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AN ANALYSIS OF THE SOUTHEAST IOWA--WEST CENTRAL ILLINOIS SNOW EVENT OF 10 DECEMBER 1989

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1. Introduction

During the late afternoon and evening of December 10, 1989, a narrow band of snow developed from near Ottumwa, Iowa (OTM) to Peoria, Illinois (PIA). Snowfall accumulations in this band averaged about four inches (Fig. 1). Nearly five inches fell in a 12-hour period at the National Weather Service (NWS) Office at PIA. The heaviest snow occurred between 0000 UTC and 0450 UTC December 11, when the rate of snowfall reached one inch per hour.

Snowfall of this magnitude is a relatively rare occurrence in PIA. During the ten previous years, PIA recorded only six snowfalls of equal or greater magnitude. Because initial snowfall forecasts were too low, the event had a much greater impact on the public than a five inch snowfall normally has for this part of the Midwest. This paper will examine the synoptic scale weather pattern associated with the snow event, and discuss important forecast parameters which may have been overlooked.

2. Synoptic Overview

At 0000 UTC December 11, 1989, a weak area of low pressure was located over extreme north-central Arkansas (Fig. 2a). The boundary layer (BL) winds indicated a cyclonic circulation over the same general area (Fig. 2b). Note the impressive cyclonic turning of the BL winds from the Ohio Valley to West Central Illinois. An inverted low pressure trough extended northeast from the Arkansas low across southern Illinois to southern Michigan. Winds north of the trough were generally north to northeast at 10 to 15 knots, while winds south of the trough were southerly at 5 to 10 knots. Mean sea level pressures were steady or rising in the vicinity of the low and trough. A cold front extended southwest

