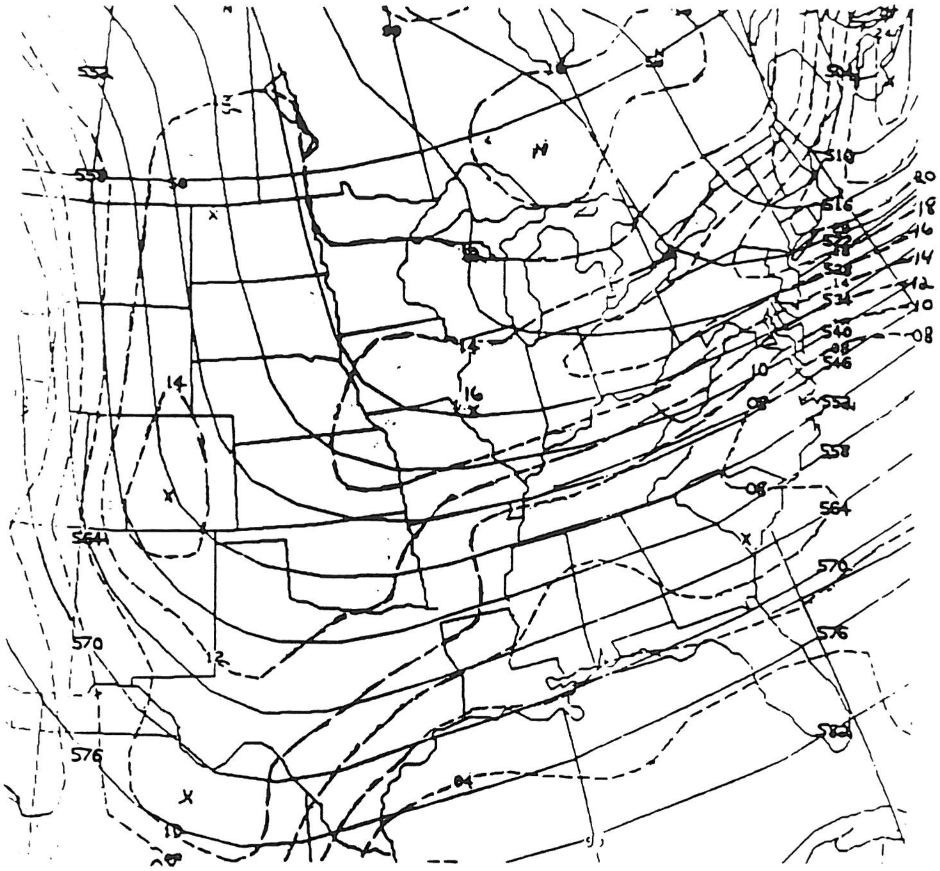


Figure 3a. LFM 500 mb height and vorticity analysis for 1200 UTC, December 22, 1989.

