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NEW YORK STATE HEAVY SNOWFALL MONDAY JANUARY 29, 1990 - TUESDAY JANUARY 30, 1990 A CASE STUDY

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INTRODUCTION

A significant snowstorm took place across New York State on Monday January 29, 1990, and continued over central and eastern sections of the state Monday night and Tuesday morning. Heavy snow accumulated 6 to 10 inches over much of upstate New York, with up to 17 inches reported across the southern Adirondacks and the upper Hudson Valley. This storm presented an excellent example of how various snow forecasting techniques such as positive isothermal vorticity advection (PIVA), and trajectory model net vertical displacements (Magic Chart technique) can be used to improve heavy snow forecasts.

SYNOPTIC SETTING

A fast, westerly flow was dominant across the United States with short-wave troughs moving rapidly through a broad upper trough. On Sunday evening (0000 UTC, Jan. 29), a 1028 mb surface high was centered near Bradford, Pennsylvania. A weak 1016 mb low was over Louisiana (Figure 1A). By Monday morning the high was progged to move off the coast near Nova Scotia. Forecast models were generally in agreement, moving the low rapidly northeastward from Tennessee to West Virginia by Monday evening (1001 mb) (Figures 1B and 1C). The 36 hour forecast continued to deepen the low to 996 mb, while moving it to near Portland, Maine, Tuesday morning (Figure 1D). Conditions looked favorable for a significant overrunning event within 24 hours, with the potential for a snowstorm over upstate New York.

A 500 mb trough was located across the plains states on Sunday evening (Figure 2A). The forecast called for the trough to move across the Ohio Valley in 24 hours (Figure 2B), and reach eastern New York by 36 hours (not shown). A strong vorticity maximum was over the Texas Panhandle at the base of the trough Sunday evening (Figure 2A). This vorticity maximum was forecast to move along with the trough, and by Monday evening, would be just east of Cincinnati, Ohio (Figure 2B). Weak positive vorticity advection (PVA) would be over New York State through 0000 UTC, Jan. 30. A quick burst of strong PVA would be expected with the passage of the vorticity maximum late Monday evening and early Tuesday. By 1200 UTC Tuesday, the vorticity maximum was centered near Albany, New York, with strong negative vorticity advection (NVA) across most of New York.

On Sunday evening, the 1000-500 mb thickness values were between 5220 m and 5280 m over New York State (Figure 1). Thickness increased over this area during the following 24 hours, with the 5400 m thickness contour over central New York by Monday evening. Colder thickness values would follow the low Tuesday.

The 18 and 24 hour NGM boundary layer wind forecasts (Figures 2C & 2D) showed the low center over southern Ohio by 1800 UTC Monday afternoon, and near Lake Erie by 0000 UTC Monday evening. A southeast flow from the Atlantic Ocean across New York State introduced additional moisture into the picture. Wind speeds also decreased indicating surface convergence over western New York.

MOS AND FOUS FORECASTS

The 0000 UTC, Jan. 29, LFM MOS guidance for Buffalo forecasted a 24 hour POP of 100%. The predicted categorical precipitation type was for snow throughout the forecast period. The probability of snow amount (POSA) gave a best category forecast of 6 inches or more. The 0000 UTC LFM MOS for Syracuse was the same as for Buffalo in these categories.

The 0000 UTC, Jan. 29, NGM FOUS forecast for Buffalo was for 0.49 inches water equivalent precipitation for the event. Using a ten to one ratio, this would equate to a 5 inch snowfall. The mean relative humidity was nearly saturated below 500 mb. The 1000-500 mb thickness values were 5370 m at 1800 UTC, and 5380 m at 0000 UTC.

The 0000 UTC, Jan. 29, LFM FOUS forecast for Buffalo gave 0.87 inches water equivalent precipitation, or nearly 9 inches of snowfall for the event. The mean RH was 99% at all levels for both 1800 UTC, Jan. 29, and 0000 UTC, Jan. 30. The 1000-500 mb thickness values were 5400 m at 1800 UTC, and 5370 m at 0000 UTC.

SNOWFALL FORECASTING

Usually heavy snow falls within 3 or 4 degrees of latitude to the left of the surface low track (Goree and Younkin, 1966). In this case, the surface low was forecast to move from the West Virginia Panhandle Monday evening (Figure 1C), to near Portland Maine Tuesday morning (Figure 1D). This track would take the low across central Pennsylvania and southeast New York, and would place western and central New York in the heavy snow area Monday night. The track of the 500 mb vorticity maximum was also favorable. Located over northeast Kentucky at 0000 UTC, Jan. 30 (Figure 2B), the vorticity maximum would move across central Pennsylvania to near Albany by 1200 UTC. This would leave portions of western and central New York 2 to 3 degrees to the left of the track; an area considered favorable for heavy snow (Goree and Younkin, 1966).

POSITIVE ISOTHERMAL VORTICITY ADVECTION (PIVA)

The PIVA technique works on the basis of the advection of vorticity by the thermal wind. On a thickness chart, the thermal wind blows parallel to the thickness contours, with colder air to the left, and warmer air to the right as you look downstream. By using the 500 mb vorticity chart, and overlaying the 1000 mb to 500 mb thickness chart, vorticity advection can be observed, and areas of upward vertical motion derived. The greatest synoptic scale lift, and subsequently the heaviest precipitation, tends to occur where the strongest vorticity is occurring as advected by the thermal wind. On the overlayed charts, the strongest PIVA would be areas where the vorticity contours cross the thickness contours at nearly right angles (Trenberth, 1978), especially where the thickness gradient is tight (i.e., the thermal wind is strongest).