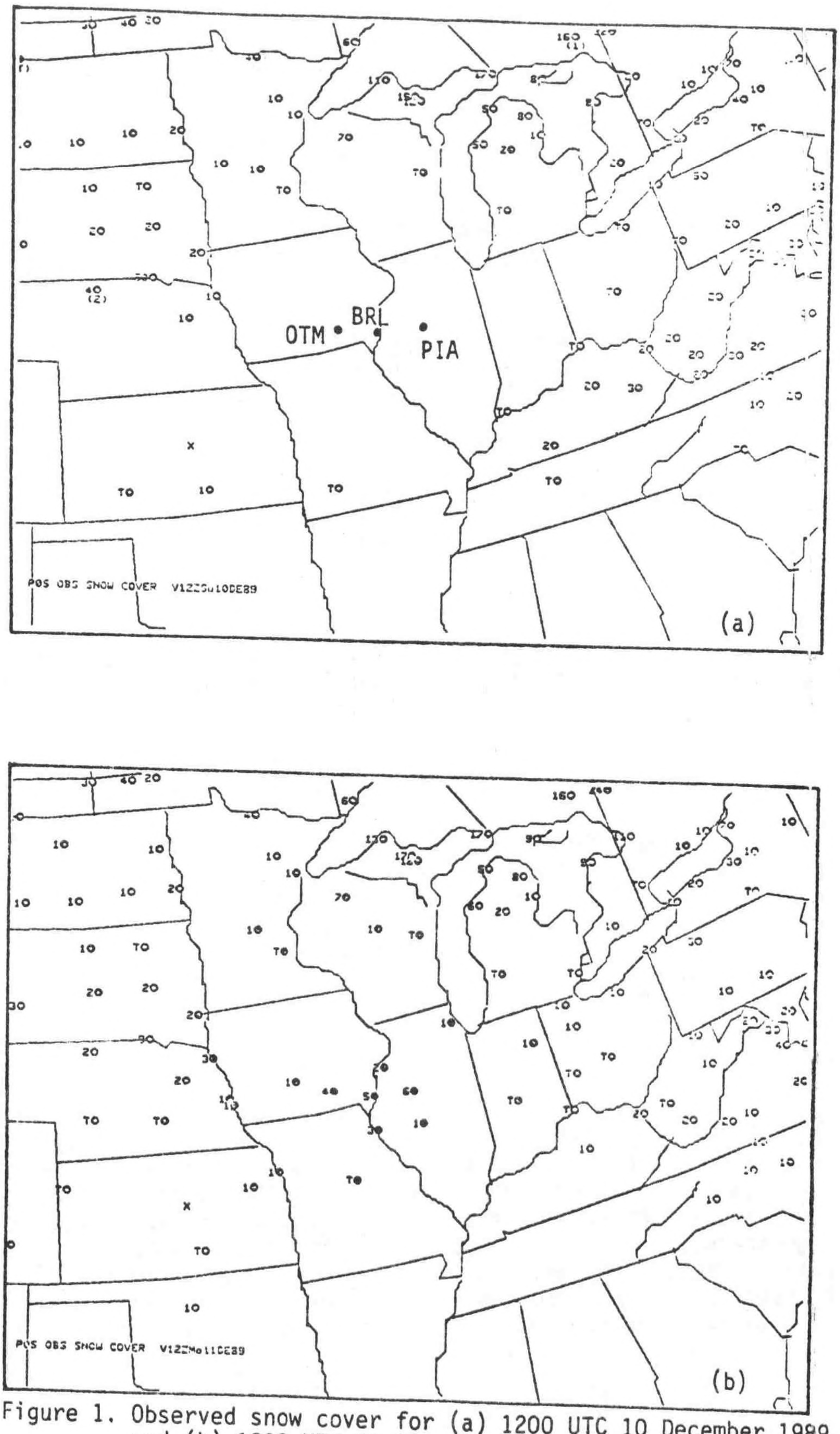

Figure 1. Observed snow cover for (a) 1200 UTC 10 December 1989, and (b) 1200 UTC 11 December 1989.