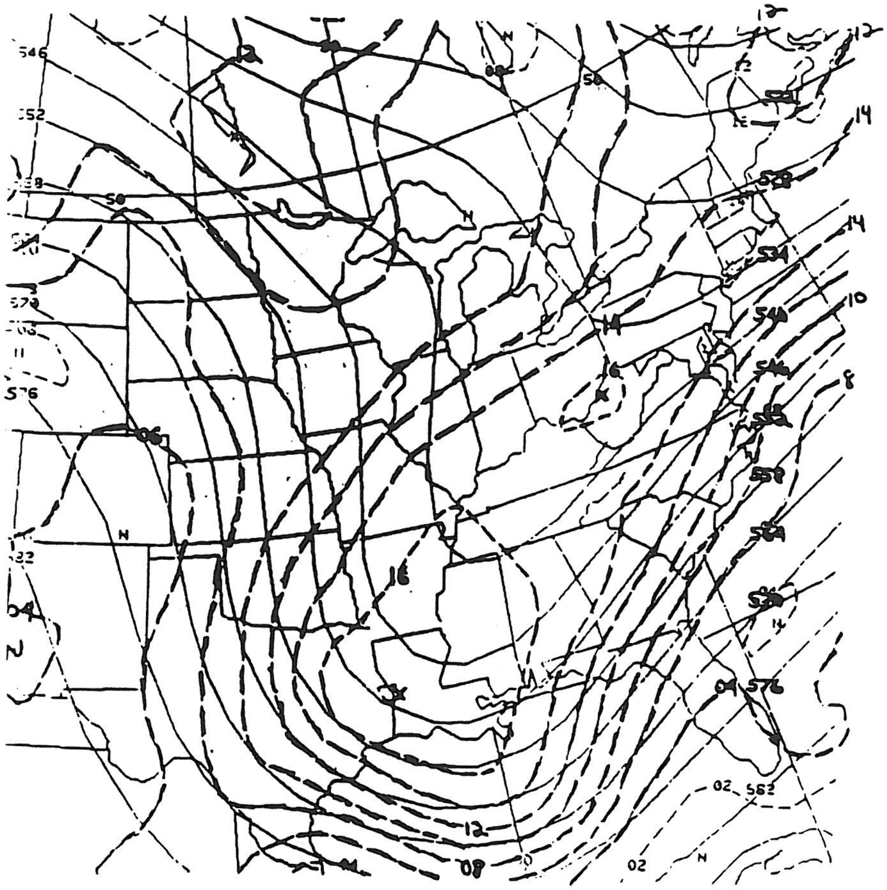


Figure 3b. LFM 500 mb height and vorticity analysis for 1200 UTC, December 23, 1989.

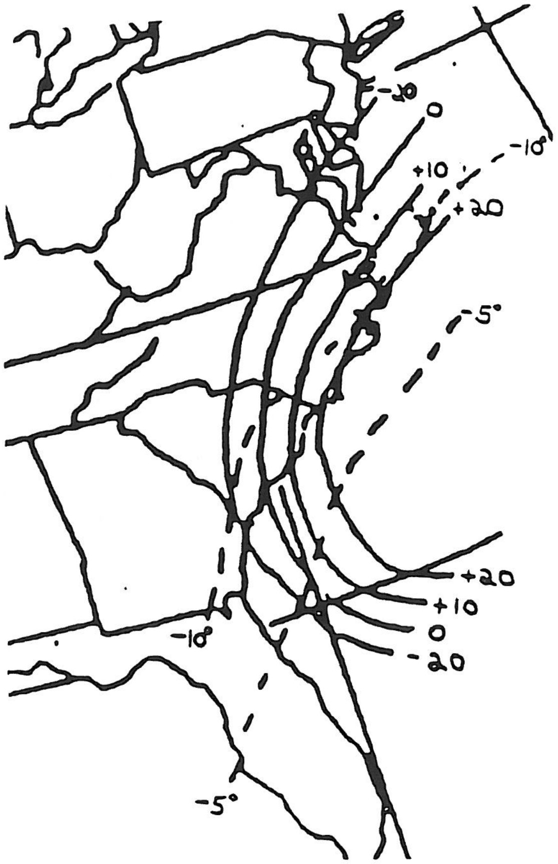


Figure 4c. "Magic Chart" for 1200 UTC, December 24, 1989.

