NOAA TECHNICAL MEMORANDUM NWS CR-106

The Use of Profiler Data for Analysis and NOWcasting of a Winter Season Extratropical Cyclone

Bradley S. Small
National Weather Service Forecast Office
St. Louis, Missouri

June 1994

U.S DEPARTMENT OF Commerce / National Oceanic and Atmospheric Administration / National Weather Service

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UNITED STATES DEPARTMENT OF COMMERCE
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Under Secretary

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THE USE OF PROFILER DATA FOR ANALYSIS AND NOWCASTING OF A WINTER SEASON EXTRATROPICAL CYCLONE

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1. INTRODUCTION

In the early 1990's, an experimental network of wind profilers was deployed across the central United States. Base profiler data in the form of time-height cross sections and standard pressure plan views have been available to the Weather Service Forecast Office (WSFO) St. Louis staff since late in 1991. In addition to the base data, derived products are now also included in the forecast office database. Wind profiler information is currently run automatically by Watchdog on AFOS every three hours and can be activated manually every hour if the forecaster desires.

Since the entire profiler network has not been established until recently, relatively few papers have been published utilizing profiler data. Most of them have focused on winter season events near the initial sites in Colorado regarding deformation zones and the development of upslope flow (Colman, 1989; Dunn, 1992; Thaler, 1989). This paper will describe the evolution of a winter storm which produced between three and six inches of snow from central Oklahoma to central Illinois. Specifically, it will be shown how profiler data is used to 1) diagnose several meteorological processes during the evolution of a winter storm event and 2) aid the forecaster in producing a short-term forecast or NOWcast.

Features discussed will include jet streak formation, the advection of cold air through the depth of the atmosphere, conveyer belt circulations and a significant overrunning episode. Unfortunately, only a limited number of profilers in the current network were available for examination at the time of the event. The sites of Conway (CNW) and Lathrop (LTH), Missouri; Haskell (HKL) and Purcell (PRC), Oklahoma; and DeQueen (DQU), Arkansas will be used in the data analyses (Figure 1).

2. INITIAL CONDITIONS

On the morning of January 13, 1992 at 1200 UTC a trough was positioned throughout the depth of the atmosphere. In the lower levels the trough axis at 850 mb extended from eastern Wisconsin to north central Texas. Utilizing only the 850 mb wind data, little evidence is given to support a closed circulation. The wind field appeared to be parallel to the axis at this level with no southerly component (Figure 2).

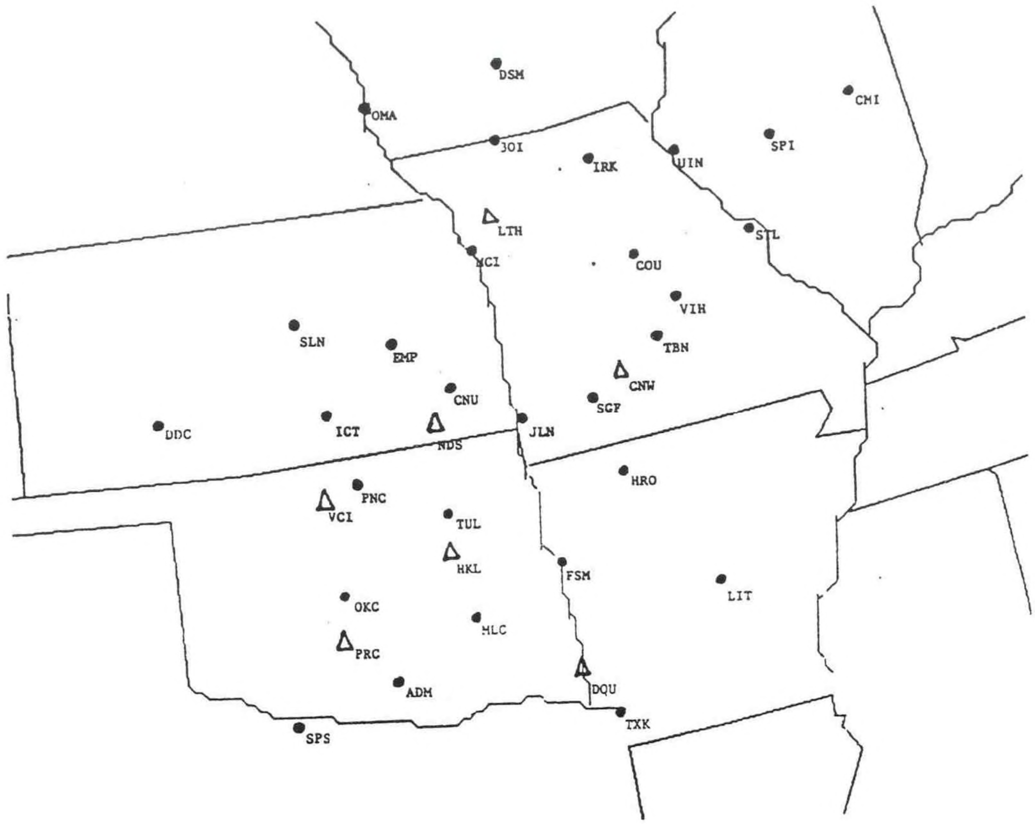

Figure 1. Map of profiler sities operational in January 1992 and selected surface observation locations.

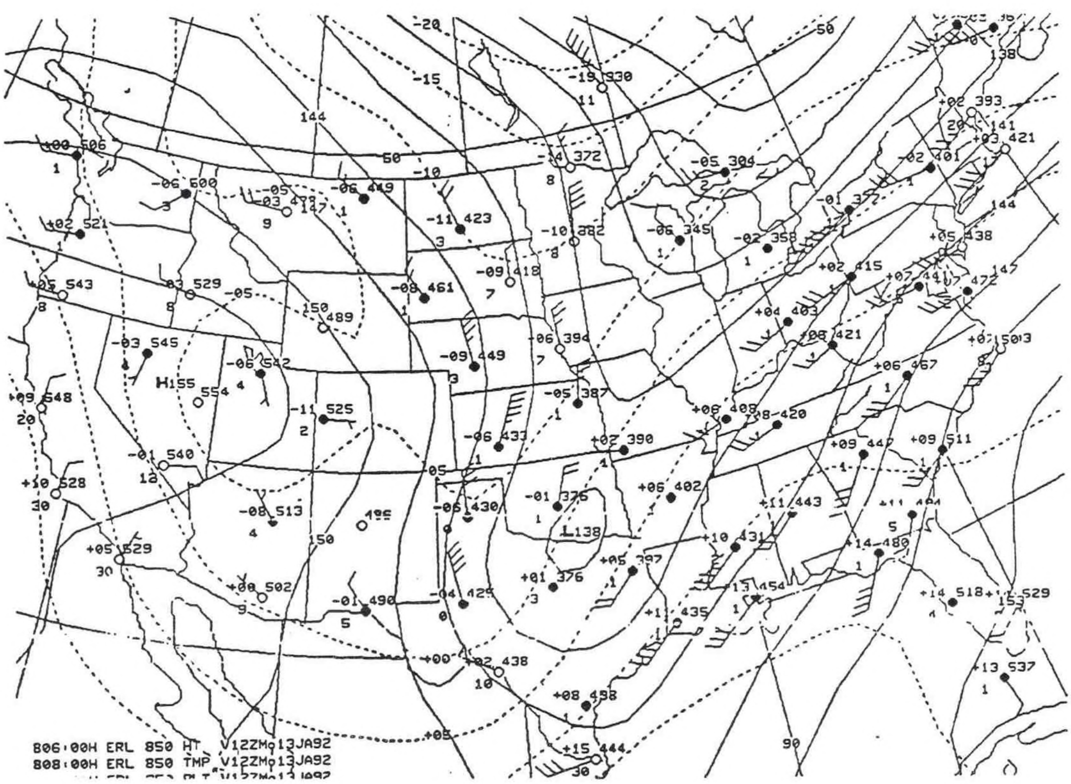

Figure 2. 850 mb plot from January 13, 1992 at 1200 UTC.