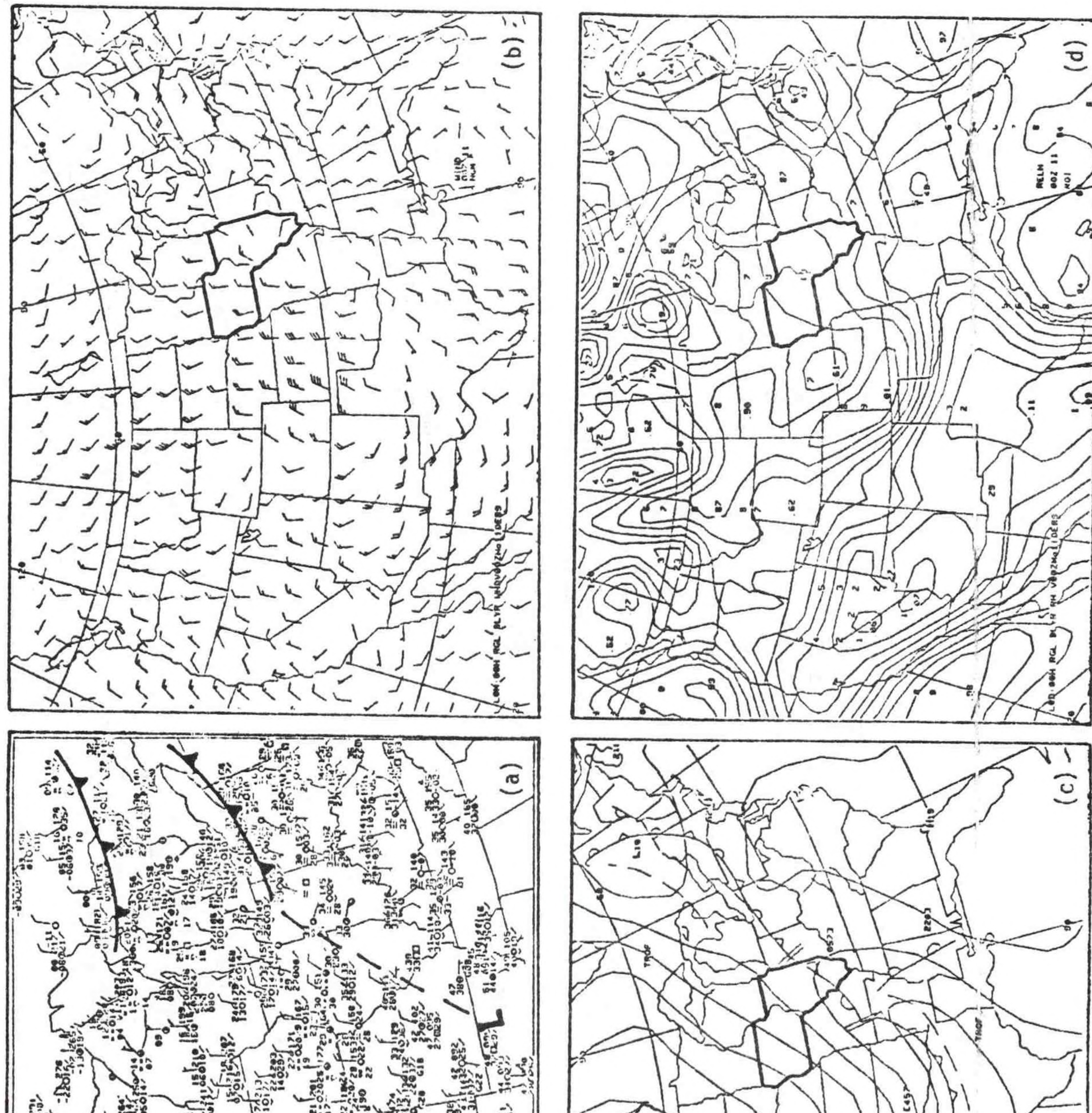

Figure 2. Low-level features at 0000 UTC 11 December 1989: (a) Midwest surface plot, (b) U.S. boundary layer winds, (c) U.S. surface analysis, and (d) U.S. boundary layer relative humidity.

from the low in Arkansas to low pressure over west-central Texas. Note that the Texas low was forecast to intensify and track east-northeast across central Arkansas on December 11.

A narrow band of moderate snow was being reported from extreme north-central Missouri to west-central Illinois at 0000 UTC. Marseilles, Illinois (MMO) radar (not shown) indicated precipitation tops to 9,000 feet near PIA at the time of heaviest snow.

Figure 2d shows the NGM analysis of boundary layer relative humidity at 0000 UTC December 11. A west to east ribbon of RH in excess of 80 percent extended from northern Missouri to western Pennsylvania.

The 0000 UTC December 11 850 mb analysis revealed a positively tilted trough located east of the region of snow (Fig. 3). The trough axis extended from northern Indiana to south-central Illinois. The upper portion of the cold front is evident at 850 mb, extending southwest from the 850 mb low in Missouri. A 35 knot jet maximum was positioned east of the 850 mb cold front from north-east Texas through Arkansas. Eastern Iowa and west-central Illinois were under the influence of cold air advection at 850 mb. The 850 mb temperature at PIA was -4^{o}C, having fallen six degrees during the previous 12 hours.

Weak cold air advection was also present at 700 mb (Fig. 4) at 0000 UTC December 11 over the area of snow. A positively tilted shortwave extended from central Wisconsin to northern New Mexico. Height falls of 30 to 40 meters were located along and ahead of the trough axis. The area of strongest winds, reaching 50 knots, extended from the Southern Plains to the Ohio Valley.

Figure 5a shows the 500 mb analysis at 0000 UTC December 11. A positively tilted shortwave axis extended from extreme western Minnesota to southern Colorado, about 200 miles west of the 700 mb shortwave axis. Height falls of 60 to 80 meters were found just east of the trough in the east-central Plains. The Nested Grid Model (NGM) 500 mb analysis of heights and vorticity indicated a positive vorticity maximum ("vort-max") over north-central Kansas (Fig. 5b). Weak positive vorticity advection (PVA) was occurring over eastern Iowa and west-central Illinois during the snow event. A vorticity lobe extended east from the Kansas vort-max across southern Illinois, just south of the area of heaviest snowfall. Note, too, the relatively strong positive isothermal vorticity advection (PIVA) which was occurring in the same region (Fig. 5c).

The NGM analysis of the 1000-500 mb thickness at 0000 UTC indicated values ranging from 5280-5340 meters across the snow event region (solid lines in Fig. 5c). Also, thickness diffluence was present in the region.