Based on the PIVA technique, the heaviest precipitation would be forecast over western Ohio and eastern Indiana at 1800 UTC on Monday afternoon (Figure 3A). By 0000 UTC Monday evening, the zone of heaviest precipitation would be just entering southwest New York State (Figure 3B). The PIVA area covered southern Ontario, Lake Erie, western Pennsylvania, and eastern

Ohio. By 36 hours, the strongest PIVA and therefore heaviest snowfall was forecast over New England, with the vorticity maximum centered near Albany (Figure 3C).

The strongest PIVA moved across New York state between 24 and 36 hours, indicating heavy precipitation from about 7 p.m. Monday night to 7 a.m. Tuesday morning (Jan. 30).

THE MAGIC CHART

The theory behind the Magic Chart technique is that the heaviest snowfall from a synoptic scale storm is likely to occur where the greatest synoptic scale lift co-exists with air that has the greatest moisture content and is cold enough for snow (Chaston, 1989). The Magic Chart utilizes charts 7WG - the 12 to 24 hour LFM trajectory forecast for 700 mb net vertical displacement (NVD), 84T - the NGM 24 hour 850 mb temperature forecast, and I4D - the NGM 24 hour mean relative humidity forecast. It should be noted that the 7WG chart was changed and became dependent upon the NGM trajectory model as of February 9, 1990. In addition, NGM-based charts 7XG (24 to 36 hour NVD) and 7YG (36 to 48 hour NVD) are now available. This paper used the LFM-based 7WG chart.

The Magic Chart technique consists of overlaying charts 7WG and 84T. The region where the greatest positive net vertical displacement coincides with the -3°C to -5°C isothermal ribbon, and chart I4D shows a mean relative humidity of 90% or greater, is where the heaviest snowfall is likely to occur from 12 to 24 hours after initial time. The prediction of snowfall during the 12 to 24 hour period after initial time involves converting the positive NVD values from millibars to inches by using a +10 mb to 1 inch of snow ratio. For example, +020 mb would become 2 inches of snowfall, +060 mb would become 6 inches of snowfall, and +140 mb would become 14 inches of new snow (Chaston, 1989). Note, the 10 to 1 ratio might need to be modified slightly for the new NGM NVD charts, since the NGM's greater resolution yields higher vertical velocities, and subsequently greater net vertical displacements.

The NGM mean RH chart for 1200 UTC Monday morning (Figure 3D) showed the 90% plus mean RH area over much of Pennsylvania, with its northern edge along the New York State line. Much drier air was to the north, with 30% or less mean RH over northern New York. The 12 hour NGM 850 mb temperature forecast for 1200 UTC Monday (Figure 4A), showed most of New York State was slightly too cold for the Magic Chart technique; the -5°C isotherm extended from IAG to BGM

By 0000 UTC, Jan. 30, the NGM 24 hour humidity forecast showed greater than 90% over all of New York State (Figure 4B). Strong upward 700 mb NVD was forecast by the trajectory model over New York state, with an area of greater than +100 mb between BGM and ALB. Overlaying the 24 hour NGM forecasted 850 mb temperatures, and using the Magic Chart technique, we found that a forecasted snowfall band of 8 to 10 inches extended in an area south of a line from ART to BTV, and north of a line from BUF to ALB (Figure 4C). South of the BUF to ALB line, temperatures were too warm to use the Magic Chart technique. Most of the southern tier of New York was forecast to be between 0°C and -2°C at 850 mb, indicating that snowfall amounts would be less in this region, with mixed precipitation more likely to occur.

Comparing the 12 hour and 24 hour conditions (Figure 4), one could see a big change taking place across New York State, as abundant moisture races in, and temperatures warmed slowly. Although Magic Chart conditions were very good at 0000 UTC for a heavy snowfall across New York State (Figure 4C), they were not 12 hours earlier (Figure 4A). This suggested that the heavy snowfall would begin late in the day, and extend into the nighttime period.

The 12 and 24 hour LFM mean RH forecast charts I25 and I45 were basically the same as their NGM counterparts, so it was decided to try the Magic Chart technique based on 850 mb LFM forecasted temperatures overlayed with the trajectory model NVD (Figure 4D). This chart gave similar results, but included more of southwestern New York in the heavy snowfall area. The area of 8 to 10 inch snowfalls extended south of a line from ERI to BUF to ART and BTV, and north of a line from ELM to SYR and ALB. The 12 hour LFM forecasted 850 mb temperature chart had the -5°C isotherm from BUF to ALB. The LFM Magic Chart put much more of western New York into the 8 to 10 inch zone than did the NGM version.

VERIFICATION

Storm snowfall totals of 6 to 10 inches were common across much of upstate New York (Figure 5). The heaviest storm totals of 10 to 17 inches extended from the Utica/Rome area across the southern Adirondacks to the upper Hudson Valley. In western New York the heaviest snow of 8 to 10 inches fell in a band from Allegany County northeast across the finger lakes to SYR and ART. Generally 4 to 6 inches fell elsewhere. Snowfall totals as of 0000 UTC Monday evening were generally 2 to 4 inches across the state, with several areas reporting 6 to 8 inches.

