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Technical Attachment

“WARM” SNOWSTORM IN OKLAHOMA
JANUARY 13, 1992

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1. Introduction

During the morning of Monday, January 13, 1992, a snowstorm in central Oklahoma produced three to five inches of snow with local amounts around seven inches (Figure 1). Light rain began at Oklahoma City shortly before 3:00 a.m. and changed to snow by 5:00 a.m. The heaviest snow at Oklahoma City fell during the next four hours with a snow accumulation of three inches by 9:00 a.m. The snow had ended by 1:00 p.m. in Oklahoma City with a storm total of five inches. North winds from 15 to 25 knots with gusts to 35 knots produced snow drifts as high as one foot in central Oklahoma.

Heavy snow forecasts are almost always a challenge, but forecasting this event was made especially difficult by the lack of low-level warm air advection which is usually associated with heavy snow events in the Southern Plains. Despite the lack of low level isentropic lift, the synoptic scale lift suggested by strong mid-level differential vorticity advection implied that heavy snow was possible. As a result, a winter storm watch was issued 24 hours before the heavy snow event. The winter storm watch was dropped to a snow advisory shortly before the heavy snow began and later upgraded to a winter storm warning during the event. This forecast scenario may require us to reconsider the way we routinely issue winter storm watches and warnings given the latitude in WSOM Chapter C-42.

In addition to reviewing the forecast problems associated with the heavy snow event, this attachment will examine the unusually high radar reflectivities displayed by the WSR-88D near Oklahoma City. Reflectivities were as high as 55 dBZ with no sleet reported at the surface. Doppler velocity wind profiles from the WSR-88D will also be presented.

2. Synoptic Overview

The 500-mb height and vorticity analyses and forecasts at 12Z January 12, 1992, (not shown) indicated a 540-dm low in northwestern Arizona with a strong vorticity maximum in west central Arizona. A weaker short wave trough was moving northeastward through the Southern Plains and was forecast to rapidly exit the Plains states by 00Z Monday. Deep low level moisture and abundant mid-level moisture preceded the short wave trough in the Southern Plains.

The strong 500-mb low and associated vorticity maximum were forecast by the 12Z, January 13, 1992, run of the RGL and AVN to move into northwestern Texas by 12Z, January 13, 1992, and into eastern Arkansas by 00Z, January 14, 1992. The previous two model runs of the RGL and AVN were similar in the track of the vorticity maximum and a little faster on the speed of its movement. Mean relative humidities and vertical velocities were predicted to increase across much of the western two-thirds of Oklahoma by 12Z Monday, January 13, 1992. RGL model data at 850-mb depicted a weak low in north central Texas at 12Z Monday, January 13, 1992, with cold air advection in central Oklahoma. RGL gridded data suggested the temperature in the column from 850700-mb would be 0oC or below. At the surface, a Pacific cold front was expected to push through western and much of central Oklahoma by 12Z Monday, January 13, 1992, with 1000-500-mb thickness values dropping to approximately 540 dm in central Oklahoma.

The following were the major concerns in evaluating the heavy snow potential in central Oklahoma:

1. Would the air behind the Pacific cold front be sufficiently cool to permit the precipitation to fall as snow?

2. Would the upward vertical motion suggested by the predicted strong PIVA be sufficient to overcome the sinking motion suggested by the low level cold advection?

3. Would precipitation be heavy enough to mix cooler air from aloft to the surface?

4. If the rain did change to snow, would the transition occur near the beginning or end of the precipitation event?

Many of these questions were difficult to answer, but the threat of heavy snow was sufficiently great to justify issuance of a winter storm watch valid for Monday in the Sunday morning forecast package.

At 00Z, January 13, 1992, the RGL upper-air analysis indicated 1000-500-mb mean RH values of 70-90 percent in New Mexico and western Texas. Within this region, rain and snow were reported in New Mexico. The surface analysis (Figure 3a) valid at 00Z Monday showed dewpoints in north central Texas ranging from the low 40s to low 50s. Precipitable water values in soundings at Norman, Oklahoma, and in east Texas (SEP and GGG) ranged from .4 to .6 inches.

Between 06Z and 09Z, the threat of heavy snow seemed to be diminishing. At 06Z, the cold front had pushed southeastward and extended from southeastern Kansas to south central Oklahoma. North to northwest winds at 10 to 20 knots followed passage of the front, with temperatures in south central Kansas and northwestern Oklahoma in the mid 30s. Temperatures in central and north central Oklahoma had only cooled into the low to mid 40s, and dew points in central and north central Oklahoma were in the upper 30s to around 40. The upper-level storm system was moving across southwestern New Mexico, with only light snow reported in the Texas Panhandle and the Texas South Plains. The 00Z RGL model continued to forecast a track similar to earlier models, with the 500-mb vorticity maximum expected to be located west of Abilene, Texas, by 12Z January 13, 1992, and along the Arkansas and Louisiana border by 00Z January 14, 1992, (Figure 4a and 4b). Strong PIVA (Figure 4c) was forecast over much of the southern one-half of Oklahoma by 12Z Monday, with modest RGL 700-mb vertical motions of approximately 2 to 4 microbars/sec. The surface low was still expected to develop in north Texas by 12Z with 1000-500-mb thickness values dropping to 540 dm in central Oklahoma (Figure 2). The 850-mb low was also still modeled over north Texas by 12Z with strong cold air advection over central Oklahoma.