An isotach analysis of the 250 mb winds at 0000 UTC is shown in Fig. 6. A 140 knot speed maximum extended from northeast Kansas across north-central Missouri to west-central Illinois.

The 0000 UTC December 11 radiosonde observation (RAOB) at PIA (Fig. 7) revealed a saturated environment from the surface to 400 mb. Note the impressive (for early December) precipitable water total of 0.45 of an inch. The 0000

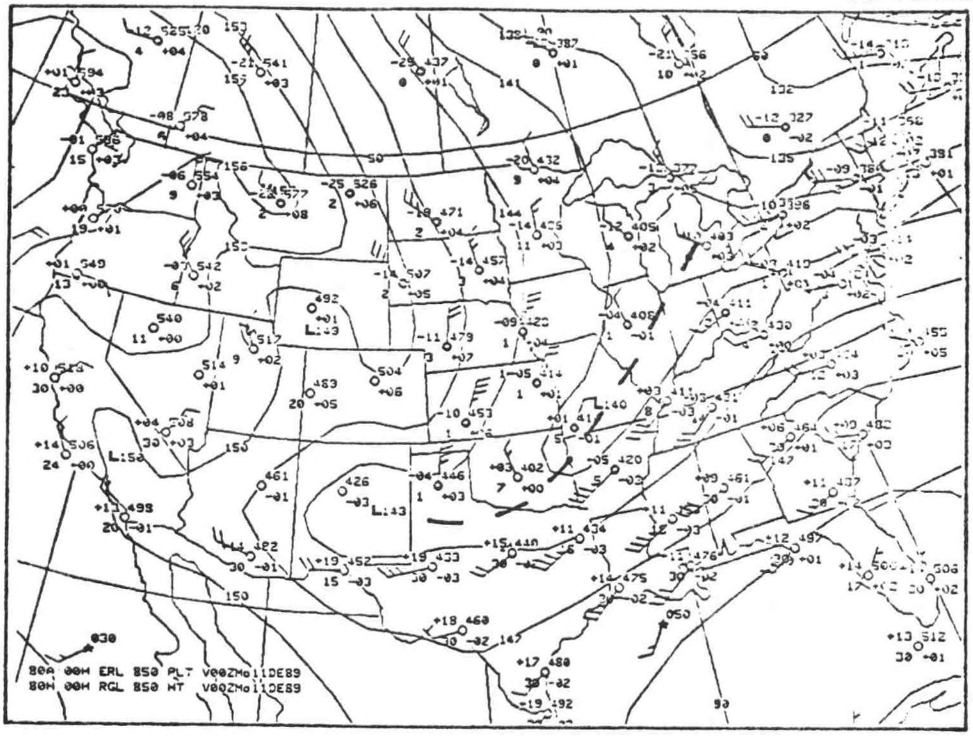

Figure 3. 850 mb analysis at 0000 UTC 11 December 1989. Solid lines are height contours. Dashed line is trough axis.