CONCLUSIONS

All of the forecast information on Sunday Jan. 28 seemed to point to a significant snowstorm for New York State on Monday afternoon and night. Winter Storm Watches were issued Sunday afternoon, and were upgraded to warnings Monday morning. The models handled the system well, and snowfall amounts were generally in the range predicted. As the boundary layer wind forecasts suggested, warmer air from the Atlantic was pulled into the storm circulation. This helped produce mixed precipitation at times instead of snow.

In this particular case, both the LFM and NGM 850 mb temperatures each had there strong and weak points in outlining the area of heaviest snowfall. The LFM temperatures worked better on the Magic Chart in delineating the heavy snow over the southwestern portion of the state. The Magic Chart based on the NGM temperatures was better over the eastern sections of the state, as well in as forecasting the more east-west orientation of maximum snowfall.

The Magic Chart snowfall amounts worked fairly well for storm totals, but amounts greater than 8-10 inches were received over many areas. This was due to two factors. First, if the Magic Chart technique was modified to include 850 mb temperatures between -1°C and -5°C, then the maximum snow area predicted by the technique would be expanded southward into the area where the NVD was forecast to be in excess of +100 mb. If precipitation falling where 850 mb temperatures are -1°C or -2°C were to remain snow, then the higher moisture content of this slightly warmer air could yield a NVD-snowfall ratio of greater than 10 to 1. This appears to have been the case in this storm. Additionally, the area of heaviest snowfall amounts may have received additional enhancement through orographic lifting caused by the southeast (windward) slopes of the Adirondacks.

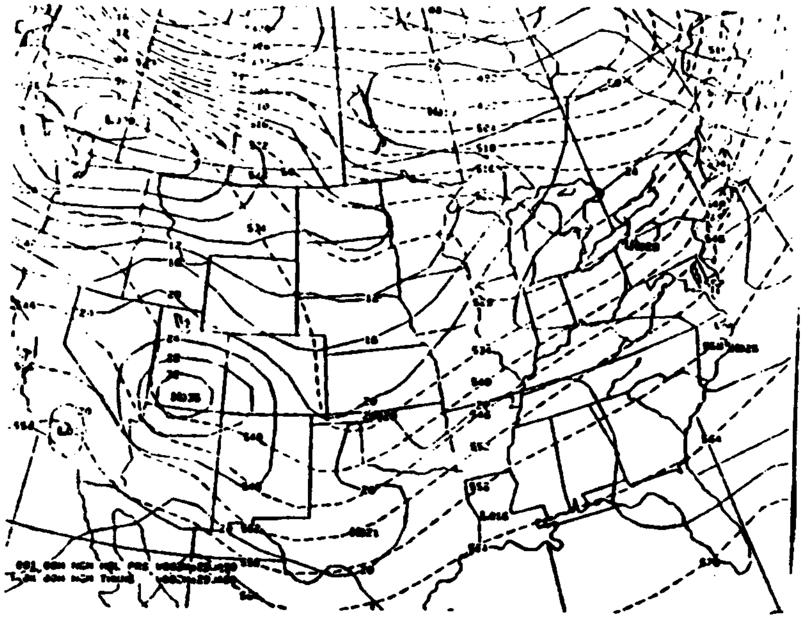
The PIVA technique worked well, as the heaviest snowfalls occurred Monday evening as the strongest PIVA crossed the state. In this case the MOS POSA categorical forecast of 6 inches or more at both BUF and SYR could have been modified based on PIVA. The POSA forecast period ended at 0000 UTC Monday evening, just as the strongest PIVA and heaviest snowfalls were beginning. By extending the forecast of heavy snow until midnight, additional accumulations associated with PIVA could have been accounted for.

REFERENCES

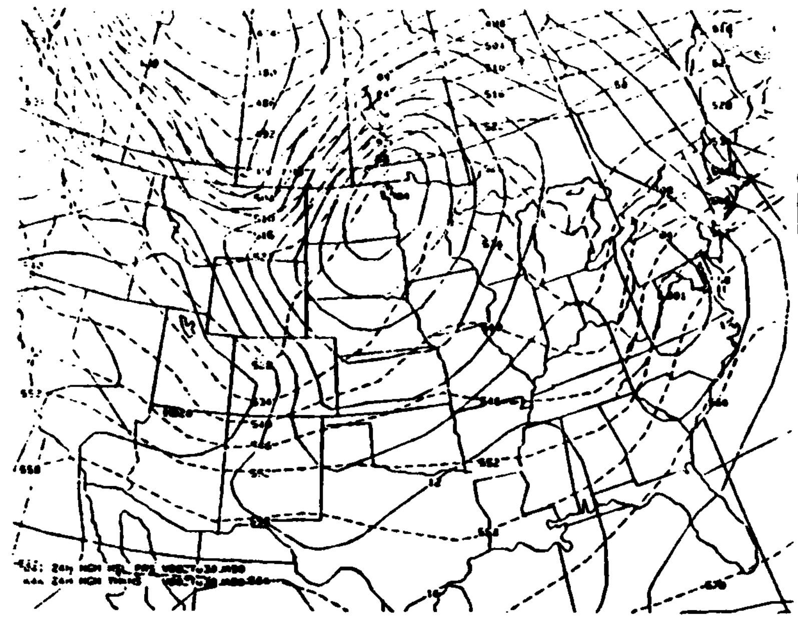
Chaston, P.R., 1989: The Magic Chart For Forecasting Snow Amounts., *National Weather Digest*, Feb 1989, Vol. 14, No. 1, 20-22.