At 09Z, one hour before the new forecast package was to be disseminated, temperatures in central Oklahoma had only cooled into the upper 30s. Light rain and light snow were occurring in southwestern Oklahoma with light snow continuing over the Texas Panhandle and Texas South Plains. Due to the warm temperatures at the surface and the fast movement of the 500-mb vorticity maximum, forecasters felt that much of the precipitation would fall as rain before changing to snow. Therefore, the winter storm watch was lowered to a snow advisory as only 1 to 3 inches were expected.

3. Storm Evolution

By early Monday morning, light rain had spread into central Oklahoma with light snow in the southwestern portion of the state. Light rain was reported at Oklahoma City at 09Z with a temperature of 38^{o}F and a dewpoint of 35^{o}F. Between 10Z and 11Z the rain changed to light snow in Oklahoma City with the temperature cooling to 33^{o}F at 11Z. Moderate snow was reported shortly after 12Z. Reflectivities from the WSR-88D were unusually high during the event with bands of 35 dBZ to 55 dBZ echoes. The higher values were generally within the region where the snow was changing to rain (bright band). Base reflectivities at 1010Z (Figure 5) revealed a bright band at the 2.4 to 4.3 degree elevation slices with reflectivities as high as 51 dBZ at the 3.4 degree elevation scan. At 1010Z rain was occurring at Norman, Oklahoma, with the rain changing to snow by 12Z.

At 12Z the Pacific cold front (Figure 3b) had passed all but the southeastern one-quarter of Oklahoma with a surface low developing just northeast of Dallas, Texas. The 12Z sounding at OUN (Figure 6) showed north to northeast winds from the surface to approximately 850-mb with south to southwest winds above 700-mb. The precipitable water in the sounding was relatively high with a value of .57 inches. A weak 850-mb low had developed as modeled in north central Texas, and local UA diagnostics of 12Z data (Figure 7) indicated strong 850-mb cold air advection over central Oklahoma. The 12Z RGL initial analyses depicted strong PIVA (Figure 4d), and local UA diagnostics revealed strong divergence of Q values (700-300-mb layer) of -100 to -300 $10^{-17}S^{-3}mb^{-1}$ (Figure 8) in central and south central Oklahoma. Divergence of Q values (850-500-mb layer) in this region ranged from -100 to -200 $10^{-17}S^{-3}mb^{-1}$.

Light to moderate snow continued throughout central Oklahoma through 15Z with radar reflectivities, as high as 47 dBZ. The moderate snow reports and data provided by UA diagnostics and the RGL prompted the issuance of a winter storm warning for parts of central Oklahoma. The winter storm warning was issued late Monday morning and was valid through Monday afternoon. Strong northerly wind of 15 to 25 knots with higher gusts were also expected to produce blowing and drifting snow.

Doppler velocities displayed by the WSR-88D allowed forecasters to view the strength of the northerly winds as well as other mesoscale and synoptic scale features during the heavy snow event. Doppler velocities at 101OZ (Figure 9) displayed north to northeasterly winds at 10 to 21 knots at approximately 3100 feet msl. The elevation of the radar site is 1277 feet msl. Doppler velocities also displayed veering with height with strong south to southwest mid level winds of 50 knots present above approximately 10,000 feet msl.

By 1550Z, the north to northeast winds had increased to 50 knots or more at about 3700 feet msl (Figure 10). In addition, other features became apparent at this time. A well defined frontal boundary was evident southeast of the radar site (Line y-z) at a greater range than was evident in Figure 9, reflecting a deepening of the cold air mass over the radar site. The frontal boundary was located at approximately 10,000 feet msl with strong north to northeast winds below that level.

At 18Z, the surface low pressure system had moved east-northeast into extreme southeastern Oklahoma. The rain had changed to snow in parts of south central, southeastern, and east central Oklahoma with the snow diminishing in central Oklahoma. By 00Z Tuesday the upper level storm system and surface low had moved rapidly out of the region.

4. Discussion

Observations during the snow event indicated that no thunder, lightning, or ice pellets occurred. Since snow is normally a poor reflector of microwave energy, it was unusual to see such high reflectivity values. The snowflakes throughout this event were wet and quite large and exhibited reflective properties similar to water-covered ice (e.g., hail). The wet snowflakes were capable of backscattering higher than normal amounts of radiation due to their large size. Due to the high reflectivities, the WSR-88D computed rainfall estimates (Figure 11) as high as 1 to 2 inches liquid equivalent with local amounts to 3 inches. The actual liquid equivalent amounts were as high as .75 inches. The Precipitation Process System (PPS) did not perform well because of the backscattering capabilities of the large and wet snowflakes. The banded structure of the Storm Total Precipitation (STP) is due to the sampling strategy employed by the WSR-88D precipitation detection algorithm. The bands of heavy precipitation are associated with different elevation angles sampling the bright band at different horizontal and vertical distances. A composite of the lowest four elevation angles of each volume scan is used as input by the PPS to generate rainfall estimates. Higher elevation angles are used closer to the radar site in order to reduce contamination by ground clutter and anomalous propagation. In this case, the bright band lowered slowly toward the surface with time. For each elevation scan used in the compositing process, the lowest elevation MSL of that scan encountered the bright band for the longest time interval. Therefore, a ring of heavy precipitation estimates was generated at a horizontal position corresponding to the closest range for which each elevation scan was utilized.