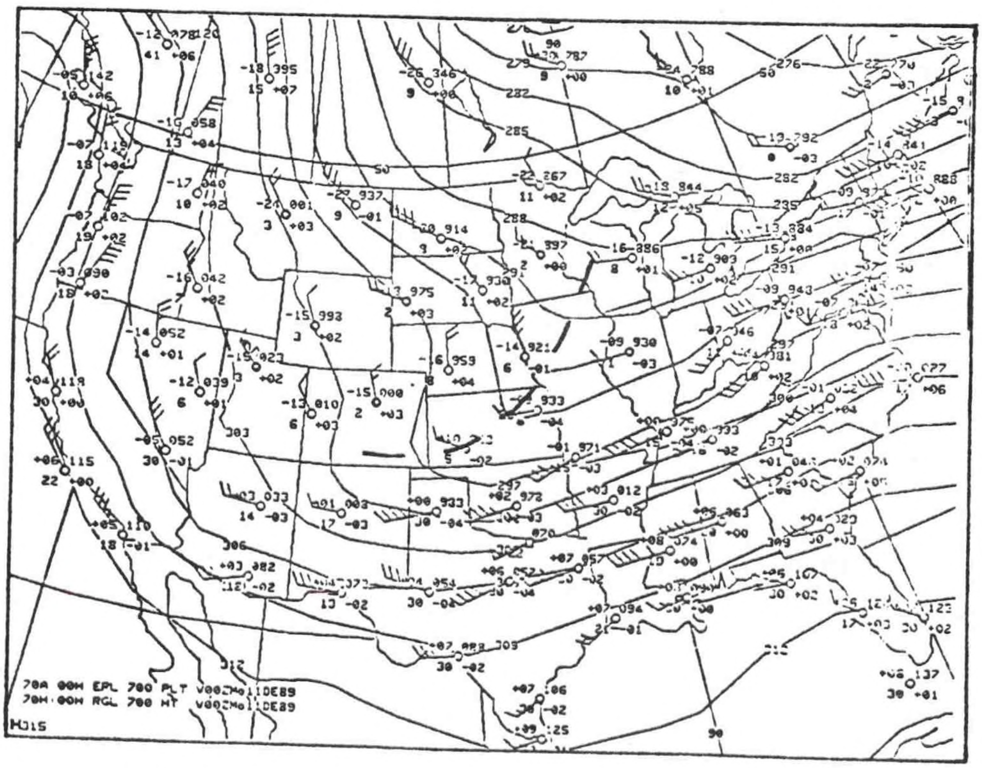

Figure 4. As in Figure 3, except at 700 mb.