Goree, P.A. and Younkin, R.J., 1966: Synoptic Climatology of Heavy Snowfall over the Central and Eastern United States., *Monthly Weather Review*, Nov 1966, Vol. 94, No. 11, 663-668.

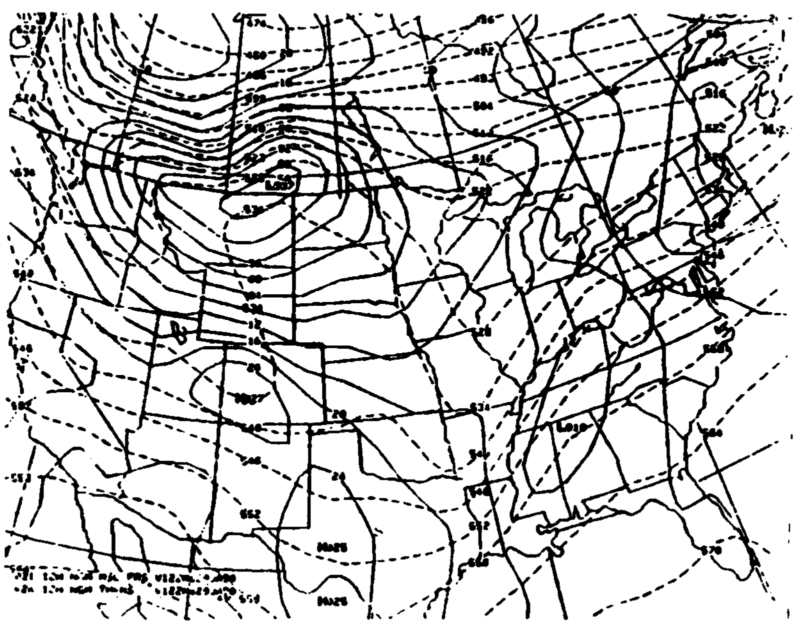
Trenberth, K., 1978: On the Interpretation of the Diagnostic Quasi-Geostrophic Omega Equation,. *Monthly Weather Review*, Jan. 1978, Vol. 106, 131-137.



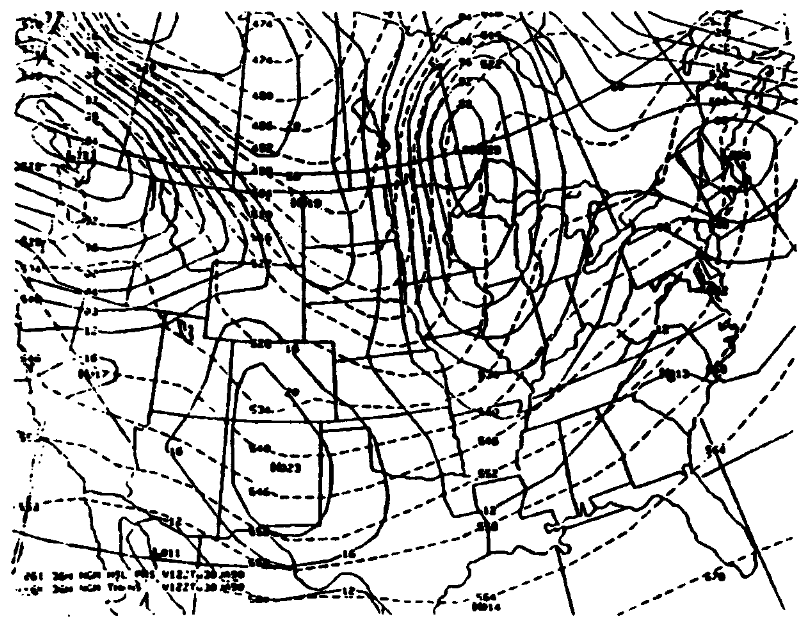
A. Initial analysis - Sunday evening 00z Jan 29, 1990.