The snow event on January 13, 1992, was made particularly difficult to forecast because the storm system exhibited characteristics usually not associated with heavy snow in central Oklahoma. Heavy snow events in central Oklahoma usually involve low-level warm advection with strong isentropic lift over a Canadian or Arctic air mass. Since surface to 850-mb cold advection was present in this episode, the rising motion suggested by strong PIVA had to overwhelm the low-level sinking motion to produce heavy snow. In addition, the transport of cold air from aloft and strong rising motion were needed to cool the relatively warm and moist Pacific air mass. All of these factors are tough to weigh subjectively, but analyzing layer divergence of Q values and/or Q vectors could help forecasters during similar events. Even after analyzing these fields, the exact impact on surface temperatures are still difficult to determine. Such was the case on January 13, 1992, when forecasters had to determine whether temperatures would cool sufficiently to cause the rain to change to snow.

Although forecasting even for the first period of some winter weather events can involve a large degree of uncertainty (e.g., January 13, 1992), there is considerable reluctance by forecasters to continue a winter storm watch into the first period. Indeed, WSOM Chapter C-42 does not strongly endorse the practice, although that option remains open to the forecaster. Specifically, WSOM Chapter C-42 states that winter storm watches **"...may be continued from a previous forecast into the latter part of the first period of the next routinely issued forecast if the onslaught of the hazardous winter weather event is still uncertain. A watch should generally not be issued for the first 6 hours of a forecast."**

Two valuable lessons were learned from the winter weather event of January 13, 1992. The first is that we should carefully consider retaining a winter storm watch in the first period if it is uncertain whether a winter storm warning is necessary. The second lesson is that we may underestimate the cooling potential exhibited by strong rising motion and the transport of cold air aloft to the surface during periods of heavy precipitation.

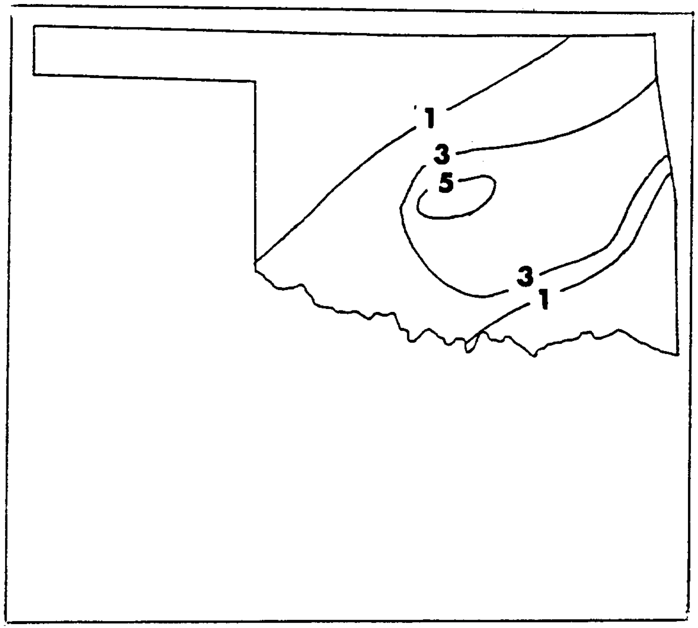


Figure 1. Snowfall in Oklahoma, January 13, 1992. Contours in inches.

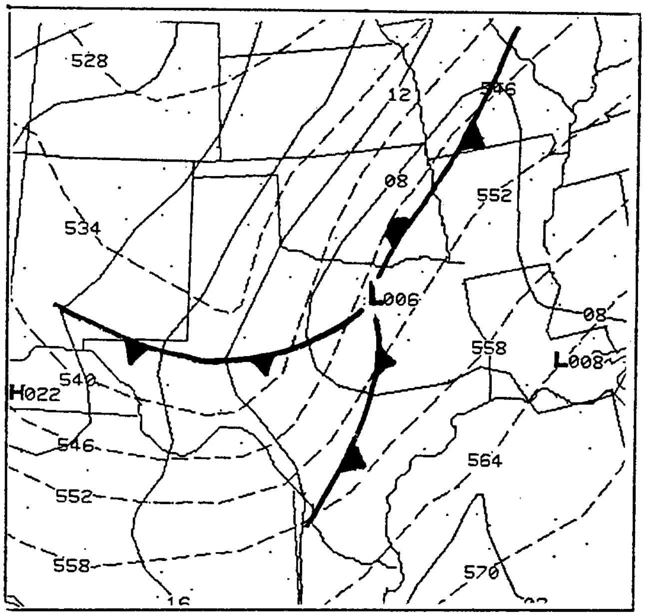


Figure 2. Forecast of surface pressure in millibars (solid) and 1000-500-mb thickness (dashed) from RGL run at 00Z, January 13, 1992 valid at 12Z, January 13, 1992.

