THE MESOSCALE ENVIRONMENT OF THE 11 JUNE 1992 SEVERE STORMS IN WESTERN TEXAS

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Abstract

One of the most significant severe weather outbreaks of the year in western Texas occurred on the afternoon and evening of 11 June 1992. The thunderstorms produced 8 tornadoes, hail as large as baseballs, and wind gusts to 85 miles an hour. Damage from the outbreak was estimated near $2 million; fortunately, no casualties resulted.

Although severe weather in June is not unusual in western Texas, the magnitude of this outbreak and the sudden increase in the causative factors of storm-relative vertical wind shear and instability are noteworthy. Several of the storms, especially those in the South Plains area around Lubbock, exhibited both visual and radar evidence of being supercell thunderstorms with mesocyclones. The storms developed in an environment which did not appear to support significant storm rotation. Nevertheless, rotation did develop.

In this paper, the convective environment which was present on 11 June 1992 over western Texas is examined. Using PC applications and data currently available to National Weather Service (NWS) forecasters, the changes which occurred in the environment are diagnosed and the author speculates as to why the storms behaved the way they did.

1. Synoptic Overview and Background

At 1200 UTC 11 June 1992, the atmosphere over western Texas was not especially conducive to severe convection (Miller 1972; Doswell 1982). Figure 1 shows an upper air composite analysis from this time. Upper air features were quite weak, with 850-mb winds from the south at 10 knots and 700-500 mb winds from the northwest at 15-20 knots. A shortwave ridge was centered over New Mexico and Colorado. Dewpoint temperatures at 850 mb were 8-12 degrees C over western Texas, but the 850-mb dewpoint at Del Rio, Texas (DRT) was 17 degrees. At 200 mb, features were more favorable for convection. Some weak difluence was evident over western Texas, and an 80-knot jet maximum was approaching the area from southern Arizona.

Figure 2 contains an area surface analysis from 1400 UTC. A weak surface trough was evident in eastern New Mexico, with a surface ridge evident over western Texas. Low-level moisture was adequate but not abundant, with surface dewpoints of 58 degrees F or greater across much of the area.

Area upper-air soundings revealed that the atmosphere was not very unstable. Temperature differences between 850 mb and 500 mb were only 27 degrees C at Amarillo, Texas (AMA) and at DRT. The lifted index at AMA was +1 with no appreciable positive area in the sounding (Fig. 3). The Midland, Texas (MAF) sounding was terminated at 700 mb. The MAF sounding showed low-level moisture extending to about 40 mb above the surface. The winds in the 900-700 mb layer were weak (below 10 knots), but veered more than 180 degrees.

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Researchers and field personnel (Weisman and Klemp 1984; Doswell 1991) have noted that mesocyclone formation is favored when convection develops in a wind environment characterized by strong (20-30 knots or greater) storm-relative winds which veer in the lowest few kilometers of the atmosphere. Other studies (e.g., Davies-Jones et al. 1990) have attempted to quantify this characteristic with a variable called helicity.

Any change in wind speed and/or direction with height produces vertical shear. The shear may be speed shear, directional shear, or a combination of the two. This vertical shear produces horizontal vorticity which is directed perpendicular and to the left of the shear vector.

Speed shear produces what is called crosswise vorticity. In the case of crosswise vorticity, the vorticity vector is directed perpendicular to the mean wind vector. The effect of crosswise vorticity is similar to a wheel rolling along the ground. On the other hand, directional shear produces a quantity called streamwise vorticity. The vorticity vector and mean wind vector are parallel in streamwise vorticity. The effect is similar to a well-thrown football pass spiralling down field.

Davies-Jones (1984) showed that streamwise vorticity in a storm's inflow layer can induce cyclonic rotation in the storm as the horizontally-oriented vorticity is tilted into the vertical and stretched by the storm's updraft. Conversely, crosswise vorticity generates counter-rotating (cyclonic and anticyclonic) vortices which cause the storm to split. Closely related to streamwise vorticity is a quantity called helicity. Technically, helicity is the dot product of the horizontal vorticity and velocity vectors, integrated through a particular layer. Operationally, helicity is related to the strength and veering of the (storm-relative) wind through the storm's inflow layer, usually the 0-3 Km layer. Helicity can also be viewed as twice the area swept out by a storm-relative wind hodograph. Although there is no "magic number" regarding helicity, values above 150 $m^2\ s^{-2}$ are generally considered sufficient for mesocyclone formation (Davies-Jones et al. 1990).