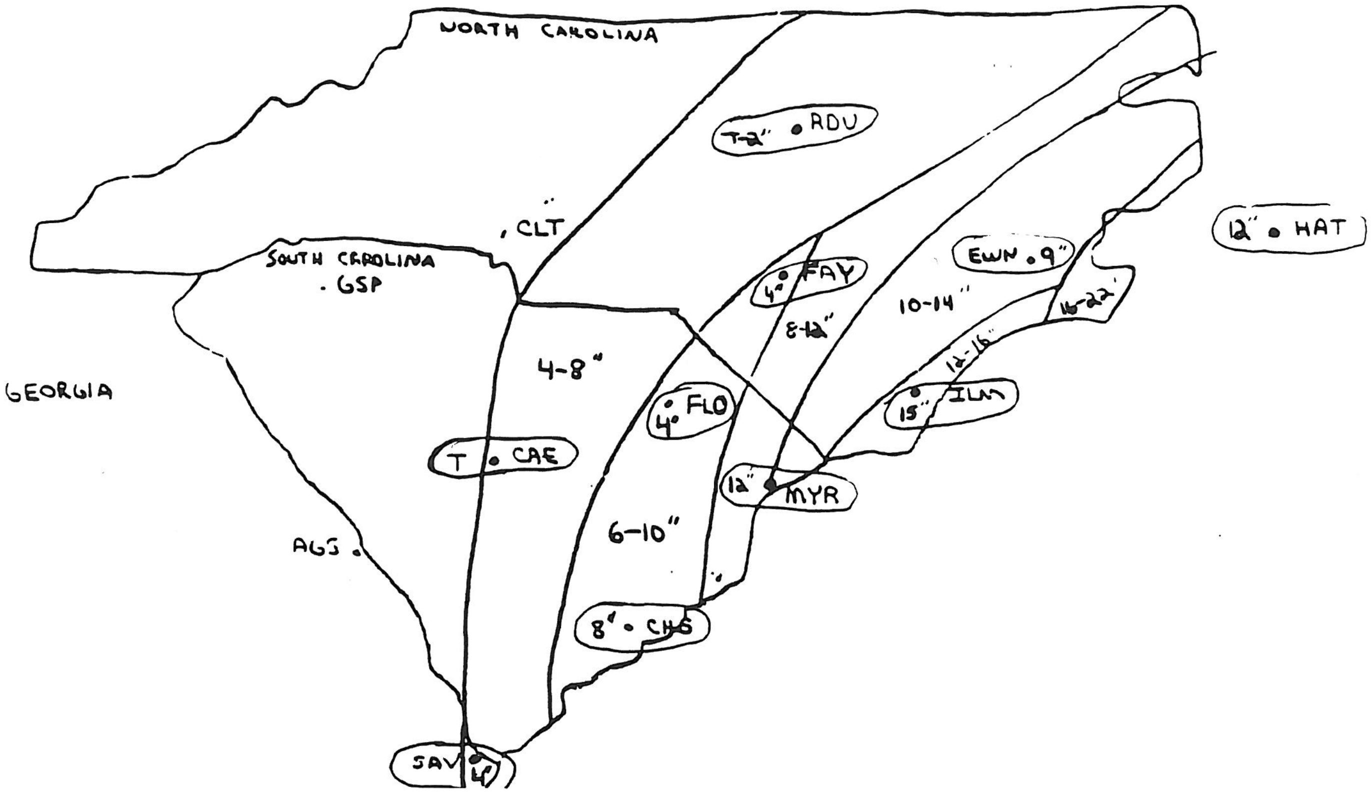


Figure 5. Total snowfall for 0000 UTC, December 23 to 1200 UTC, December 24, 1989, based on net vertical displacements only. Observed snowfall totals are circled.

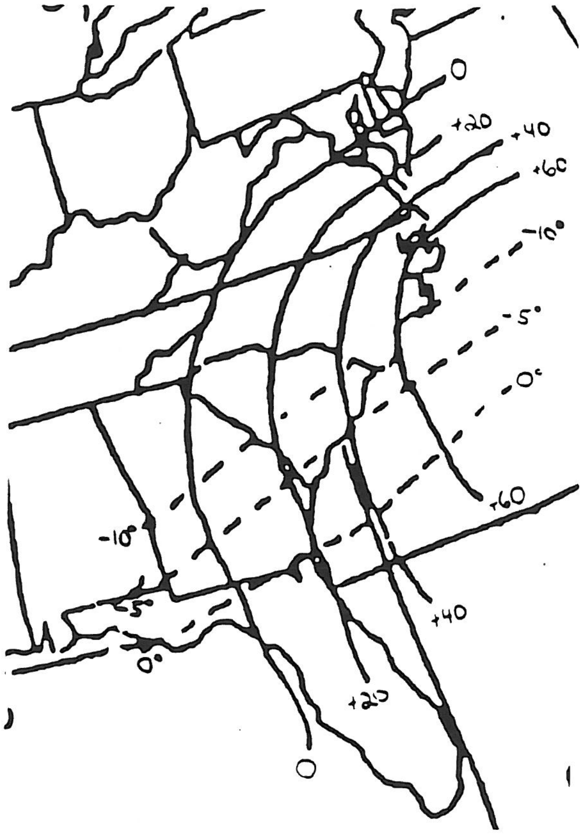


Figure 4a. "Magic Chart" for 1200 UTC, December 23, 1989. Solid lines are 700 mb net vertical displacements for 0000-1200 UTC, December 23, and dashed lines are 12-hour NGM 850 mb temperatures for 0000 UTC, December 23, 1989.