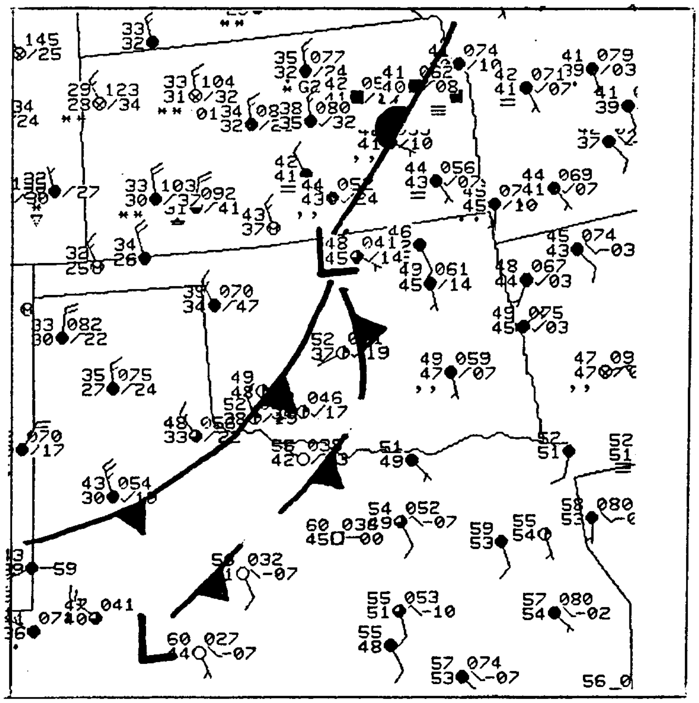


Figure 3a. Local surface analysis valid at 00Z, January 13, 1992.

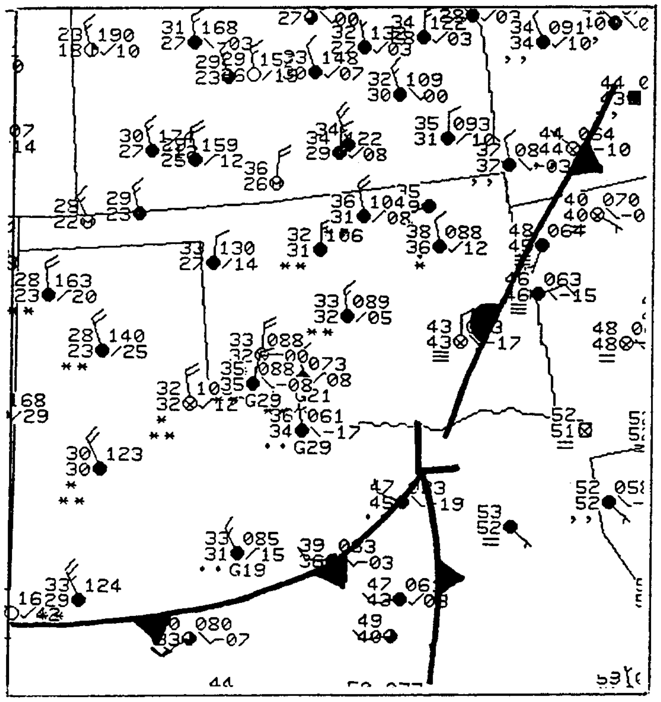


Figure 3b. Local surface analysis valid at 12Z, January 13, 1992.

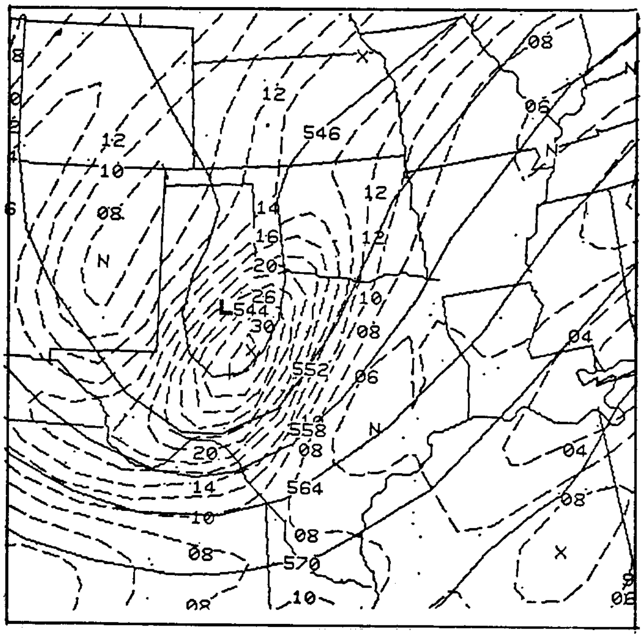


Figure 4a. Forecast 500-mb heights (solid) and vorticity (dashed) from the RGL run at 00Z, January 13, 1992, valid at 12Z, January 13, 1992.