It has been noted (Woodall 1990; Davies-Jones et al. 1990) that storm-relative helicity is the only physically meaningful helicity measurement. Thus, in order to generate forecast helicity values, one must use an empirical formula to estimate storm motion. The Skew-T/Hodograph Analysis and Research Program (SHARP workstation, Hart and Korotky 1990) calculates the mean wind from the surface to 6 Km. Storm motion is then estimated as 30 degrees to the right of the mean wind direction and 75 percent of the mean wind speed. The Regional Helicity Prediction Program (RHPP, Woodall 1990) estimates the storm motion as 25 degrees to the right of the 0–6 Km mean wind direction and 80 percent of the mean wind speed. While these formulae are good first guesses at storm motion, it should be remembered that they are estimates.

The 1200 UTC environment over western Texas was unfavorable for mesocyclone formation as well. The AMA sound-

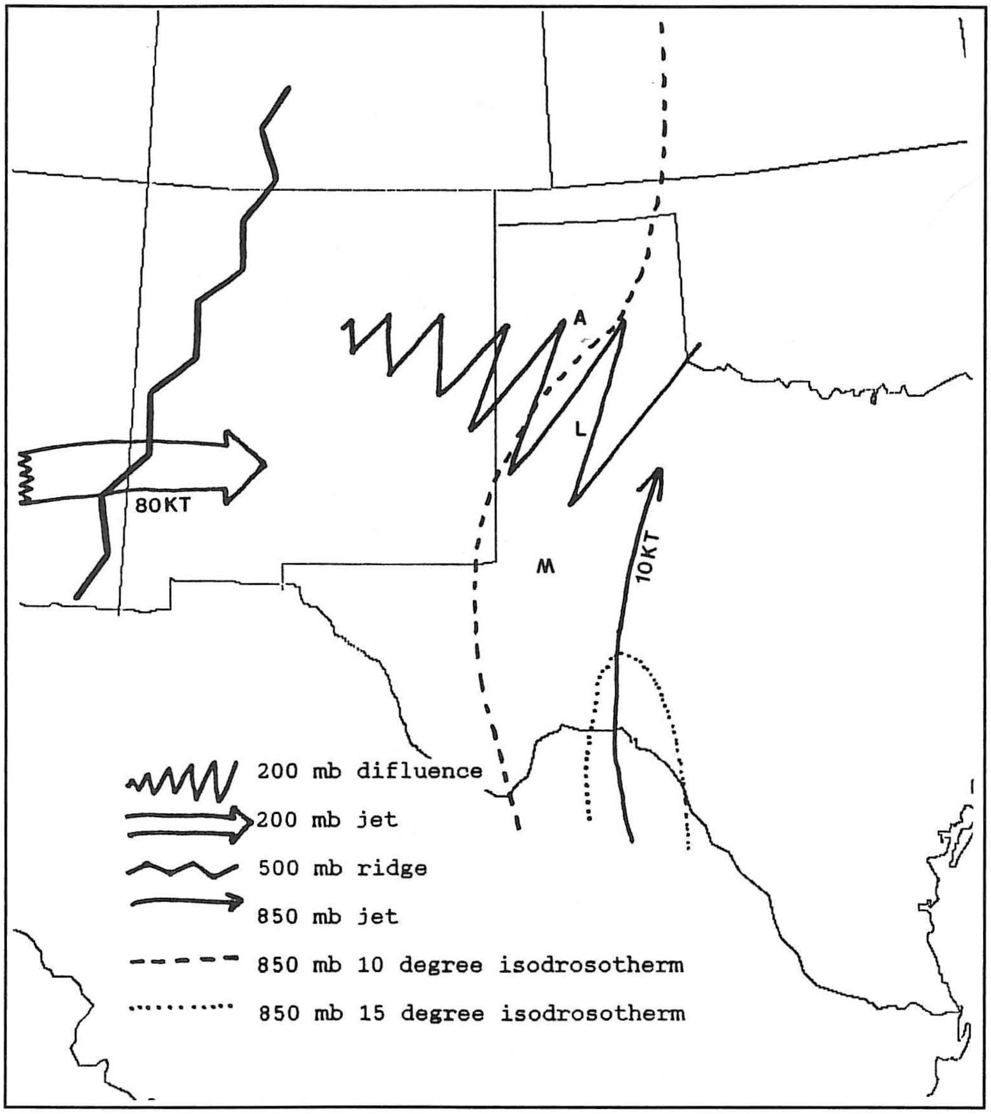

Fig. 1. Upper air composite analysis over New Mexico and west Texas, 1200 UTC 11 June 1992. A, L, and M mark locations of Amarillo, Lubbock, and Midland, Texas.