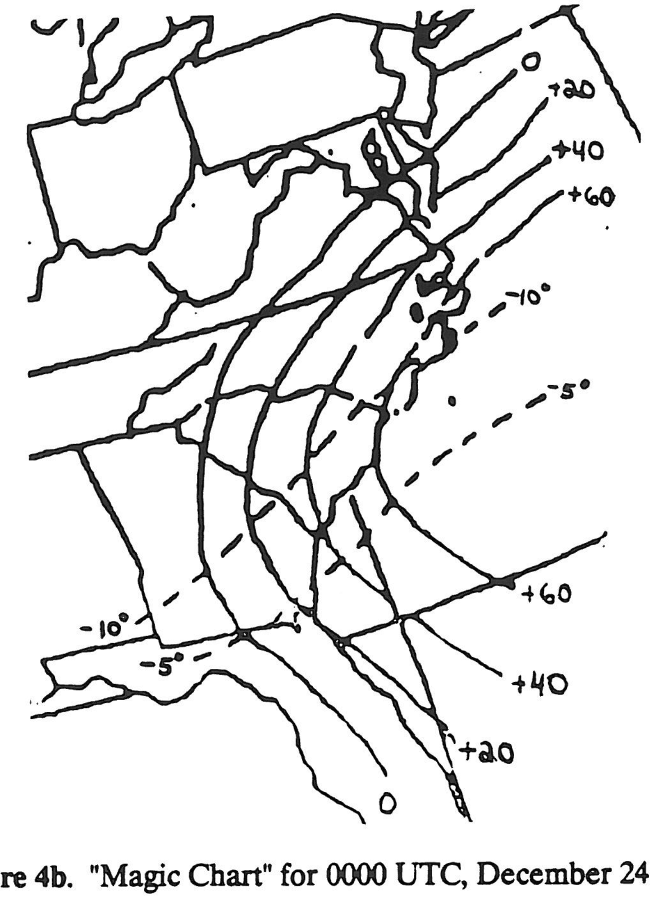


Figure 4b. "Magic Chart" for 0000 UTC, December 24, 1989.

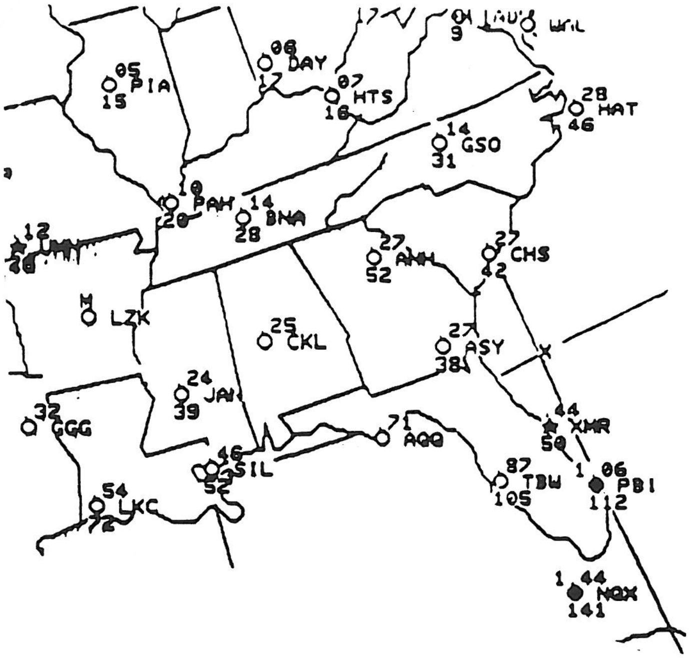


Figure 6a. Observed precipitable water (top) and percent of normal precipitable water (bottom) for 1200 UTC, December 22, 1989.