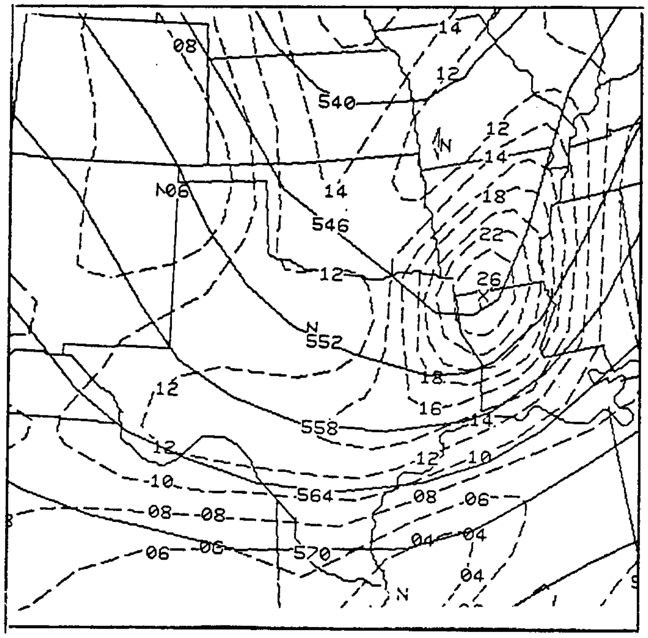


Figure 4b. Forecast 500-mb heights (solid) and vorticity (dashed) from the RGL run of 00Z, January 13, 1992, valid at 00Z, January 14, 1992.

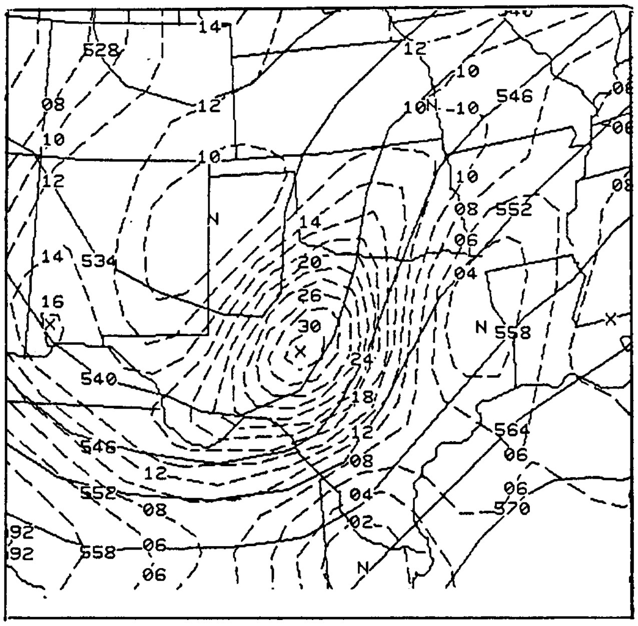


Figure 4c. PIVA forecast. 500-mb vorticity (dashed) and 1000-500-mb thickness (solid) from the RGL run of 00Z, January 13, 1992, valid at 12Z, January 13, 1992.