C. 24 hour - Monday evening 00z Jan 30, 1990.

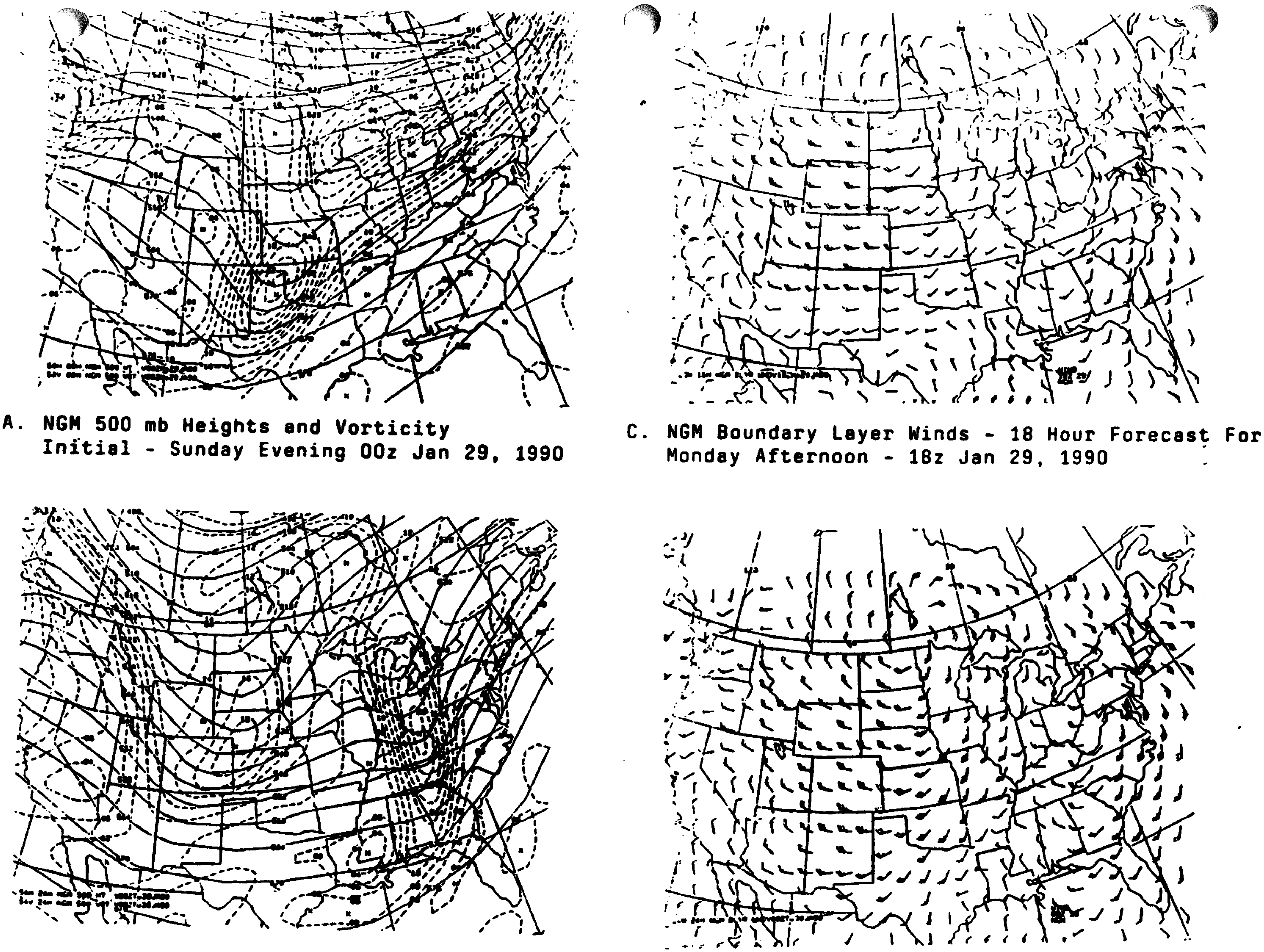


B. 12 hour - Monday morning 12z Jan 29, 1990.



D. 36 hour - Tuesday morning 12z Jan 30, 1990.

Figure 1 - NGM Analyses and Forecasts of Surface Pressure and Thickness



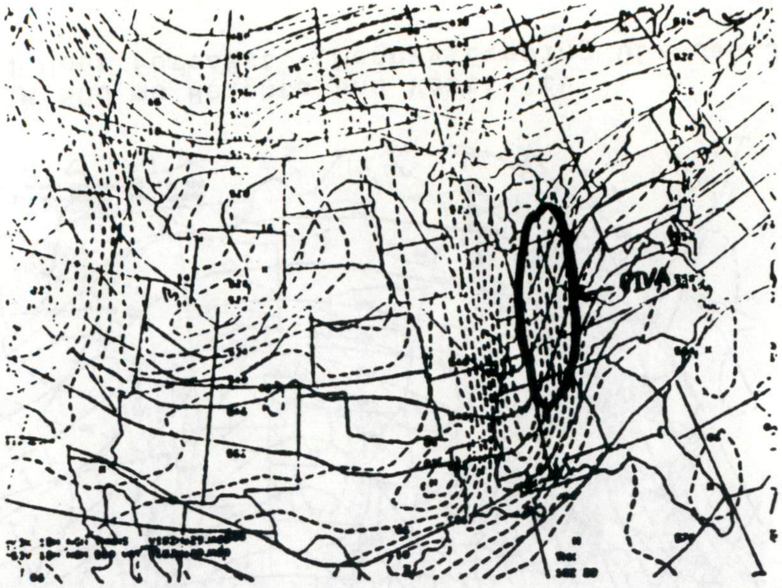
A. NGM 500 mb Heights and Vorticity
Initial - Sunday Evening 00z Jan 29, 1990