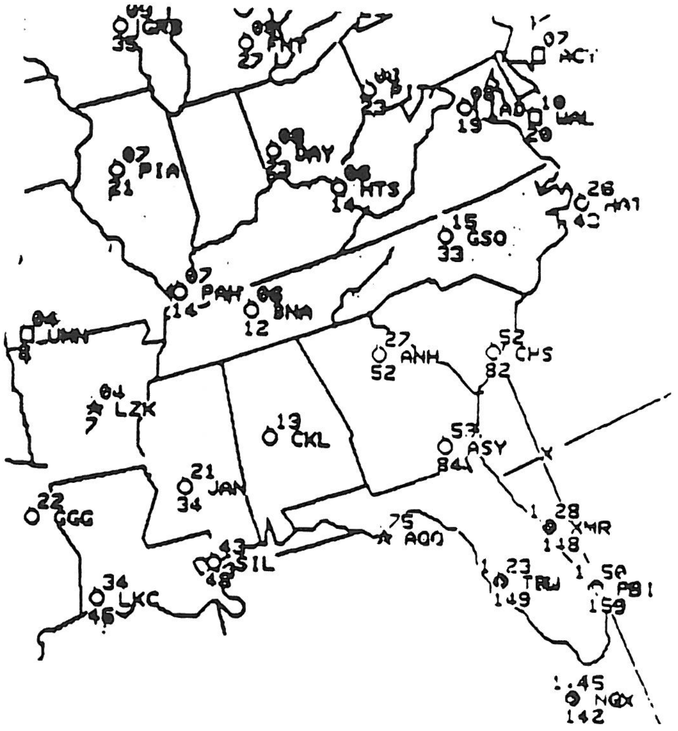


Figure 6b. Same as Figure 6a except for 0000 UTC, December 23, 1989.

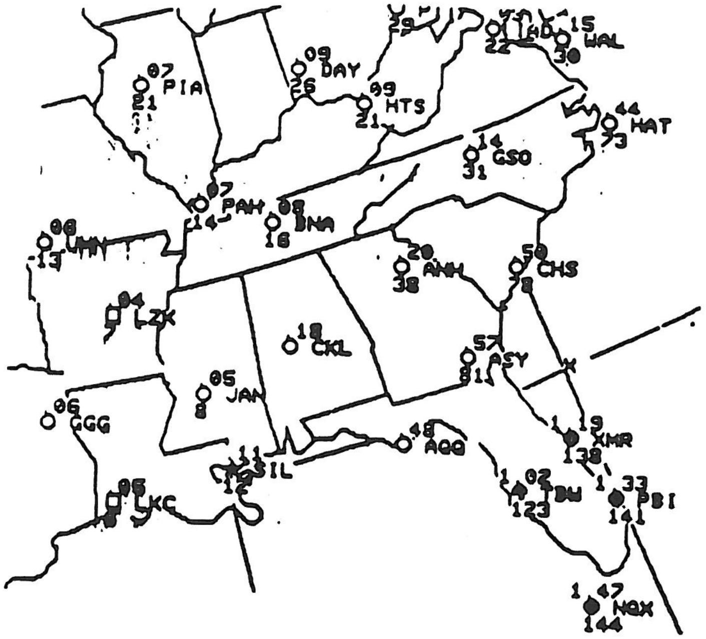


Figure 6c. Same as Figure 6a except for 1200 UTC, December 23, 1989.

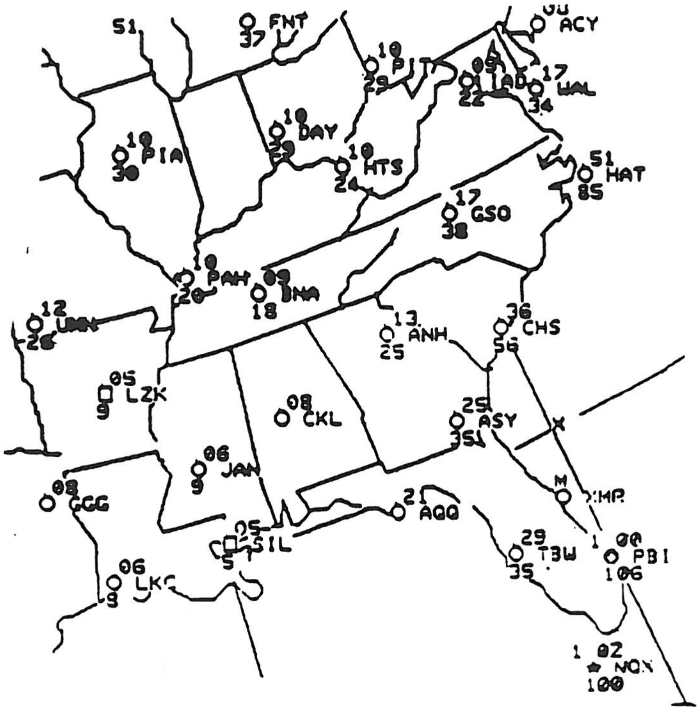


Figure 6d. Same as Figure 6a except for 0000 UTC, December 24, 1989.