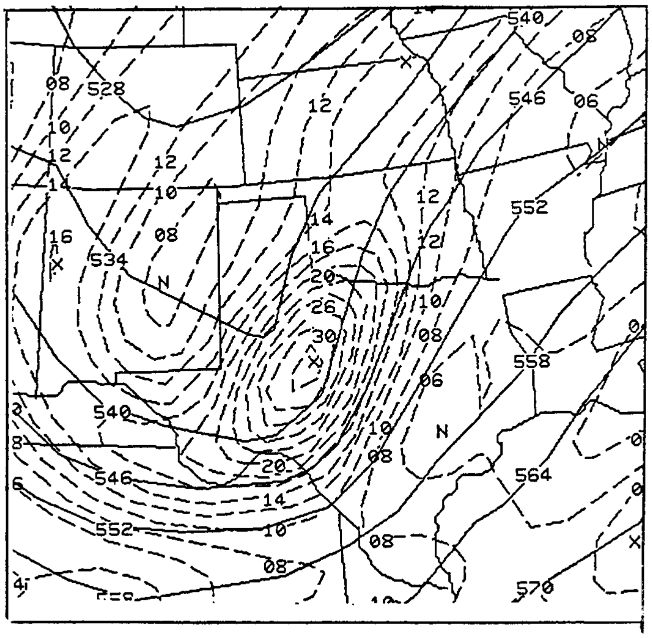


Figure 4d. RGL initial PIVA analysis valid at 12Z, January 13, 1992

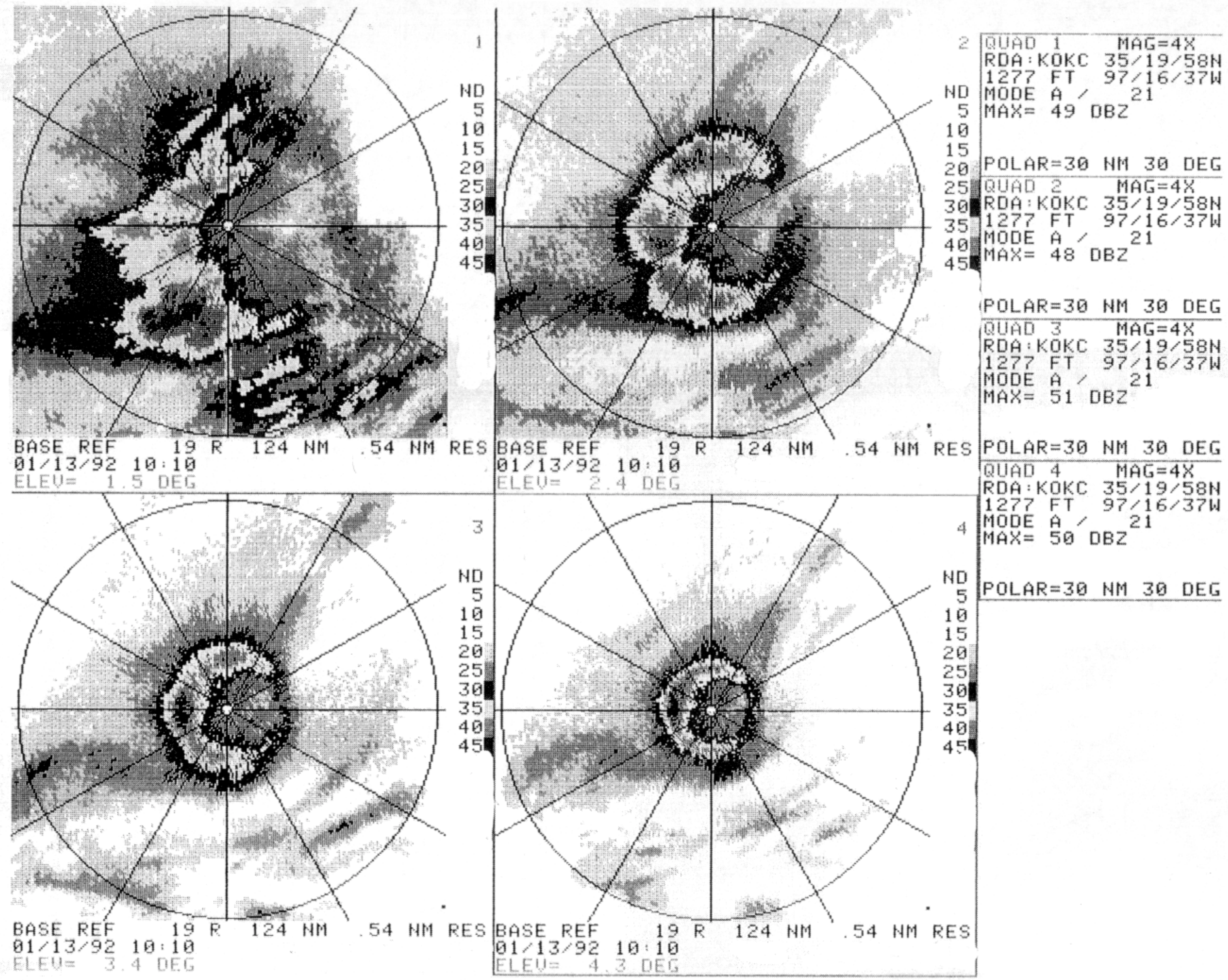


Figure 5. Four-panel base reflectivities (elevation increments of 1.5, 2.4, 3.4 and 4.3 degrees) valid at 1010Z, January 13, 1992. Range rings in 30-nm increments with dBZ scale labeled at upper right in each quadrant.