Although the 700 mb analysis suggested the presence of a closed circulation over north central Texas, surrounding wind data revealed no indications of a strong southerly component. Except for a light southeast wind at Oklahoma City, Oklahoma, the wind field was generally parallel to the trough axis at this level also (Figure 3).

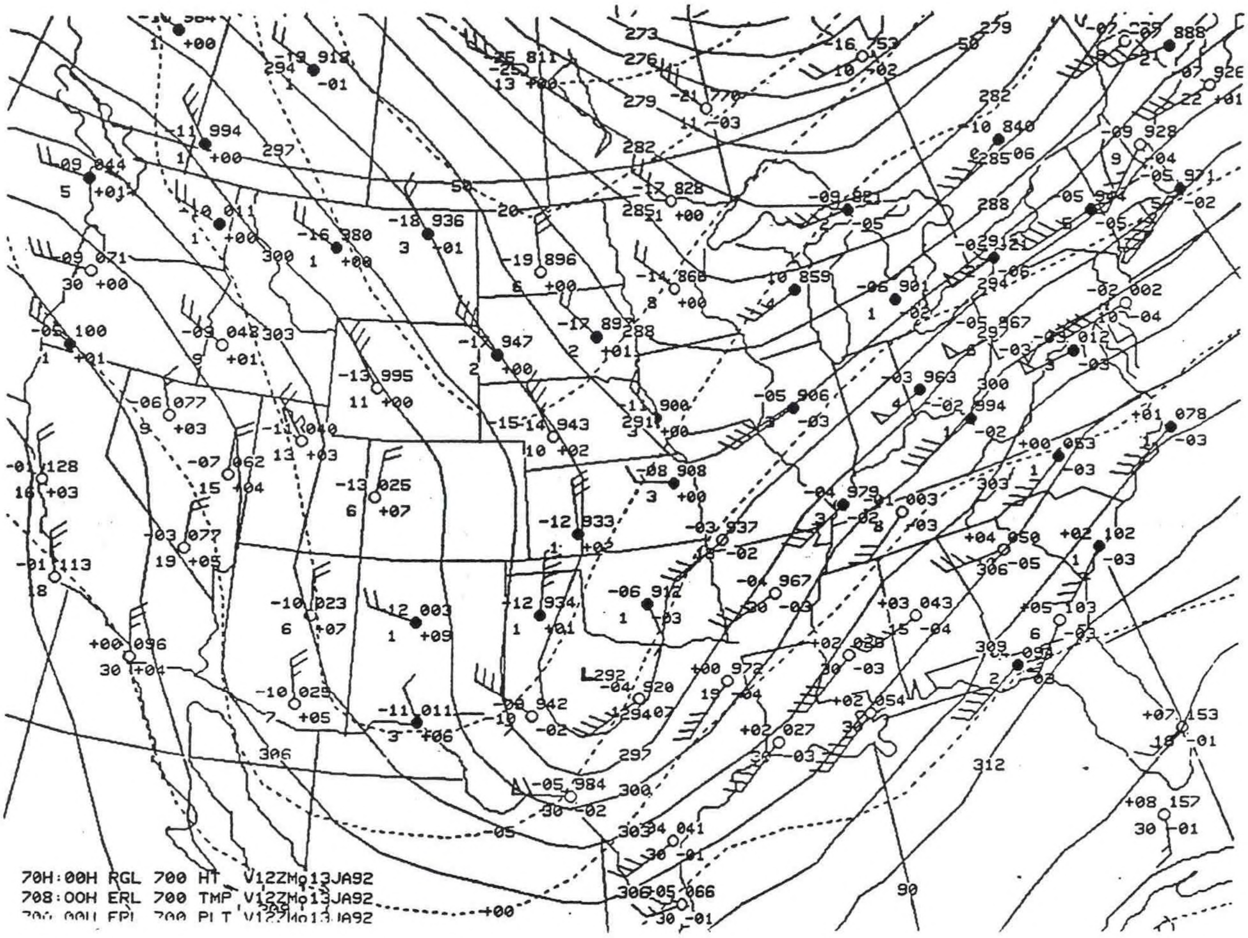

Figure 3. 700 mb plot from January 13, 1992 at 1200 UTC.

At 500 mb, the trough axis extended from central Nebraska to just east of Amarillo, Texas (Figure 4). Two areas of relatively strong flow were occurring ahead of and behind the trough. The strongest and most significant winds stretched from southeast New Mexico, around the base of the trough, and farther northeastward across New England. Wind speeds of greater than 50 knots were common in the wind field, with a 70 knot wind maximum in Texas as indicated by the soundings at Longview and Stephenville.

The 300 mb jet axis of at least 75 knots was positioned from the base of the trough to New England (Figure 5). The 300 mb trough axis was oriented north to south and was centered near Midland, Texas. Several local speed maxima of at least 100 knots were noted with the strongest from Peoria, Illinois to the Atlantic coast off New York.