ing (Fig. 3) did show some veering from the surface to 700 mb, but the winds were very weak. Winds from the surface to 700 mb were generally less than 15 knots, and the 0-3 Km storm-relative helicity was 33 m^2 s^{-2}. The MAF sounding showed more pronounced veering, but again the winds were very weak. Clearly, some drastic changes were needed in both the thermodynamic and the kinematic fields before supercells would be possible.

The 1200 UTC Nested Grid Model (NGM) and FD Winds and Temperatures Aloft forecast guidance from NWS/ National Meteorological Center (NMC) suggested that changes would indeed take place during the afternoon. The upper-level jet maximum would continue propagating eastward, placing western Texas under the left exit region (left front quadrant) by 0000 UTC 12 June. The flow at 700 mb and 500 mb was forecast to increase slightly, but the veering in the lowest few kilometers was to become even more pronounced. Surface heating and low-level moisture advection were expected to destabilize the atmosphere, with lifted index values at 500 mb estimated to reach -8 by 0000 UTC based on forecast maximum temperatures, forecast dewpoint temperatures, assumption of a well mixed boundary layer, and estimation of 500-mb temperatures from the 18,000 foot FD temperature forecasts.

The RHPP output reflected the forecast changes in the wind field (Fig. 4). Forecast helicity values for 0000 UTC 12 June included 65 m^2 s^{-2} at AMA, 95 m^2 s^{-2} at Wink, Texas (near MAF), and 105 m^2 s^{-2} at Lubbock (LBB). Predicted cell motions were from 310-320 degrees at 12-14 knots, suggesting an increase in the 0-6 Km mean wind speed to around 20 knots. Although the environment would become more favorable for storm rotation, it still would not approach the threshold suggested by Davies-Jones et al. (1990).

Surface conditions had become more conducive to thunderstorm formation by 1900 UTC (Fig. 5). The surface ridge had moved slightly east, veering the surface wind to southeast across western Texas and allowing more pronounced low-level moisture to move into the area. The surface trough had moved eastward to near the Texas-New Mexico border. Surface temperatures had reached the mid to upper 80's, approaching the convective temperature of 88 degrees F estimated from the incomplete 1200 UTC MAF sounding.