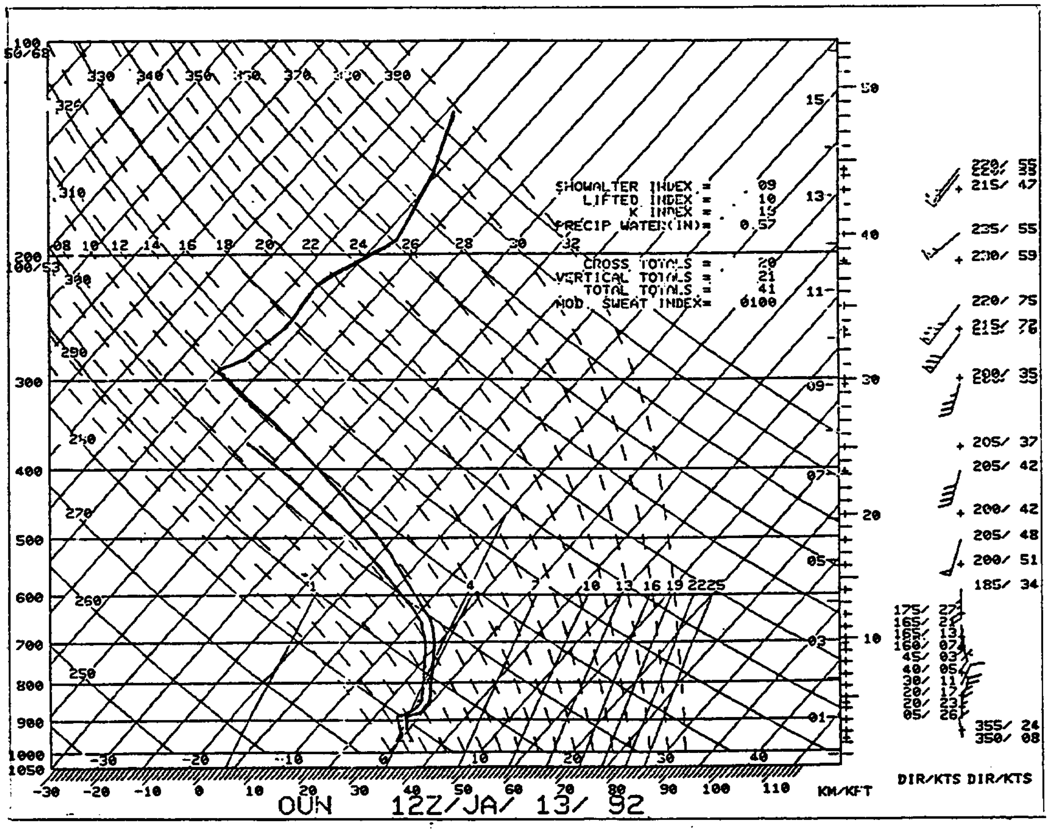


Figure 6. SKEW-T sounding from Norman, Oklahoma (OUN), 12Z, January 13, 1992

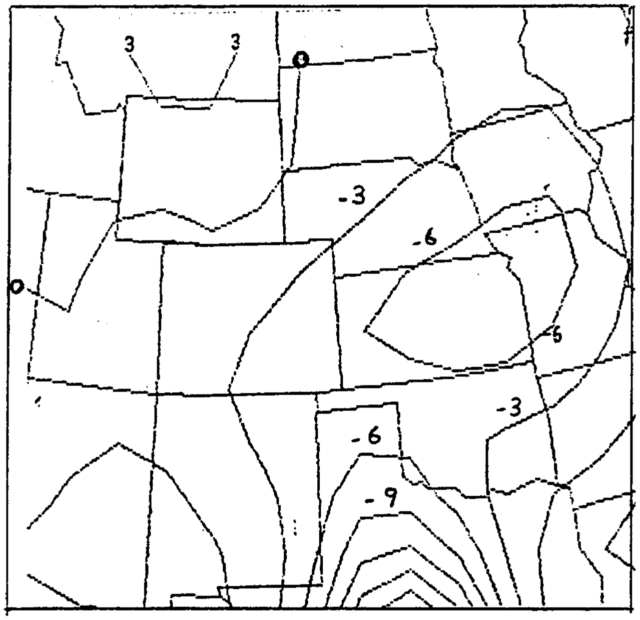


Figure 7. 850-mb temperature advection (°C/12-hr) valid at 12Z, January 13, 1992.