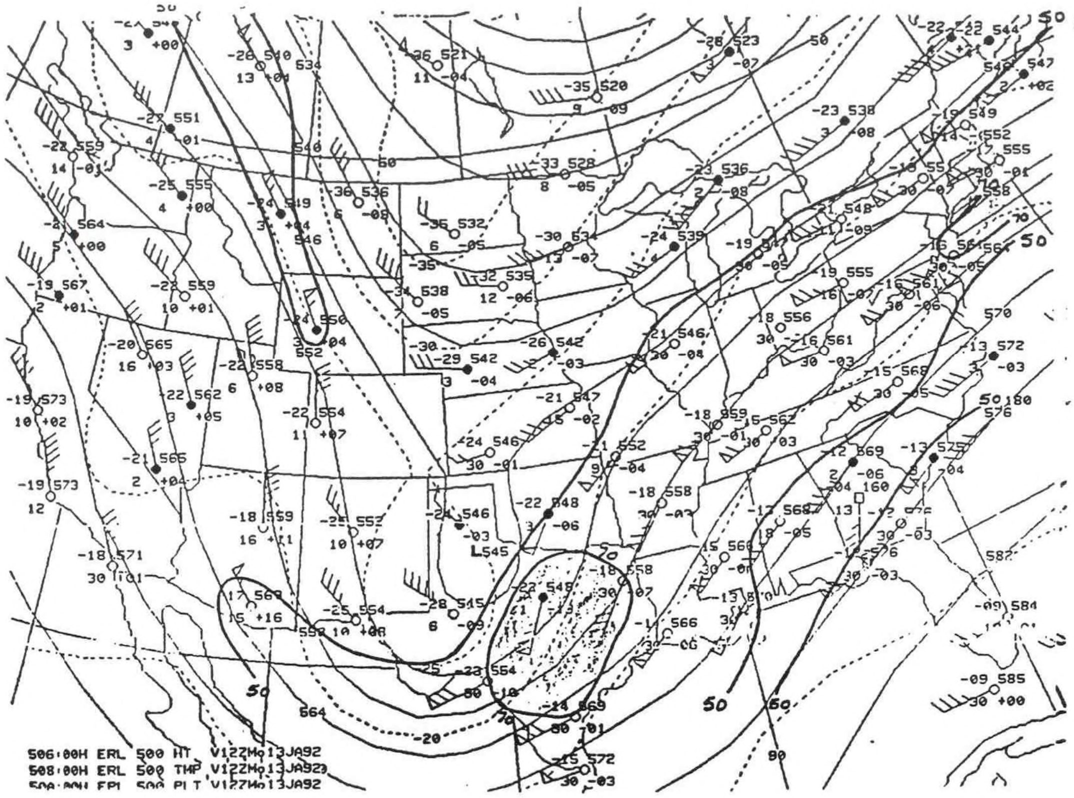

Figure 4. 500 mb plot and isotachs from January 13, 1992

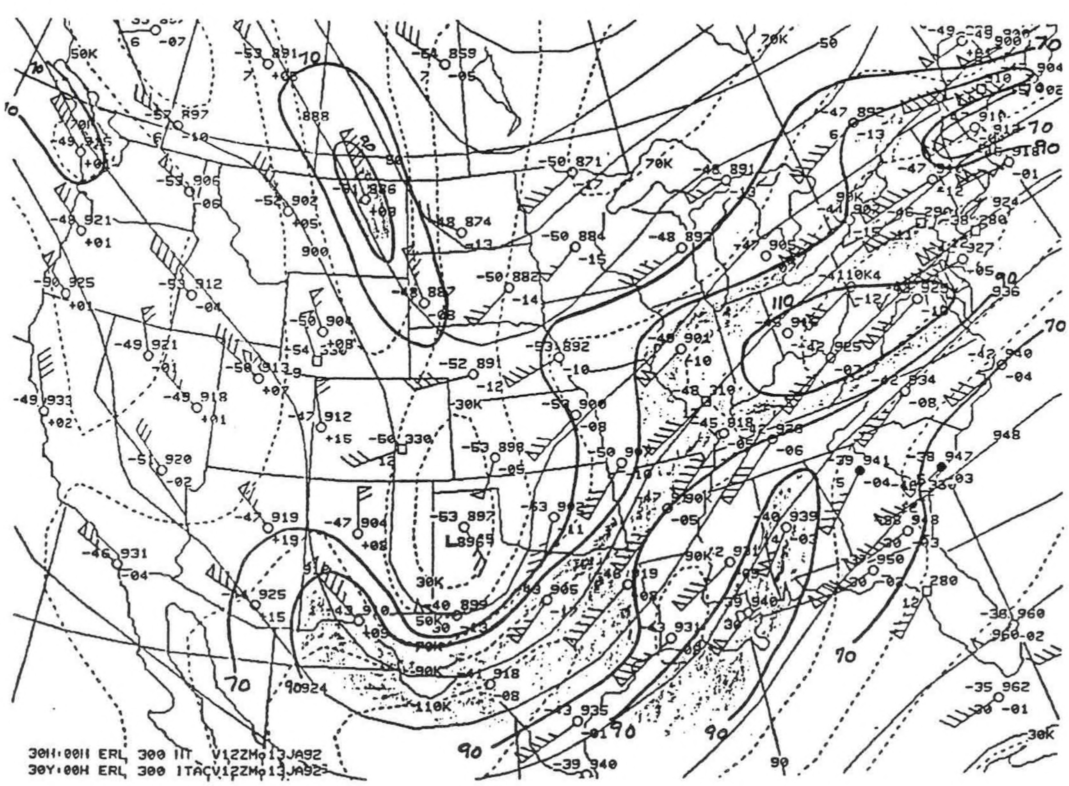

Figure 5. 300 mb plot and isotachs from January 13,, 1992 at 1200 UTC.

The operational profiler data available during the event were comparable to most of the conventional upper air wind data. The jet streak structure identified at mid- and upper-levels was quite similar on both sounding and profiler data sets. The time-height profiler cross sections at HKL, CNW and DQU (Figures 6, 7 and 8) at 1200 UTC all revealed at least a 50 knot flow at 500 mb. In the mid- and lower-levels, both HKL and LTH showed the intrusion of cold air reaching a depth of between 5000 - 6000 ft. A moderate northerly flow at the lowest levels was already evident at both locations.

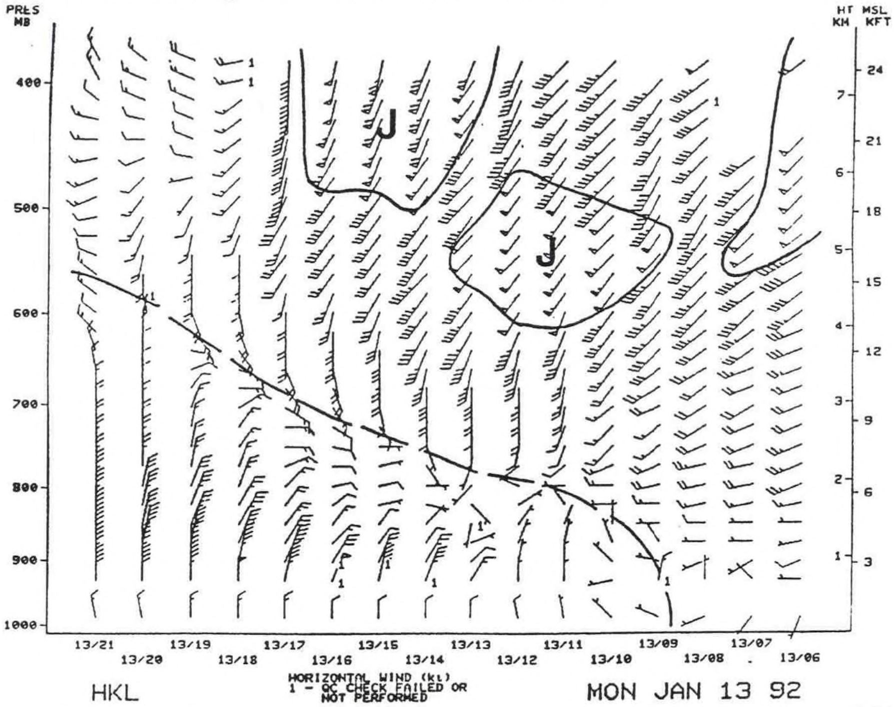

Figure 6. Time-height wind profiler cross-section from Haskell, Oklahoma (HKL).