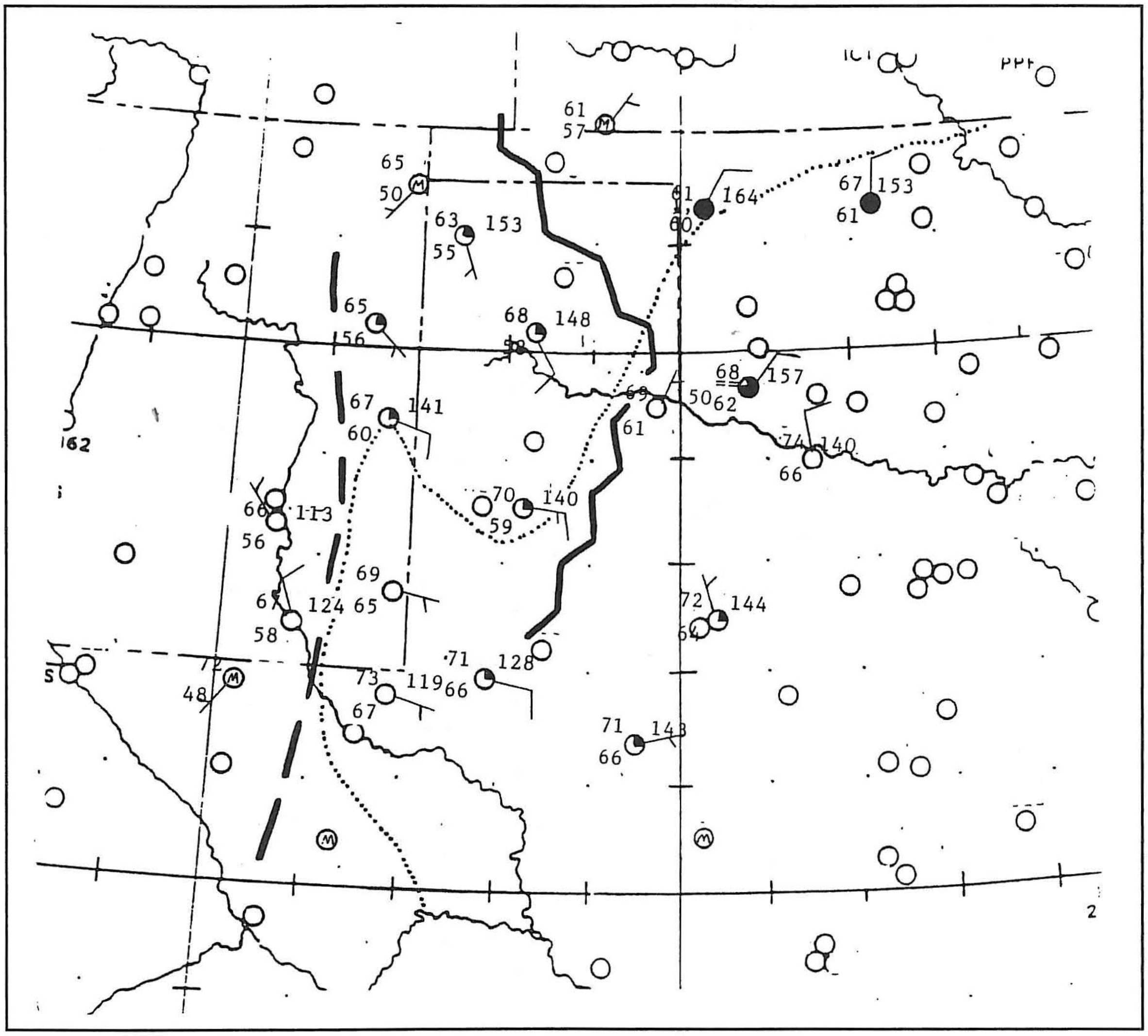

Fig. 2. Area surface analysis over eastern New Mexico and northwest Texas, 1400 UTC 11 June 1992. Surface pressure trough and ridge are marked with standard symbols. Dotted line indicates the 60 degree F isodrosotherm.

2. The Severe Weather Event

Thunderstorms developed over western Texas during the mid-afternoon. The first severe weather reports were received at approximately 2200 UTC 11 June 1992 and continued until nearly 0500 UTC 12 June. Figure 6 shows the location and type of severe weather which was reported during the late afternoon and evening. Many of the storms, especially those in the Lubbock vicinity, were classified as supercells. Overlays from the LBB WSR-74C local warning radar (Fig. 7) showed numerous hook echoes from storms in the area. Note that the storm northwest of Lubbock at 0012 UTC 12 June and west of Lubbock at 0055 UTC is the same storm. This storm maintained a hook echo for approximately 1 hour.

Several spotters and storm chasers were in excellent position to view the storms. At least three of the storms (near Lamesa at 0020 UTC 12 June, near Abernathy at 0055 UTC, and west of Lubbock at 0055 UTC) possessed striations, wall clouds, inflow bands, mid-level cloud bands, and bell-shaped updraft towers. Any one of these features is evidence of at least weak rotation within the storms (Moller and Doswell, 1988). The fact that these storms had all of these visual features suggests that significant mesocyclones may have been present.

3. The Mesoscale Environment

Examination of the 0000 UTC 12 June MAF sounding (Fig. 8a) via the SHARP workstation indicated that some of the changes which were forecast had in fact taken place. The MAF sounding was chosen because the AMA sounding was contaminated from nearby convection. The winds from the surface to 700 mb were still weak, but did show more pronounced veering. The winds from 700 mb to 500 mb increased significantly over the 1200 UTC AMA sounding. The atmosphere had destabilized, with a Convective Available Potential Energy (CAPE) of 666 J Kg^{-1} and a 500-mb lifted index of -4 (lifting a mean boundary layer parcel, not a surface