C. NGM Boundary Layer Winds - 18 Hour Forecast For
Monday Afternoon - 18z Jan 29, 1990

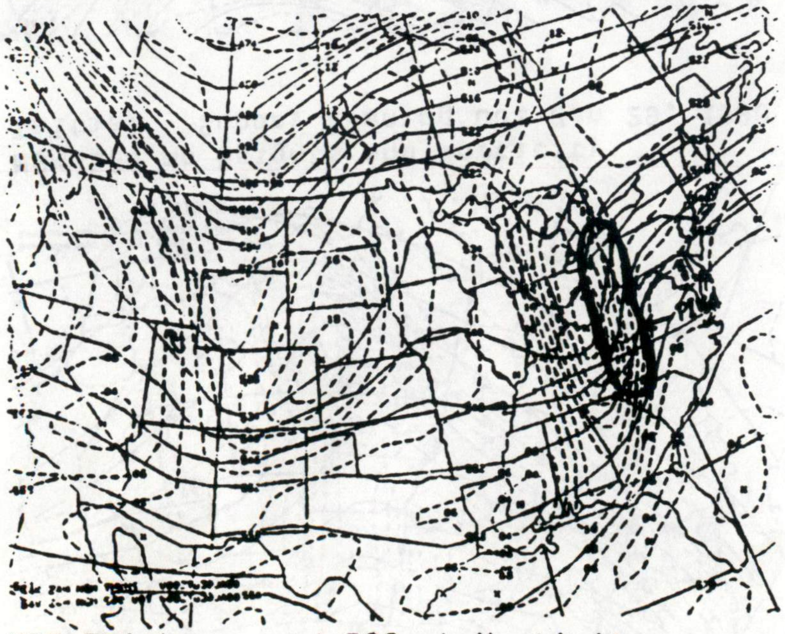
B. NGM 500 mb Heights and Vorticity
24 Hour Forecast - Monday Evening 00z Jan 30

D. NGM Boundary Layer Winds - 24 Hour Forecast For
Monday Evening - 00z Jan 30, 1990

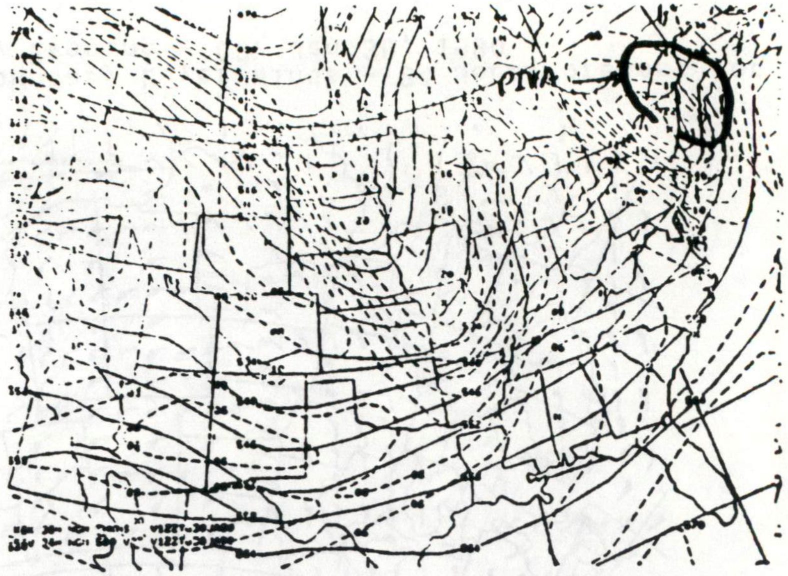
Figure 2



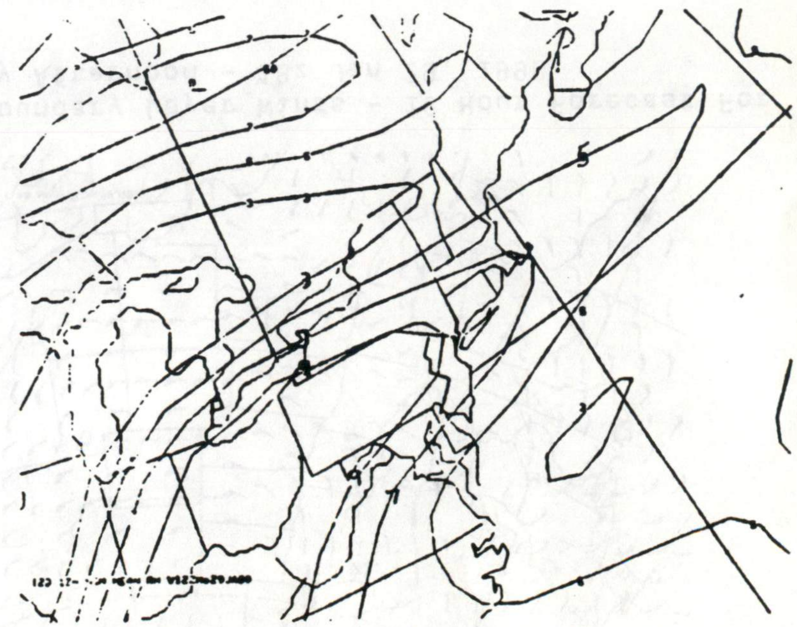
A. NGM Thickness and 500 mb Vorticity
18 Hour Forecast for 18z Monday Afternoon
January 29, 1990