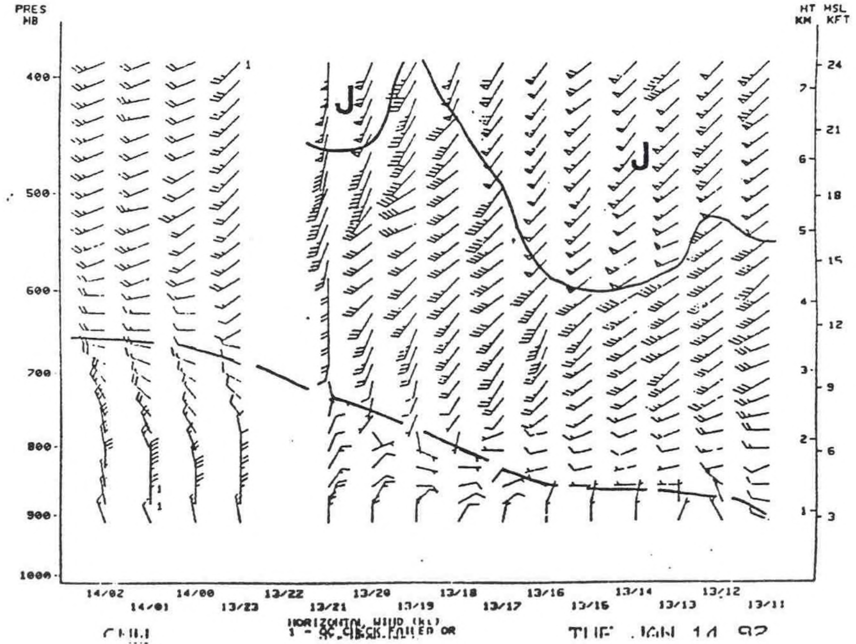

Figure 7. Time-height wind profiler cross-section from Conway. Missouri (CNW).

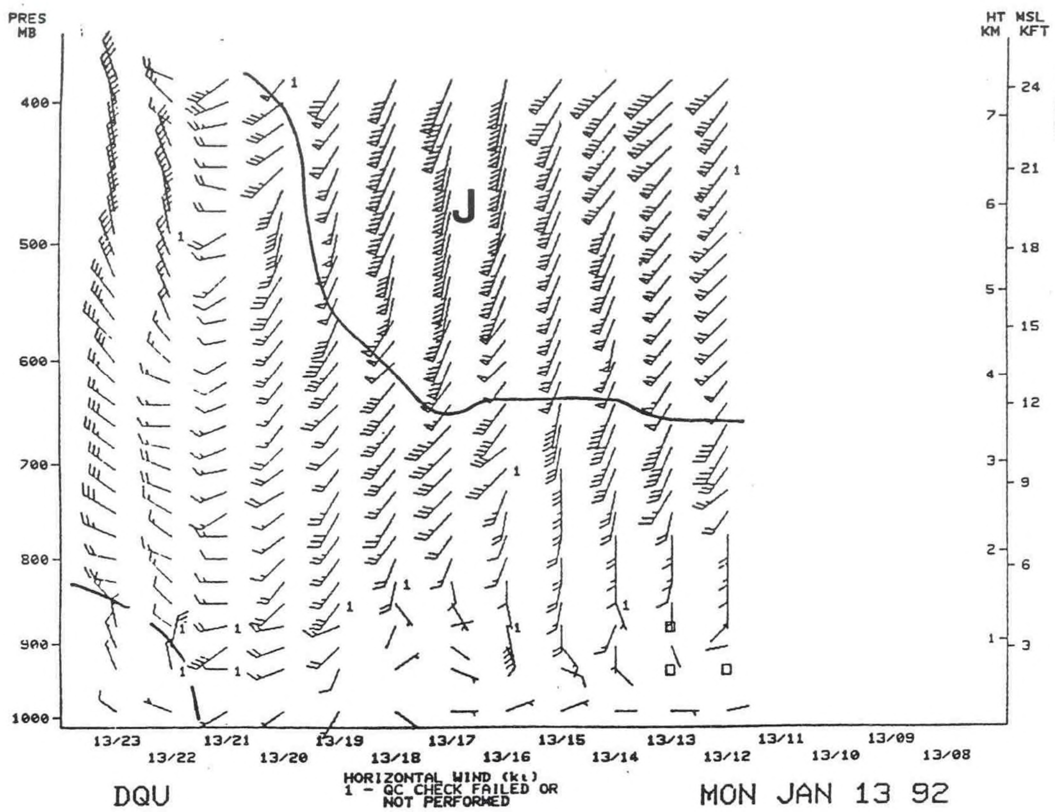

Figure 8. Time-height wind profiler cross-section from DeQueen, Arkansas (DQU).

Two possible conveyer belt structures were revealed by the profiler data. At HKL a weak cold conveyer belt was visible at 6000 ft around 1400 UTC with very light easterly flow. Above the light east wind, a strong warm conveyer belt was present. This was not reflected well in the conventional data and showed how wind profilers can identify atmospheric features that might otherwise go undetected. The wind speed quickly increased to 30 knots from the south suggesting a strong warm advection pattern (Figure 6). Rapid directional shear or veering at PRC also supported the warm advection with a wind direction change from around 40 to 160 degrees in only a few hundred feet in the vertical (Figure 9). Data from these two sites indicated the presence of strong warm advection above 720 mb from central Oklahoma through southwest Missouri. This type of conveyer belt structure appeared to be similar to a warm conveyer belt described by Browning (1986).

3. STORM EVOLUTION

During the morning hours from 1200 UTC to 1500 UTC, the profiler data indicated that the cold air depth had increased across parts of Oklahoma at PRC and HKL about a thousand feet (Figures 9 and 6). However, the cold air mass remained very shallow in central Missouri with no indication of deepening as shown by the CNW profiler site (Figure 7).

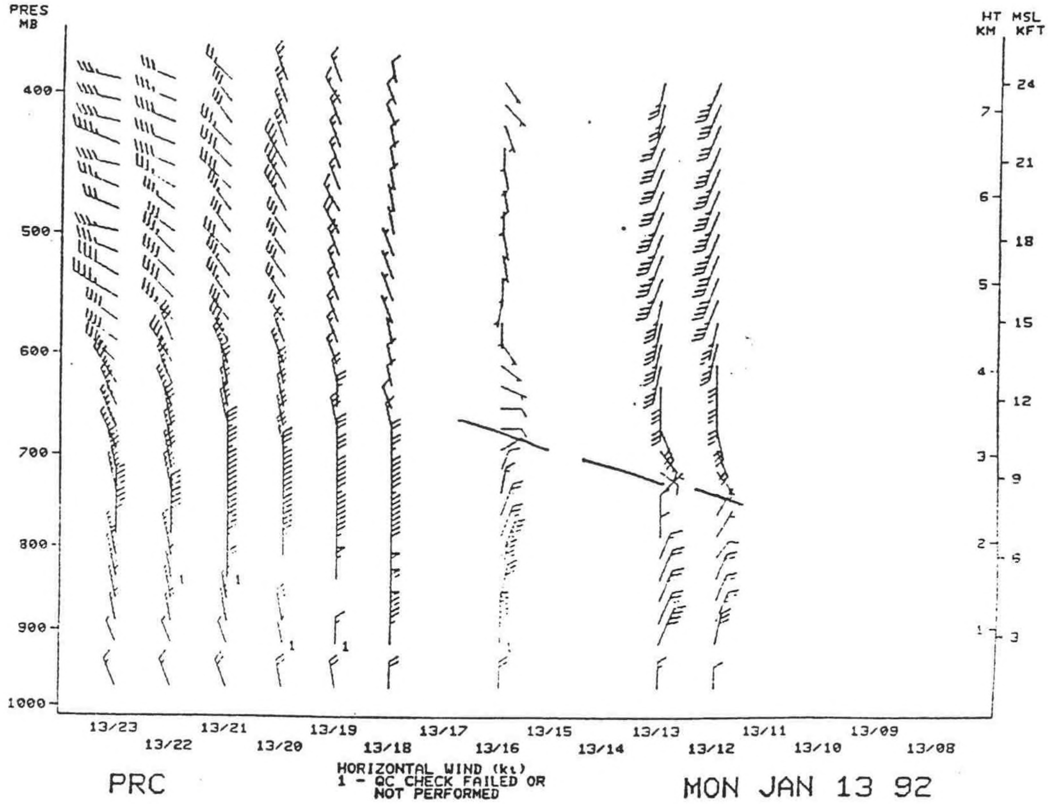

Figure 9. Time-height wind profiler cross-section from Purcell, Oklahoma (PRC).