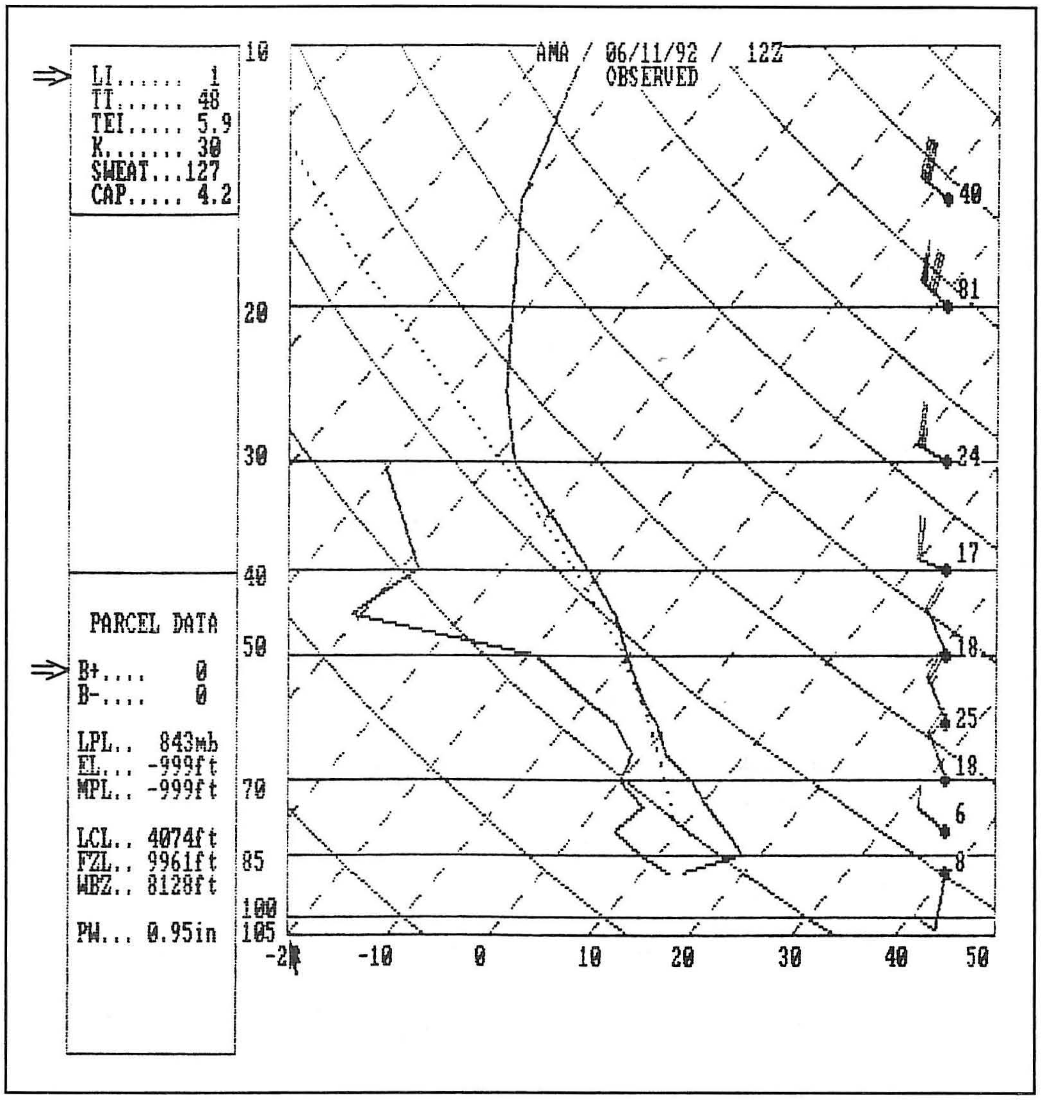

Fig. 3. Amarillo, Texas upper-air sounding taken 1200 UTC 11 June 1992, in skew-T log-p format. Arrows point to pertinent stability indices.

parcel). The hodograph (Fig. 8b) shows some curvature in the lowest 2-3 Km. The 0-3 Km storm-relative helicity was 95 $m^2\ s^{-2}$ but the predicted storm motion was 305 degrees at only 8 knots.

The LBB surface observation from 2250 UTC (taken at the approximate time of storm formation around Lubbock) indicated a temperature of 86 degrees F, a dewpoint temperature of 65 degrees F, and a wind from 120 degrees at 14 knots. Radar observations indicated that the storms moved from approximately 340 degrees at 20 knots. This speed is faster and slightly more to the right of the mean wind than was predicted by RHPP. Spotters noted that low-level clouds (about 2,000 ft AGL) were moving from the south at roughly 15 knots. The FD Prognostics program (Woodall and Baker 1992) suggested that the mid-level temperatures (700–500 mb) near LBB would be about 1 degree C cooler than at MAF.