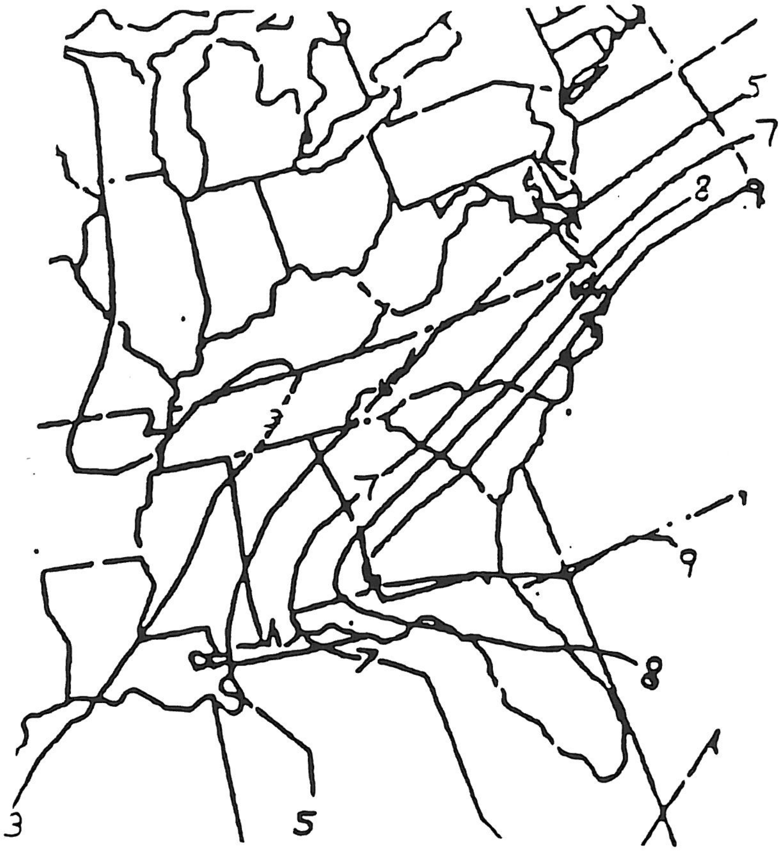


Figure 7a. NGM 12-hour forecast of 1000-500 mb mean relative humidity for 1200 UTC, December 23, 1989.

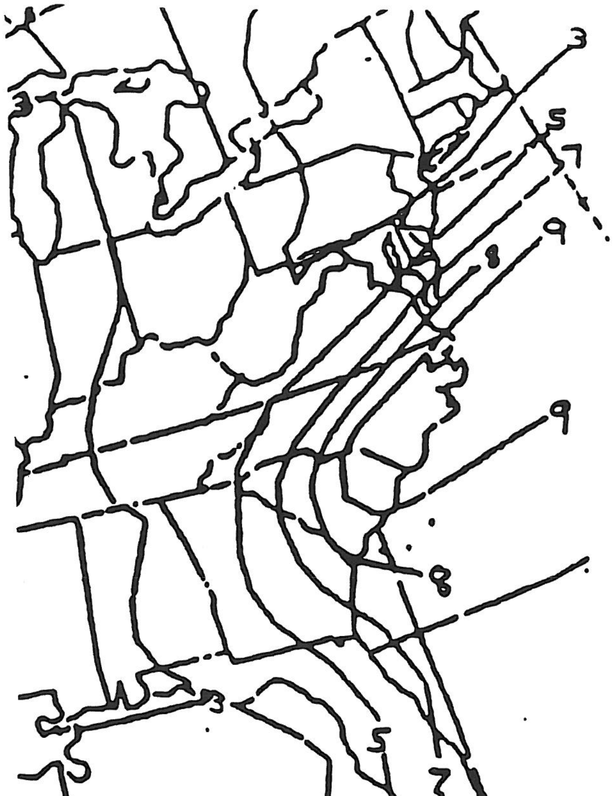


Figure 7b. NGM 12-hour forecast of 1000-500 mb mean relative humidity for 0000 UTC, December 24, 1989.