The jet maximum that extended from the base of the trough through the New England states remained evident at both CNW and DQU (Figures 7 and 8). Both continued to show at least 50 knot winds from around 600 mb and higher throughout the period.

However, from 1200 to 1400 UTC, the 500 mb speed maximum that was positioned across central and eastern Texas seemed to move off to the south or east as the trough propagated eastward. Both CNW and DQU revealed the progression of the speed maximum during this period, while it was no longer visible at HKL. However, HKL revealed two separate and distinct jet streak features at 1300 UTC (Figures 6, 7 and 8). The earlier wind maximum was centered around 550 mb, while a second jet appeared close to 400 mb. From 1300 UTC to 1500 UTC this newly observed flow strengthened with backing winds in response to the approaching trough. The evolution of the second jet streak and its backing characteristic was a good illustration of how near real-time data can aid the forecaster in the identification of jet streaks.

At 1500 UTC, the surface map showed a quasi-stationary frontal boundary extending from a low pressure center in northeast Texas through central Arkansas, southeast Missouri into southern and east central Illinois (Figure 10). Light to moderate rain was falling along and south of a line from Macallister, Oklahoma (MLC); to Joplin, Missouri; (JLN) to Columbia, Missouri (COU). To the north and west of this area, light to moderate snow was occurring as far northwest as Chanute, Kansas and Enid, Oklahoma.

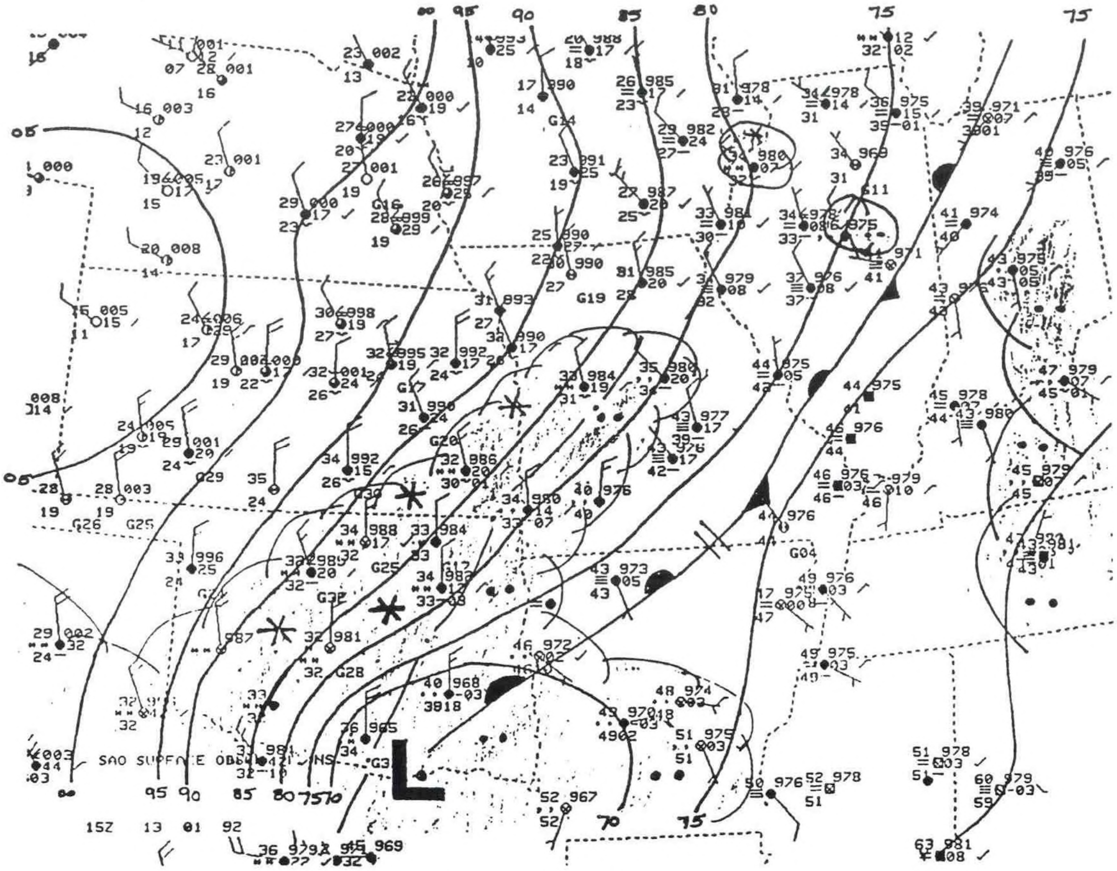

Figure 10. **Surface Analysis for January 13, 1992 at 1500 UTC.**

In addition to the conveyor belt structures identified earlier, the wind field at HKL between 2.5 and 4.5 km veered with height suggesting warm advection above the cold conveyor belt. This feature was initially identified at 1200 UTC and continued through 1700 UTC. Wind speeds up to 50 kts were present at or above 600 mb from 1200 UTC through 1400 UTC, possibly enhancing the vertical motion fields and snowfall rates from northeast Oklahoma through southwest Missouri (Figure 6).

Since PRC and HKL showed that cold air continued to deepen across central and eastern Oklahoma, the forecaster could expect a change to frozen precipitation at these locations in the near future (Figures 6 and 9). However, farther to the east over central Missouri, the CNW profiler indicated that between 1200 UTC and 1700 UTC the shallow layer of colder air did not deepen (Figure 7). The forecaster would not expect a change in precipitation type due to the absence of a deepening layer of colder air. Profiler data between 1100 UTC and 1600 UTC at HKL and PRC continued to reveal significant warm advection indicating that precipitation intensity would at least remain constant over much of Oklahoma and adjacent locations during the period.

Examination of the 1600 UTC surface analysis indicated that the use of profiler data to forecast timing of precipitation changeover was verifying. Near the Oklahoma profilers, temperatures had dropped 2 degrees from 1500 UTC to 1600 UTC at Ardmore, Oklahoma and MLC with a change to snow in extreme southwest Missouri near the Oklahoma border at JLN. However, over the same period in central Missouri where the cold air advection was weaker, conditions remained almost identical at COU and Fort Leonard Wood, Missouri (TBN). Temperatures remained the same with no change in precipitation type from 1500 UTC (Figure 10).