When SHARP was used to modify the MAF sounding based on these observations, some rather interesting changes became apparent. The modified sounding was more unstable, with a CAPE of 1674 J Kg^{-1} and a 500-mb lifted index (again lifting a mean boundary layer parcel) of −7 (Fig. 9a). Adjusting the surface wind while leaving the original predicted storm motion (304 degrees at 8 knots) increased storm-relative helicity in the 0–3 Km layer to 121 $m^2\ s^{-2}$ nearing the consensus threshold for mesocyclone formation. When the actual storm motion (340 degrees at 20 knots) was substituted, helicity increased to 242 $m^2\ s^{-2}$ sufficient for mesocyclone formation (Fig. 9b).

Davies-Jones et al. (1990) demonstrated the importance of storm-relative inflow for the formation and persistence of a mesocyclone. This quantity can be easily evaluated using the SHARP workstation. For the unmodified 0000 UTC 12 June MAF sounding, storm-relative inflow wind directions ranged from 133 to 207 degrees with speeds generally 14-18 knots, slightly below the value suggested by Davies-Jones et al. When the above-mentioned modifications were made to the low-level winds and storm motion, the storm relative

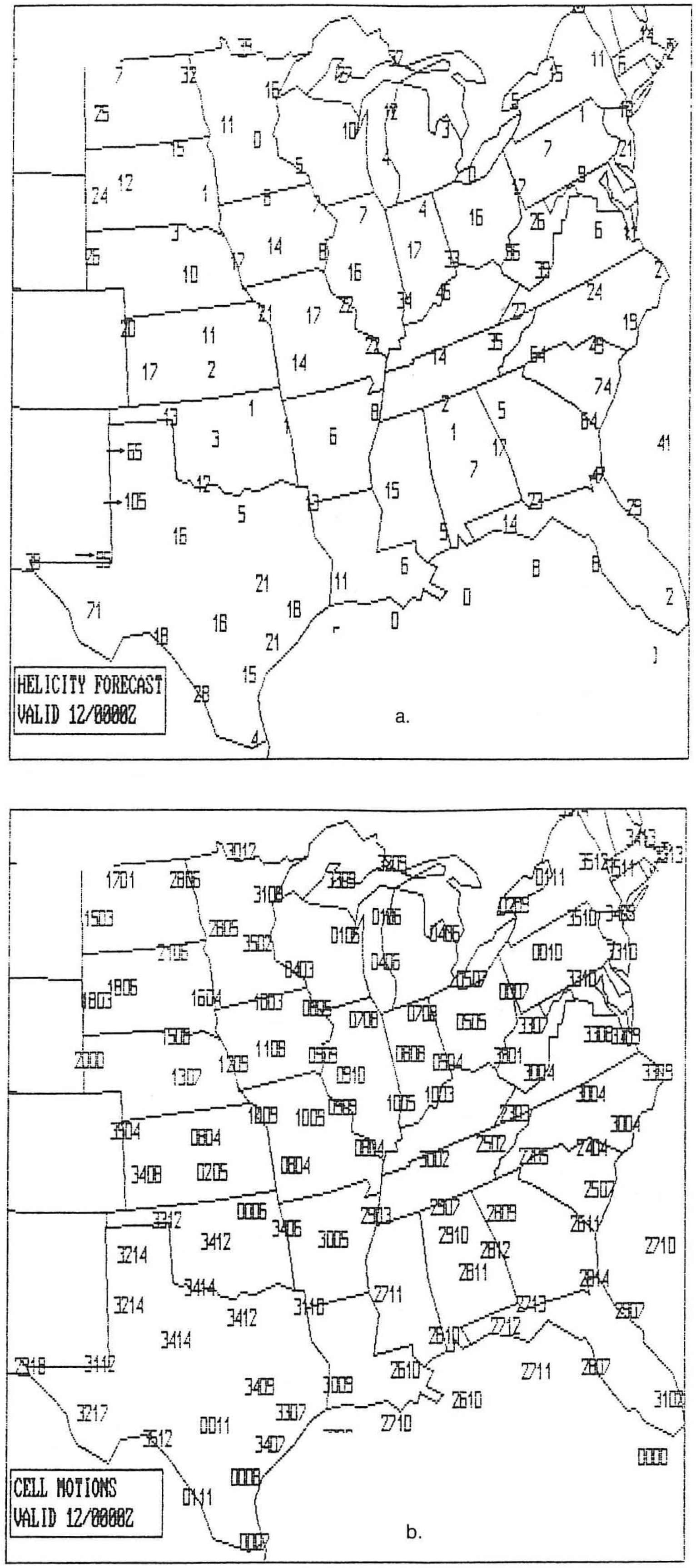

Fig. 4. Output from RHPP version 4.01 valid 0000 UTC 12 June 1992. (a) Helicity forecast. (b) Cell motion forecast.