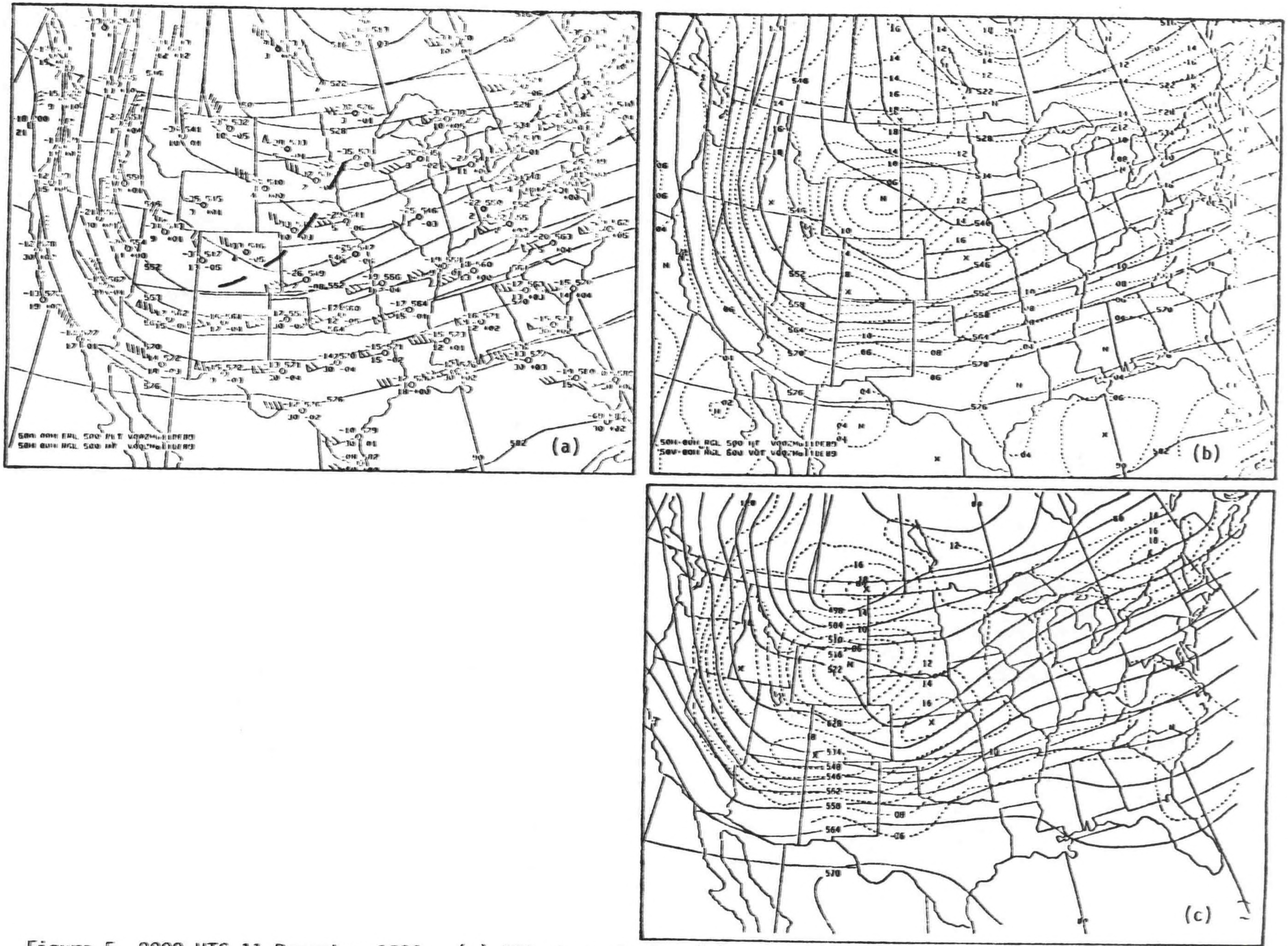

Figure 5. 0000 UTC 11 December 1989: (a) 500 mb analysis, (b) 500 mb heights (solid lines) and vorticity, and (c) 1000-500 mb thickness (solid lines) and vorticity.

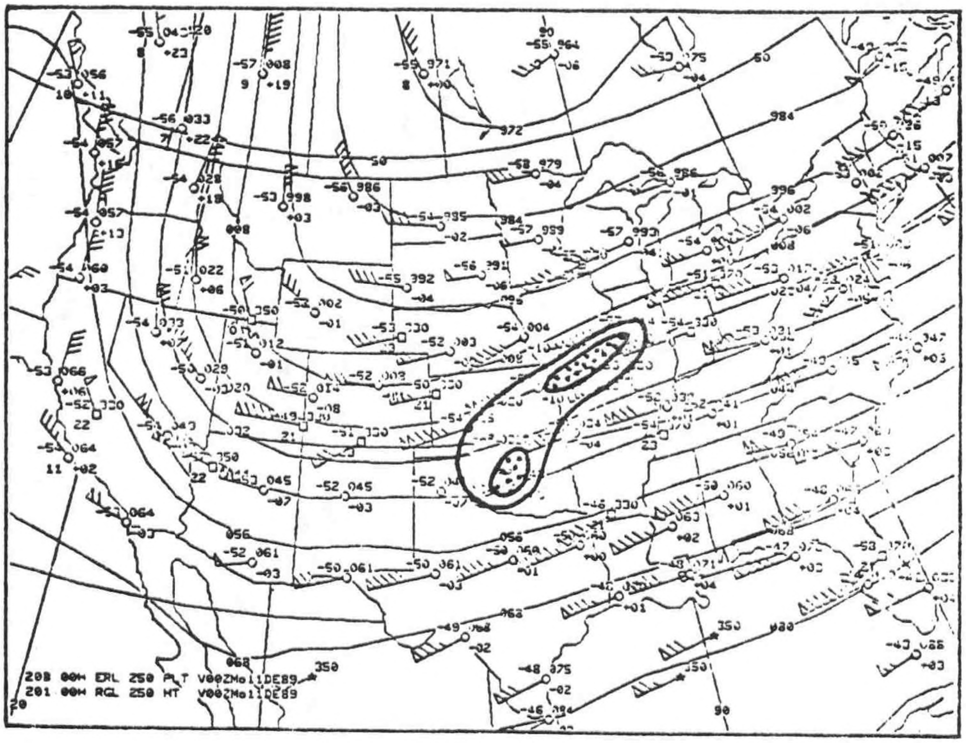

Figure 6. As in Figure 4, except at 250 mb. Area outlined denote winds in excess of 135 knots. Stippled region are winds of 140 knots or greater.