As the morning progressed from 1500 UTC to 1800 UTC, the low level cold air depth continued to deepen at LTH, PRC and HKL. After 1700 UTC, an increasing depth of the east-northeast flow, shown on the time-height cross-section at CNW, indicated that the cold air mass was gradually deepening (Figures 6,7 and 9).

The surface map at 1800 UTC (Figure 11) showed that the entire system was progressing and strengthening with a central low pressure falling at least 0.12 inches since 1500 UTC. At this time, the depth of the cold air had increased at all four of the profiler sites including CNW. The precipitation had switched to snow at COU, Springfield, Missouri and MLC at 1800 UTC.

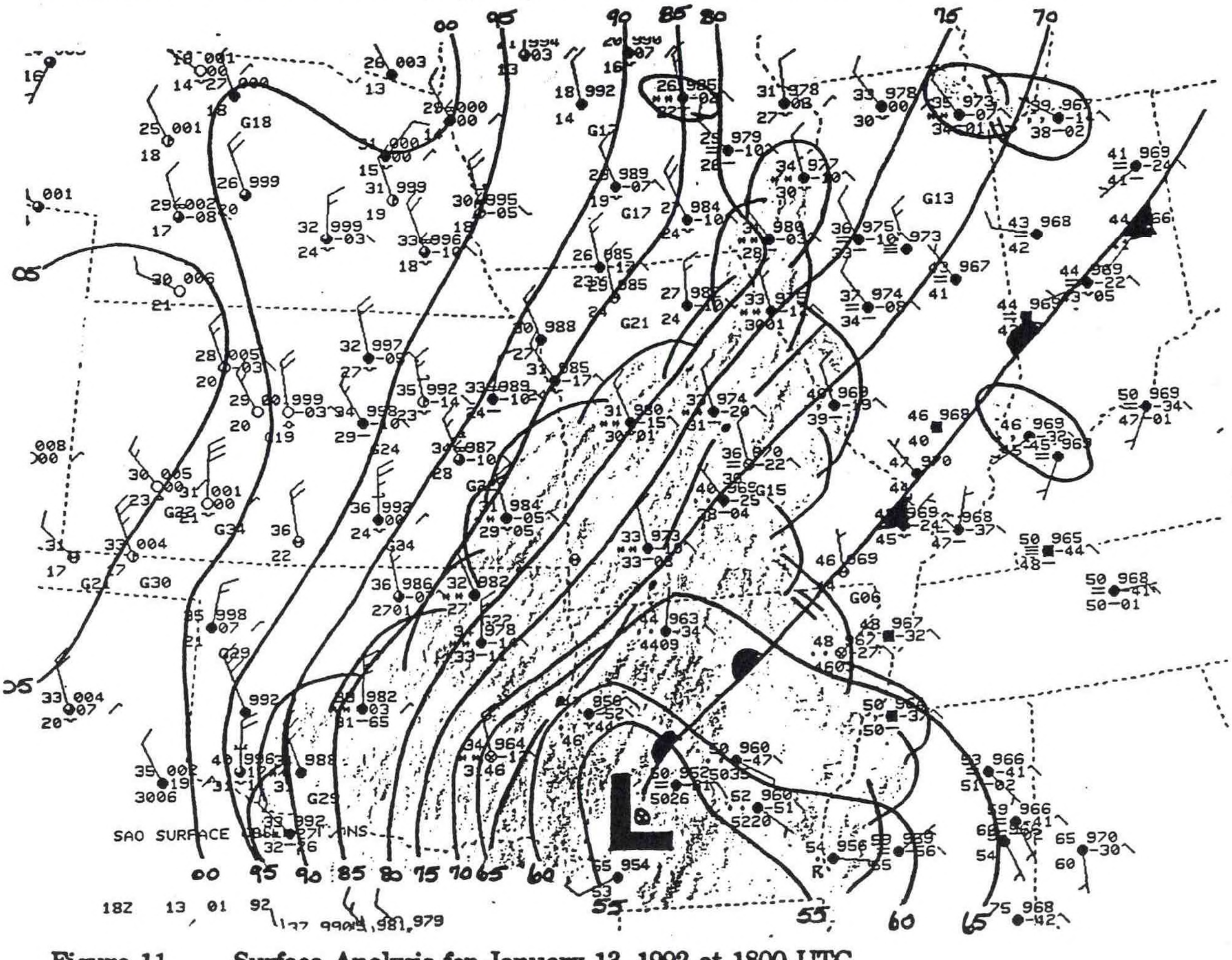

Figure 11. Surface Analysis for January 13, 1992 at 1800 UTC.

By the early afternoon, the jet maximum that appeared over the midwest near HKL between 1300 UTC and 1600 UTC had strengthened and was now observed over CNW after 1900 UTC (Figure 7). Between 1800 UTC and 2100 UTC, the entrance region of the jet and trailing trough axis had moved from eastern Oklahoma to a position in central Missouri. The 300 mb plan view at 2000 UTC displayed these features very well with a 90 knot jet over Missouri (CNW,LTH) and only a 15 kt flow at HKL (Figure 12). It was also apparent that the warm conveyer belt and warm advection pattern continued above 750 mb after examining both CNW and HKL during this period. After diagnosing the mesoscale airflow structures in the profiler data, a forecaster would expect both the warm advection and right rear quadrant of the advancing jet streak to enhance vertical velocities in the area below the entrance region. Additionally, the presence of a thermally direct circulation near the entrance region of the upper level jet streak would have further aided in the deepening of the cold air over parts of southwest and south central Missouri similar to observations documented by Uccellini and Kocin (1987).

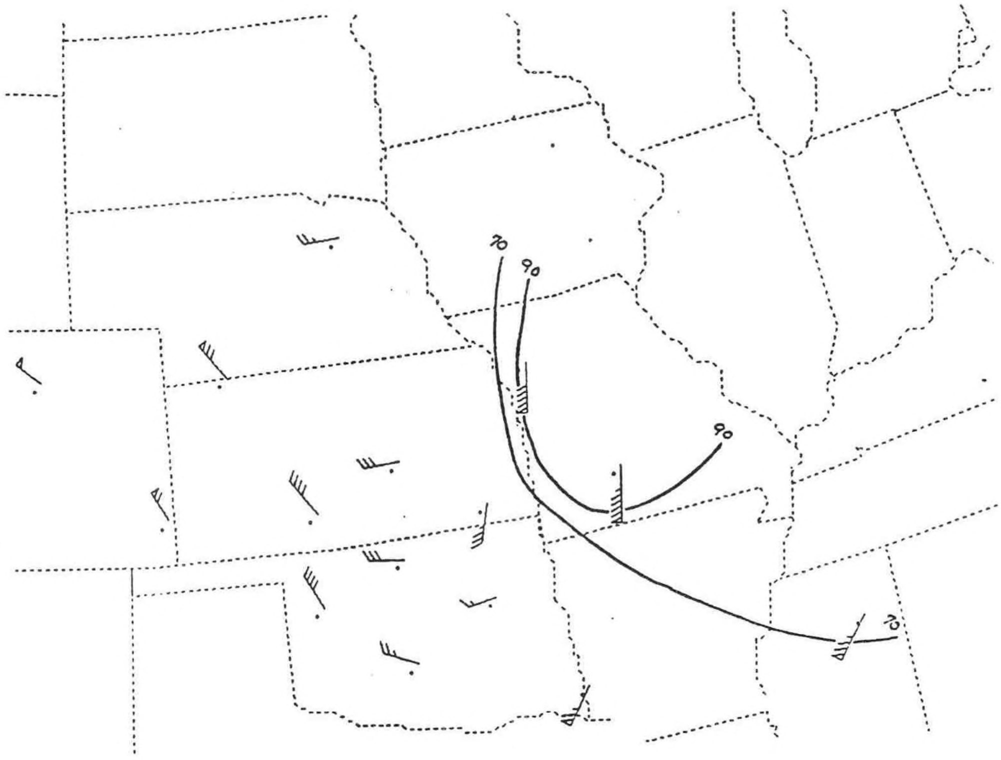

Figure 12. 300 mb wind profiler plan view from January 13, 1992 at 2000 UTC.