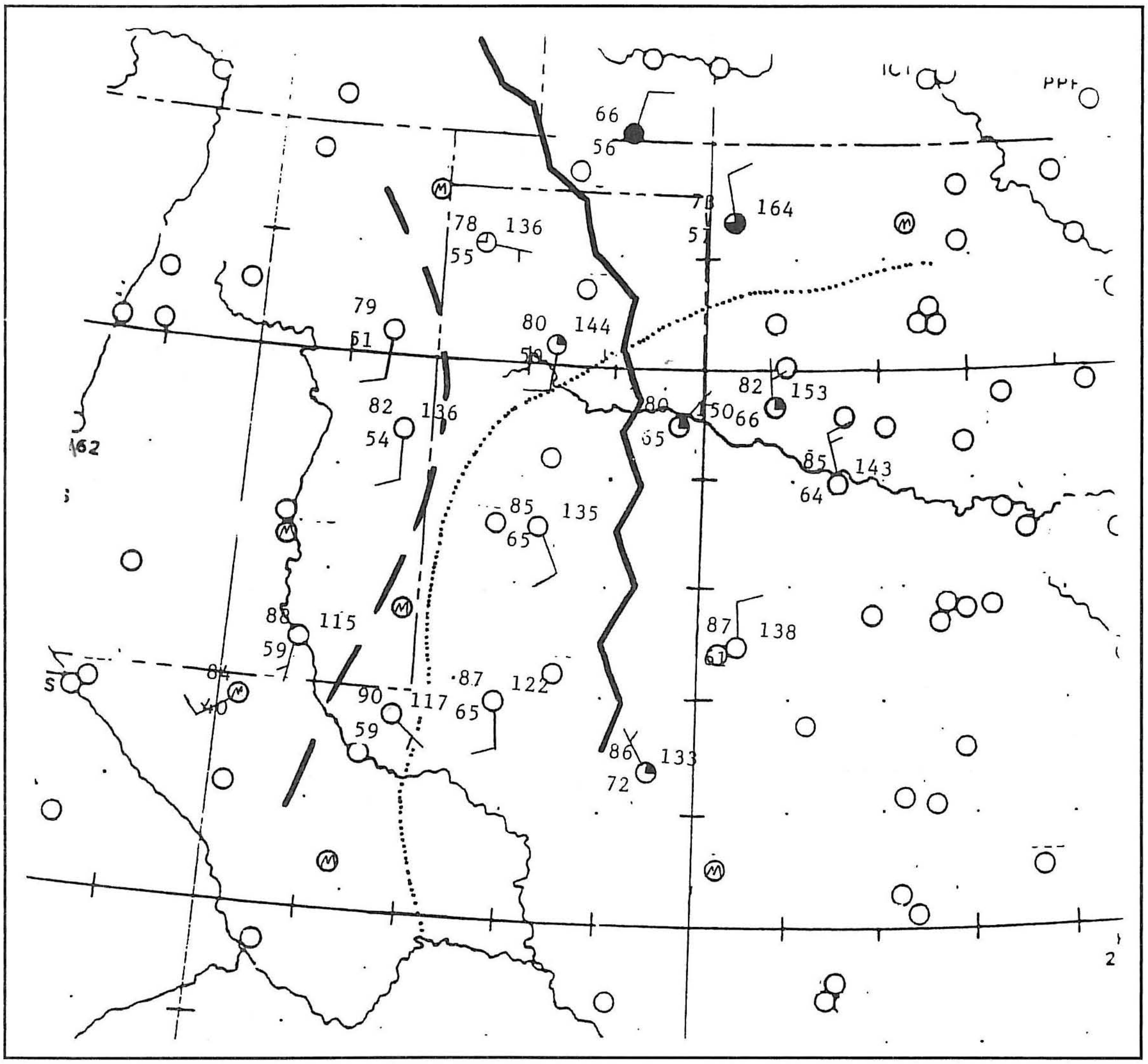

Fig. 5. As in Fig. 2, but for 1900 UTC 11 June 1992.

inflow wind directions changed little, but the speeds increased to around 30 knots. Thus, another of Davies-Jones et al.'s observed conditions for mesocyclone formation was met.