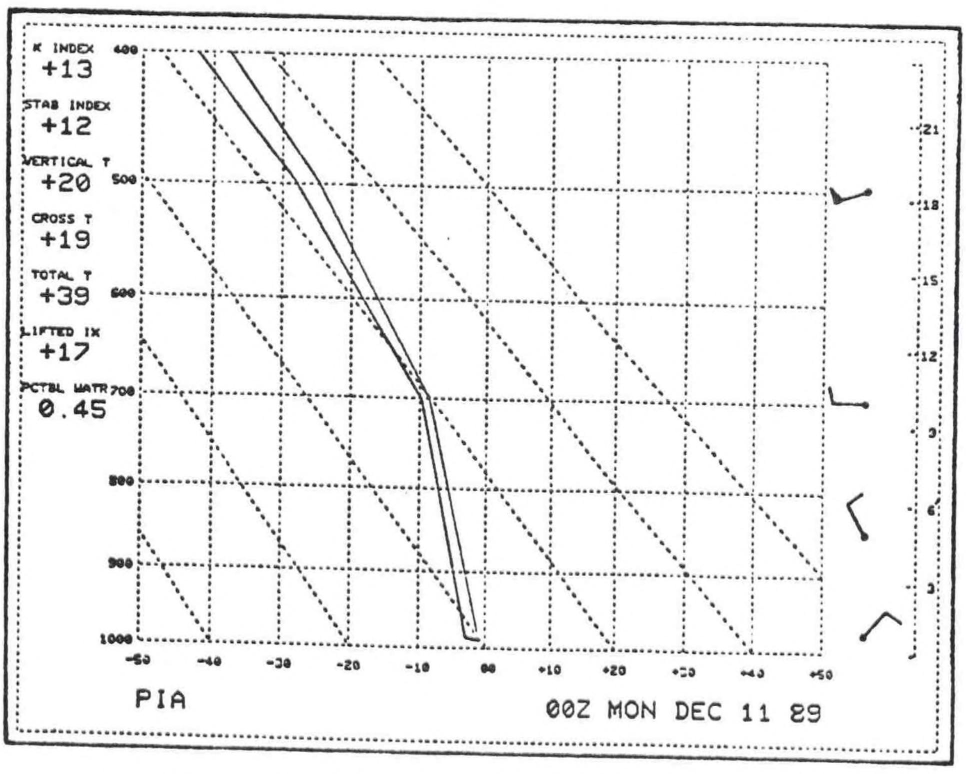

Figure 7. Plot of Peoria, Illinois (PIA) radiosonde observation from 0000 UTC 11 December 1989. Temperature and dew point are solid lines (degrees C).

UTC RAOB also displayed backing winds with height, from the surface to 500 mb, indicating cold air advection over central Illinois.

Finally, infrared satellite imagery (not shown here, nor available to the PIA NWS Office at the time of the snow event) revealed that the region receiving the moderate snow was under the southern edge of the coldest cloud tops. This region is typically associated with heavy precipitation.

3. Early Forecasts

The NWS Forecast Office at St. Louis, Missouri (STL) issued a Winter Storm Watch at 1000 UTC December 10. The watch covered southern Missouri and was in effect Monday, December 11. The NWS Forecast Office at Chicago, Illinois (CHI) also discussed the likelihood of snow for late on the 10th and on the 11th (local time) over much of Illinois. The 0000 UTC December 10 Limited-Area Fine Mesh Model (LFM) and NGM Output Statistics (MOS) for PIA both showed a probability of precipitation (PoP) greater than 50 percent for late on December 11 into December 12 local time. They also indicated the possibility of snow from the developing storm over Texas. Both models indicated that the low pressure area in Texas might develop into a winter storm.

Output from the 1200 UTC December 10 models appeared much less favorable for heavy snow over the watch area in Missouri. At the same time, however, the new LFM MOS PoP for PIA increased to 90 percent for the evening hours, local time, of December 10 (around 0000 UTC December 11), in response to a weak shortwave that was forecast to move east, ahead of the main trough. The increase in MOS PoPs was an obvious clue that snow was likely to move into western and central Illinois well ahead of the main system in the southwest U.S.