The two features previously mentioned proved to be excellent examples of how wind profiler data can help improve short-term forecasting or NOWcasting. Although the profiler network at the time was not dense enough to determine the exact location, profiler data from 1700 UTC through 2100 UTC at HKL and CNW clearly showed the progression of the jet streak through Oklahoma and into Missouri (Figures 6 and 7). The trough axis in the mid- and upper-levels, as well as the trailing edge of the associated speed maximum, had passed through eastern Oklahoma at HKL by 1700 UTC. Using this information, the forecaster could now look for the entrance region of the jet, differential positive vorticity advection (PVA) associated with the trough axis, and the thermally direct circulation as factors of enhancing vertical velocities across south central Missouri.

The deepening of the northerly flow after 1700 UTC at HKL likely resulted from the thermally direct circulation induced by the jet streak. The depth of the cold air also increased at a faster rate after the speed max moved to the east. A northerly flow of 50 knots was occurring just above the surface at 1800 UTC and north winds up to 600 mb were present by 2000 UTC resulting in a significant increased depth of cold air over a few hours (Figure 6).

Viewing the profiler data at CNW and the surface map at 2100 UTC seemed to confirm that the significant snowfall in Oklahoma had advanced northeastward into Missouri (Figures 7 and 13). The mid- and upper-level trough had passed CNW at near 2100 UTC with the jet streak leaving the area. After 2100 UTC, the depth of the cold air again increased a few thousand feet over two hours with north winds of at least 30 knots in the lower levels.

Examination of the 2100 UTC surface map showed moderate to heavy snow falling across much of southwest and south central Missouri (Figure 13). This region would seem to be a favored area for lifting as previously shown from the 2000 UTC wind profiler plan view. (Figure 12). The entrance region of the speed maximum shown on the plan view suggested an enhanced upward vertical motion field in this area.

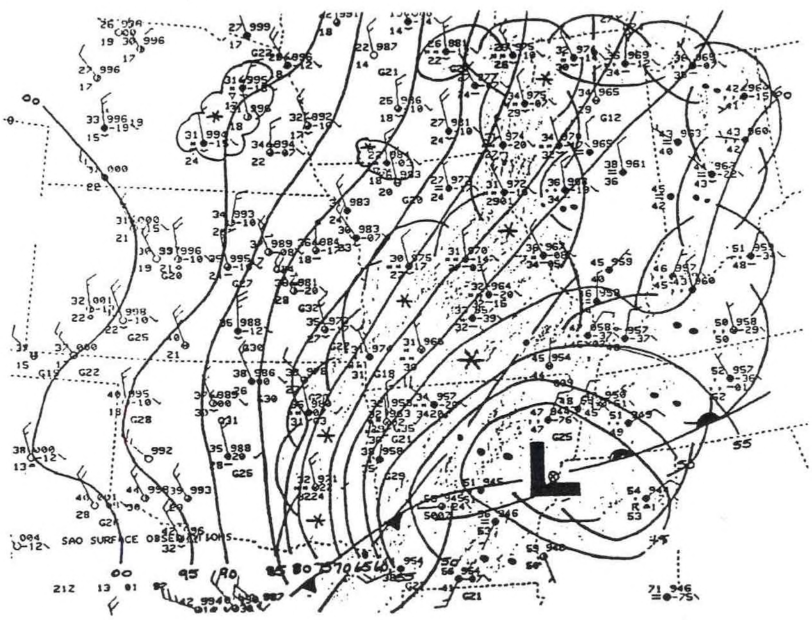

Figure 13. Surface Analysis for January 13, 1992 at 2100 UTC.

The area of heavy snow moved across Missouri into Illinois in correlation with the back edge of the jet streak. At 0000 UTC on January 14, heavy snow was reported at both TBN and Vichy, Missouri (Figure 14). The 500 mb level data at this time showed a 70 knot jet maximum extending back toward southern Illinois while a second jet streak extended across the Gulf Coast states (Figure 15). The center of the northern wind maximum diagnosed on conventional data was not totally aligned with the wind maximum identified on limited profiler data at 2000 UTC. This probably was due to the continued evolution of the upper-level jet streak. However, the entrance region of the upper-level jet streak noted on profiler data across Missouri (Figure 12) continued to remain a favored area of upward vertical motion. In this case, profiler data not only provided data between 0000 and 1200, but also supplemented the existing network at the observation times.

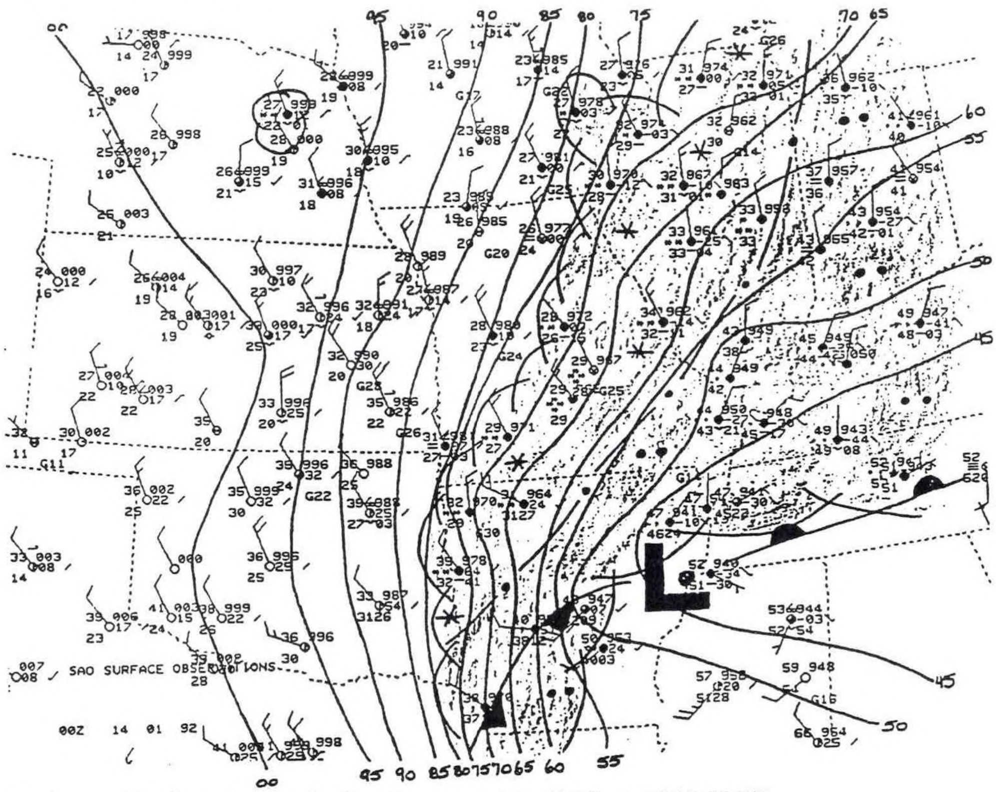

Figure 14. Surface Analysis for January 14, 1992 at 0000 UTC.