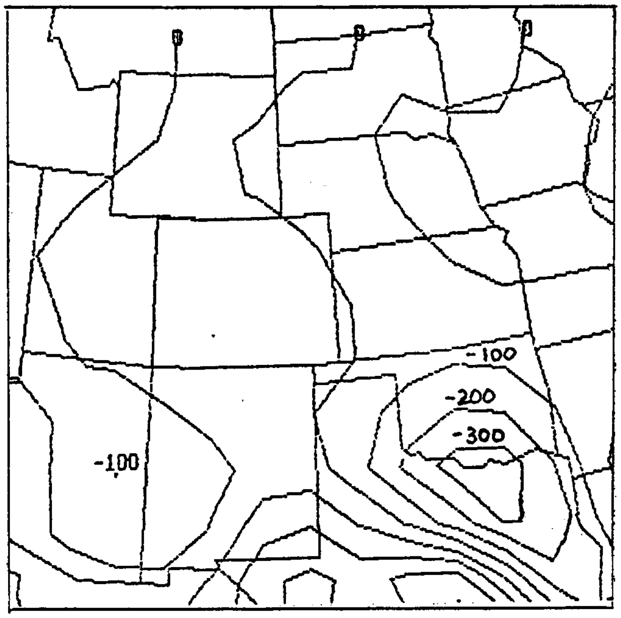
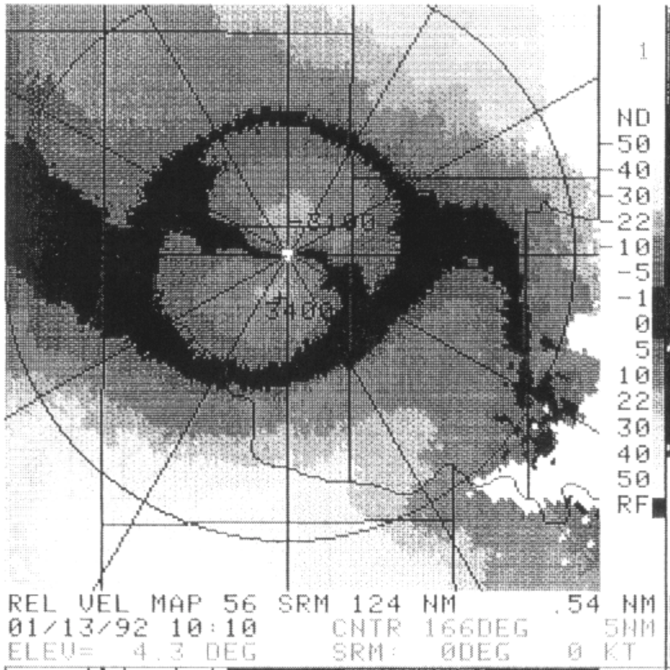
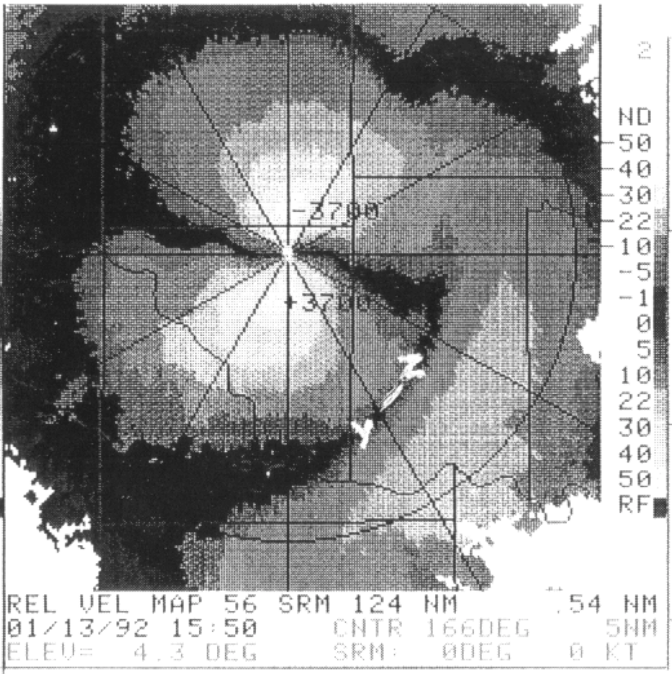
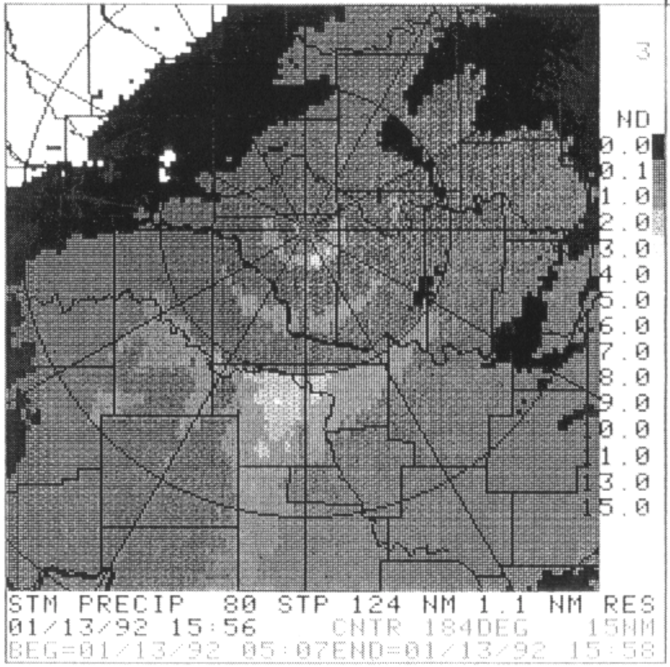
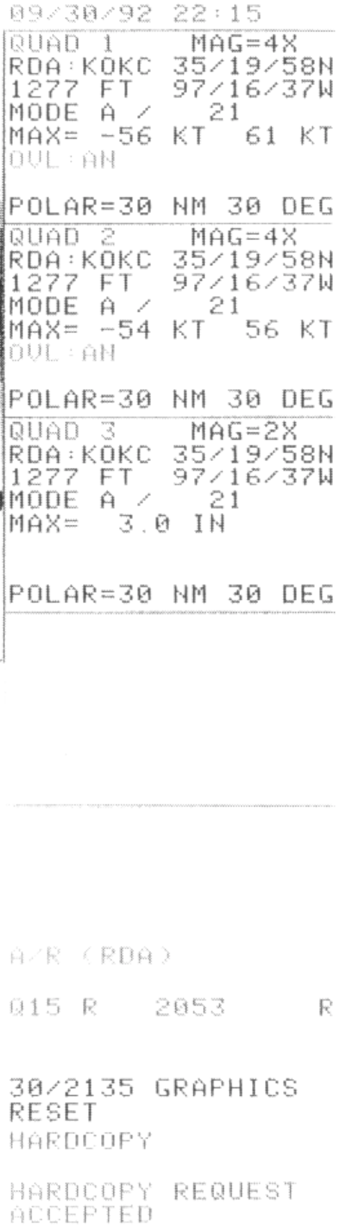


Figure 8. Divergence of Q (700-300-mb layer) ($10^{-17} S^{-3} mb^{-1}$)









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OVL:AN

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1277 FT   97/16/37W
MODE A /     21
MAX= -54 KT   56 KT
OVL:AN

POLAR=30 NM 30 DEG
QUAD 3       MAG=2X
RDA:KOKC  35/19/58N
1277 FT   97/16/37W
MODE A /     21
MAX=   3.0 IN

POLAR=30 NM 30 DEG



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Figure 9 (upper left). Base velocities (kts) displayed by the WSR-88D at 1010Z, January 13, 1992. Inbound velocities are labeled as negative. Outbound labeled as positive. Heights are in feet msl at positions labeled.

Figure 10 (upper right). Base velocities (kts) displayed by the WSR-88D at 1550Z, January 13, 1992. Format same as Figure 9. Line y-z denotes frontal boundary.

Figure 11 (lower left). Storm total precipitation from 0507Z to 1556Z, January 13, 1992. Values labeled in upper right.