B. NGM Thickness and 500 mb Vorticity
24 Hour Forecast for 00z Monday Evening
January 30, 1990

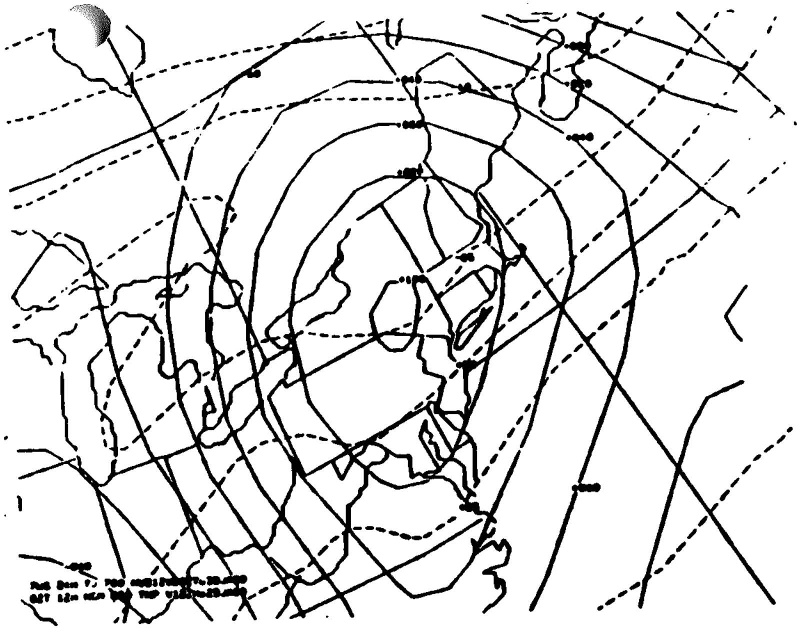


C. NGM Thickness and 500 mb Vorticity (IVA)
36 Hour Forecast for 12z Tuesday Morning
January 30, 1990

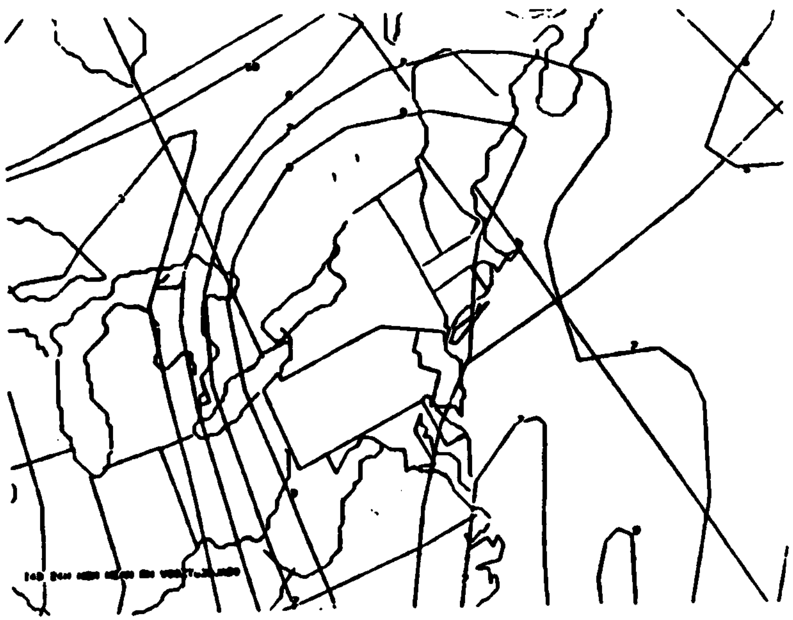


D. NGM 12 Hour Mean RH Forecast for 12z
Monday Morning January 29, 1990

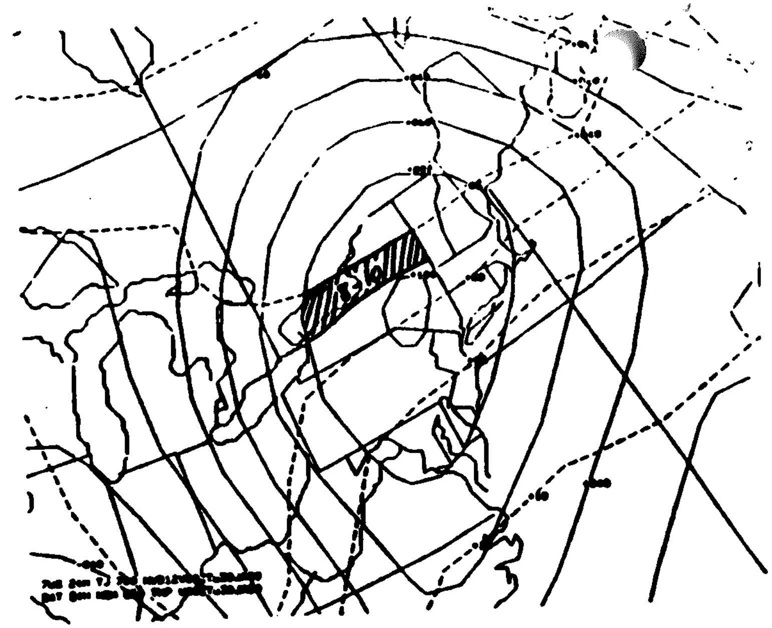
Figure 3



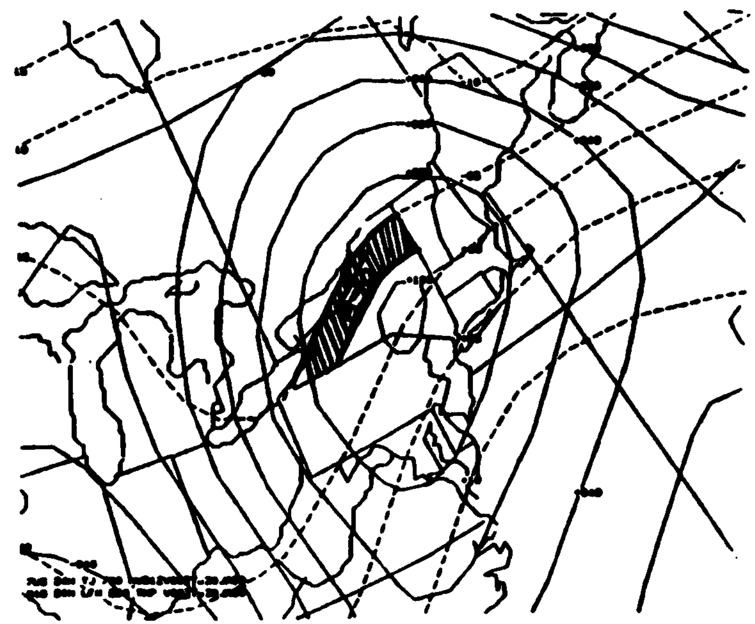
A. 12 hour NGM forecasted 850 mb temps (12z Jan 29) with 24 hour 700 mb NVD forecast (00z Jan 30). Shows 850 mb temps at beginning of Magic Chart 12 hour forecast period.



B. NGM 24 hour mean RH forecast for Monday evening 00z January 30, 1990.



C. Magic Chart using 24 hour NGM forecasted 850 mb temps for Monday evening 00z January 30, 1990.



D. Magic Chart using 24 hour LFM forecasted 850 mb temps for Monday evening 00z Jan 30, 1990.

FIGURE 4

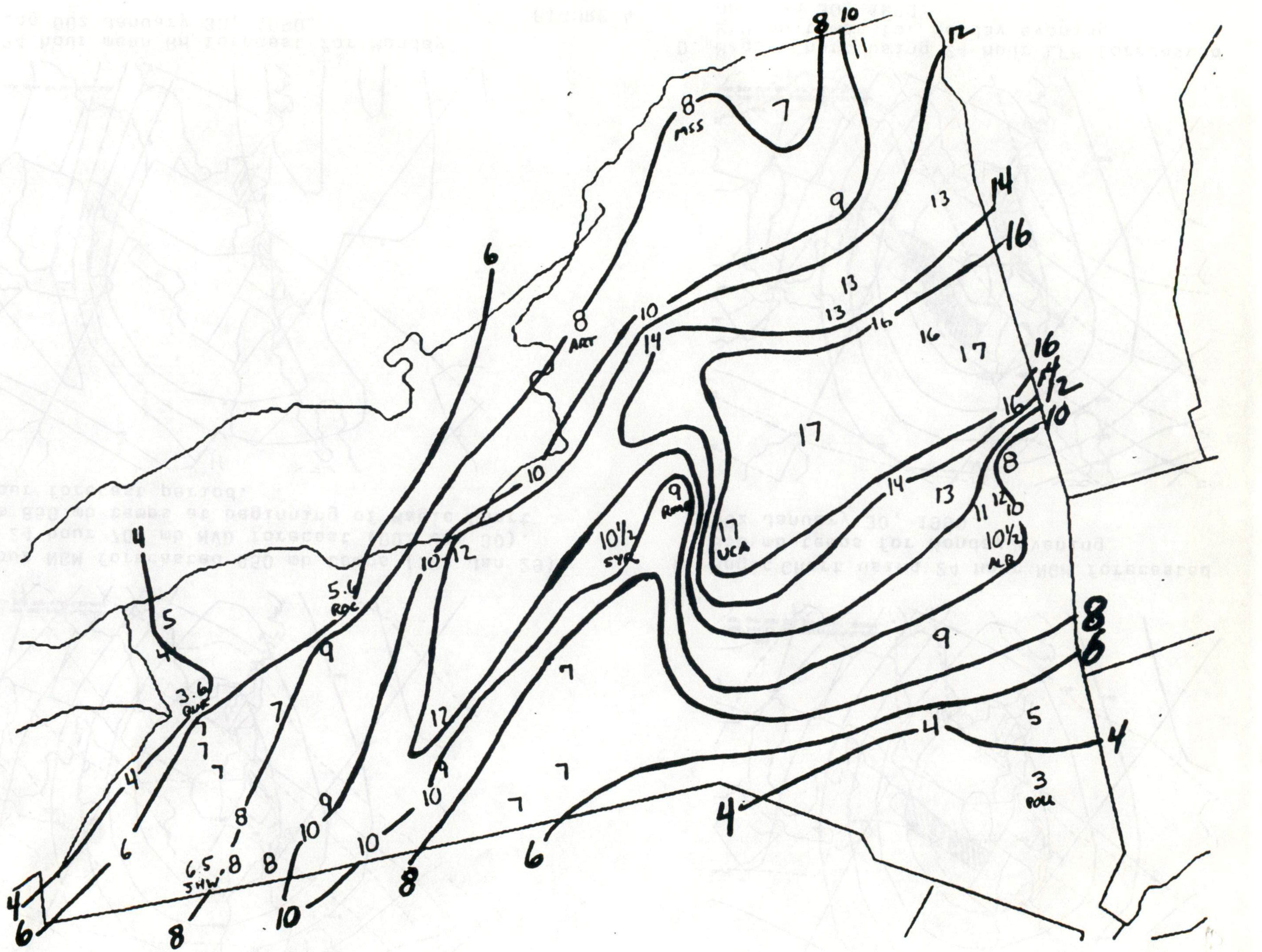


Figure 5 - Snowfall Amounts - Storm Totals from Monday Afternoon January 29, 1990 through Tuesday Morning January 30, 1990.