4. Discussion

Many of the meteorological parameters that produced the heavy snow that affected southeast Iowa and west-central Illinois were relatively subtle, and did not fall under the list of "classic" heavy snow indicators. Most noticeably absent was an organized low pressure center in the vicinity of the snow area. Upper level features were poorly organized as well. PVA was weak and moisture advection and low-level warm air advection were also limited. There were a few features, however, that played major roles and, working together, produced the heavy snow.

At 850 mb, a band of strong southwest winds from northeast Texas to southern Illinois were creating convergence near the Ohio Valley. This flow, however, was not advecting significant moisture into southern Iowa or central Illinois. Much of the moisture over the heavy snow region was already in place before the first flakes of snow fell. Warm air advection was non-existent over Iowa and Illinois. The 850 mb wind at PIA was north at 10 knots at 0000 UTC December 11, about two hours before the heaviest snow fell.

The "fanning" of the 1000-500 mb thickness pattern (Fig. 5c) over the mid-Mississippi Valley and Midwest implies upper level diffluence, and is an area favorable for heavy precipitation. In fact, diffluence at 250 mb is seen in the same region in Figure 6; it is a good bet that upward synoptic scale vertical motion is occurring in this area.

Positive isothermal vorticity advection, or PIVA, played a key role in the snow event. PIVA was probably the best indicator of the potential for heavy snow. As shown by Trenborth (1978), synoptic scale ascent in the middle troposphere is proportional to the advection of cyclonic vorticity by the thermal wind. Operationally this can be approximated by superimposing the 500 mb vorticity and 1000-500 mb thickness fields (Sangster, 1980). A look at Fig. 5c reveals the PIVA occurring over the area of heaviest snow. Durran and Snellman (1987) demonstrated that this approach gives a good approximation to the total forcing found by evaluating quasi-geostrophic vertical velocity numerically (e.g., the "Q-vector" method).

Another feature that had a major impact on the snow event was the 250 mb jet-maximum. Figure 6 shows a 140 knot jetlet extending from northeast Kansas to west-central Illinois. The area of heaviest snowfall was under the left front quadrant of this jetlet. This quadrant of a jet max is associated with upper level mass divergence, and complemented by upward lower tropospheric vertical velocities (Uccellini and Johnson, 1979).

5. Summary and Conclusions

The December 10-11, 1989 snow event which occurred in southeast Iowa and west-central Illinois would not have been considered a "major snowstorm" worthy of an analysis in most Midwest locations. However, climatologically, 24-hour snowfalls greater than five inches are rare in Peoria, occurring on the average only once every two years. Adding to the significance (and traveller's inconvenience) was that the amount of snow was not forecast prior to its onset. An analysis of the data revealed the lack of an organized synoptic scale surface low pressure, and other classic heavy snow signatures (e.g., closed 850 mb low, 700 mb warm air advection, strong PVA, etc.).

Through the use of synoptic scale analysis and a few basic principles of dynamic meteorology, though, it has been shown that there are other important factors that need to be considered as signatures of significant snowfalls. Two such factors played important roles in the development of this snow event. The combination of PIVA and the location of the left front quadrant of the 250 mb jet max both contributed to the development and persistence of the snow.

As an aside, it should be noted that the snow cover that resulted from the event was an important contributor to the longevity and severity of the record cold wave that affected central Illinois shortly afterward.

6. Acknowledgments

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7. References

Durran, D. R. and L. W. Snellman, 1987: The diagnosis of synoptic scale vertical motion in an operational environment. Wea. and Forecasting, 2, 17-31.

Sangster, Wayne E., 1980: A new concept in diagnosing large scale vertical motion. National Weather Service Central Region Technical Attachment 80-20. Available from NWS Central Region, Scientific Services Division, Kansas City, MO.

Trenborth, K. E., 1978: On the interpretation of the diagnostic quasi-geostrophic omega equation. Mon. Wea. Rev., 106, 131-137.

Uccellini, L. W. and D. E. Johnson, 1979: The coupling of upper and lower tropospheric jet streaks and implications for the development of severe convective storms. Mon. Wea. Rev., 107, 682-703.