The area of moderate to heavy snow continued its movement northeast during the evening hours in accordance with where the profilers last showed the entrance region of the jet streak and its expected movement. Moderate to heavy snow was falling at St. Louis, Missouri at 0200 UTC (Figure 16) and moved into east central Illinois at Champaign, Illinois by 0400 UTC.

4. SUMMARY

Profiler data used in this winter storm event proved to be a valuable tool in diagnosing several meteorological processes including: 1) the formation of an

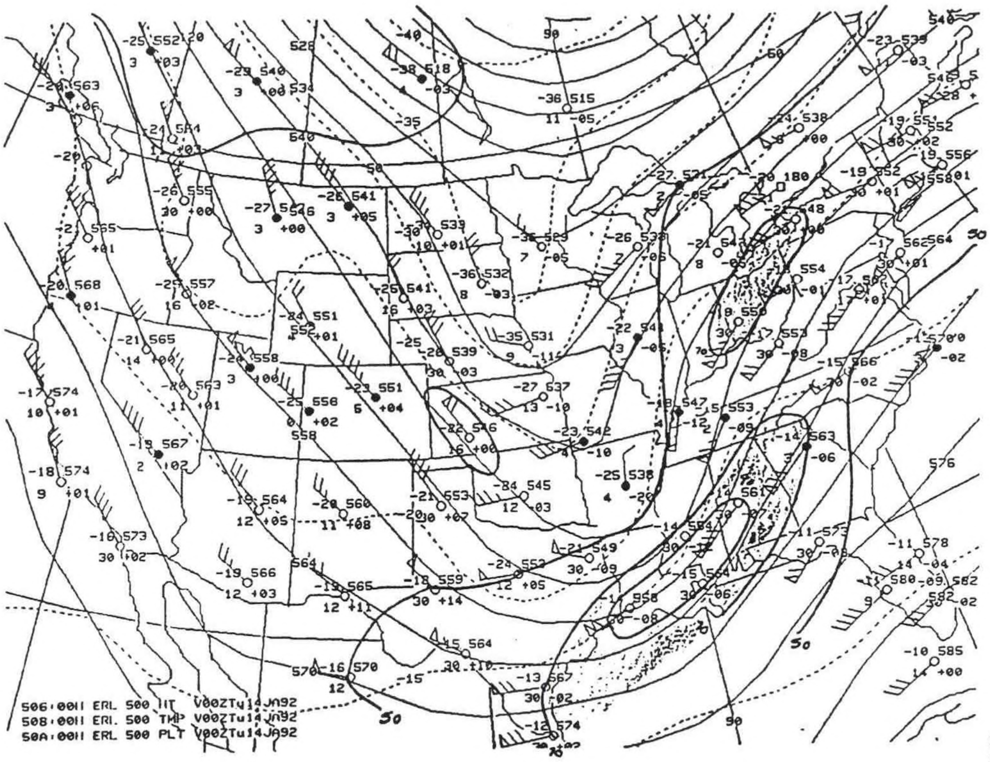

Figure 15. **500 mb plot and isotachs from January 14, 1992 at 0000 UTC.**

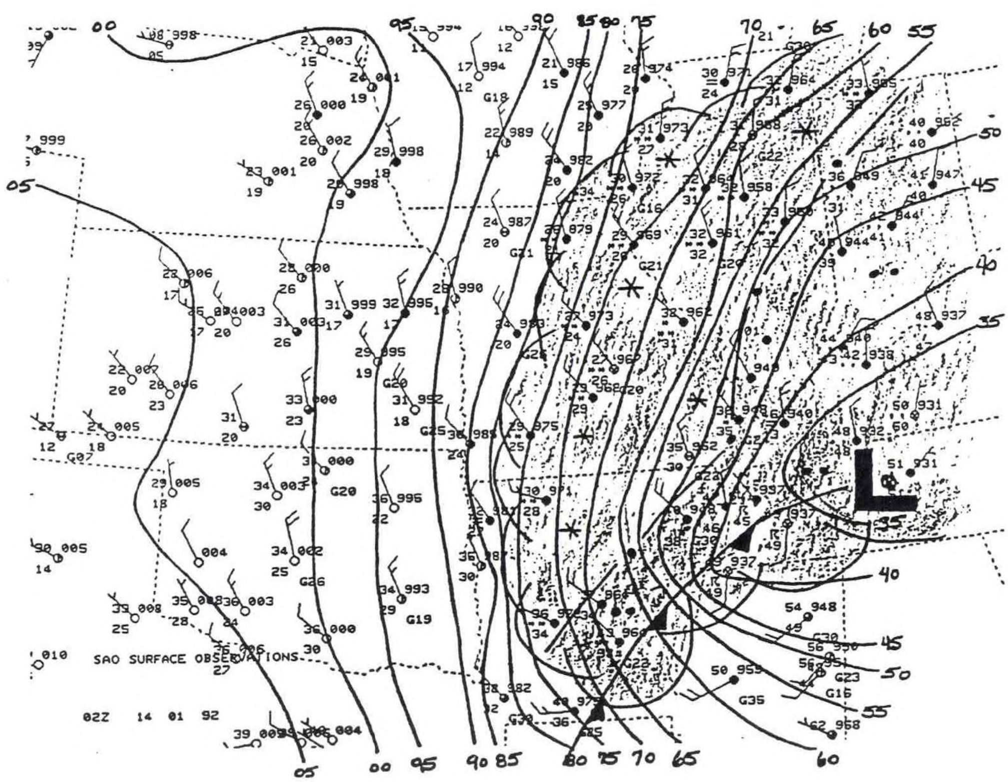

Figure 16. **Surface Analysis for January 14, 1992 at 0200 UTC.**

upper-level jet streak downwind from the 500 mb synoptic scale trough, 2) airflow structure associated with warm and cold conveyor belt settings, and 3) the advection and increasing depth of colder air behind the entrance region of the upper-level jet streak. The warm conveyor belt airflow structure appeared to be similar to the conveyer belt structure introduced by Browning (1986). Advection of the colder air behind the entrance region of the jet streak seemed comparable to the process described by Uccellini and Kocin (1987).

There are many advantages of utilizing profilers across the United States. These advantages include: 1) contributing supplemental data to the existing upper air network, 2) providing much better spacial resolution of upper air features, and 3) producing increased temporal resolution. This allows forecasters to view smaller scale phenomena previously unrecognizable by the existing radiosonde network. Atmospheric processes can also be diagnosed in near real-time. The increase in both the frequency and amount of information received should enhance the ability to forecast the intensity and duration of precipitation, as well as other atmospheric phenomena.

5. ACKNOWLEDGEMENTS

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