4. Discussion and Conclusions

An unusually severe and widespread severe weather outbreak struck western Texas during the late afternoon and evening of 11 June 1992. Tornadoes, giant hail, and extreme downburst winds combined to produce nearly $2 million of damage across the area. The event was characterized by a number of supercell storms which exhibited radar and visual evidence of mesocyclones.

The environment in which these storms developed proved to be intriguing. During the morning, the atmosphere was not conducive to significant convection, much less storm rotation. By mid-afternoon, surface heating and low-level moisture advection acted to destabilize the atmosphere. However, low- and mid-level winds remained weak, which suggested that significant storm rotation would not occur.

By utilizing actual observations of storm motion and surface wind to modify the convective environment displayed by the SHARP program, it was demonstrated that the environment could indeed support mesocyclone formation. The deviant storm motion which was observed seemed to be a significant storm-relative helicity-generating mechanism, although the backed surface wind contributed to the increased helicity as well.

Although the deviant storm motion was not predicted before the storms developed, PC-based tools allowed NWS forecasters to do a real-time assessment of the convective environment in the area. This case also illustrated the value of wind and cloud motion observations made by spotters in the field. As a postscript, modifications to RHPP have been made which enable the user to display and modify a forecast hodograph, for use in those cases when actual sounding data are either unavailable or unrepresentative.

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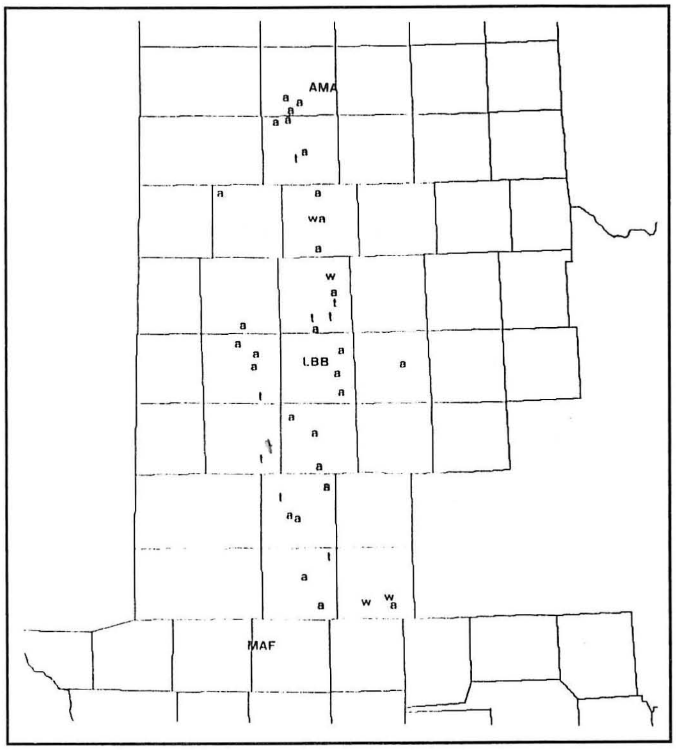

Fig. 6. Severe weather reports over northwest Texas from the afternoon and evening of 11 June 1992 between Amarillo (AMA), Lubbock (LBB) and Midland (MAF). (t = tornado, a = hail, w = thunderstorm wind)

and hodographs. Andy Anderson and David McLaughlin at the NWS Forecast Office in Lubbock, Texas provided the initial review of the manuscript. Dan Smith and Lans Rothfusz of the Scientific Services Division, NWS Southern Region Headquarters, provided additional comments. My thanks to Alan Moller, Larry Ruthi, and Steve Weiss for their reviews and suggestions. Melody Woodall assisted with the figure preparation.

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Gary R. Woodall received a B.S. in Meteorology in 1985 from Florida State University. He obtained a M.S. in Meteorology from the University of Oklahoma in 1988, and served with the University of Oklahoma severe storm intercept program during the spring seasons of 1986 and 1987. After completing his M.S. course work, he joined the National Weather Service as a Meteorologist Intern at the NWS Office in Midland, Texas. In May 1990, he was promoted to the position of Warning and Preparedness Meteorologist at the Weather Service Forecast Office in Lubbock, Texas. His meteorological interests include the design and evaluation of storm spotter networks and training programs, storm-environment interactions, and the visual and radar aspects of low-precipitation supercells. In July 1993, he moved to the Meteorological Services Division of the NWS Southern Region Headquarters, Fort Worth, Texas.

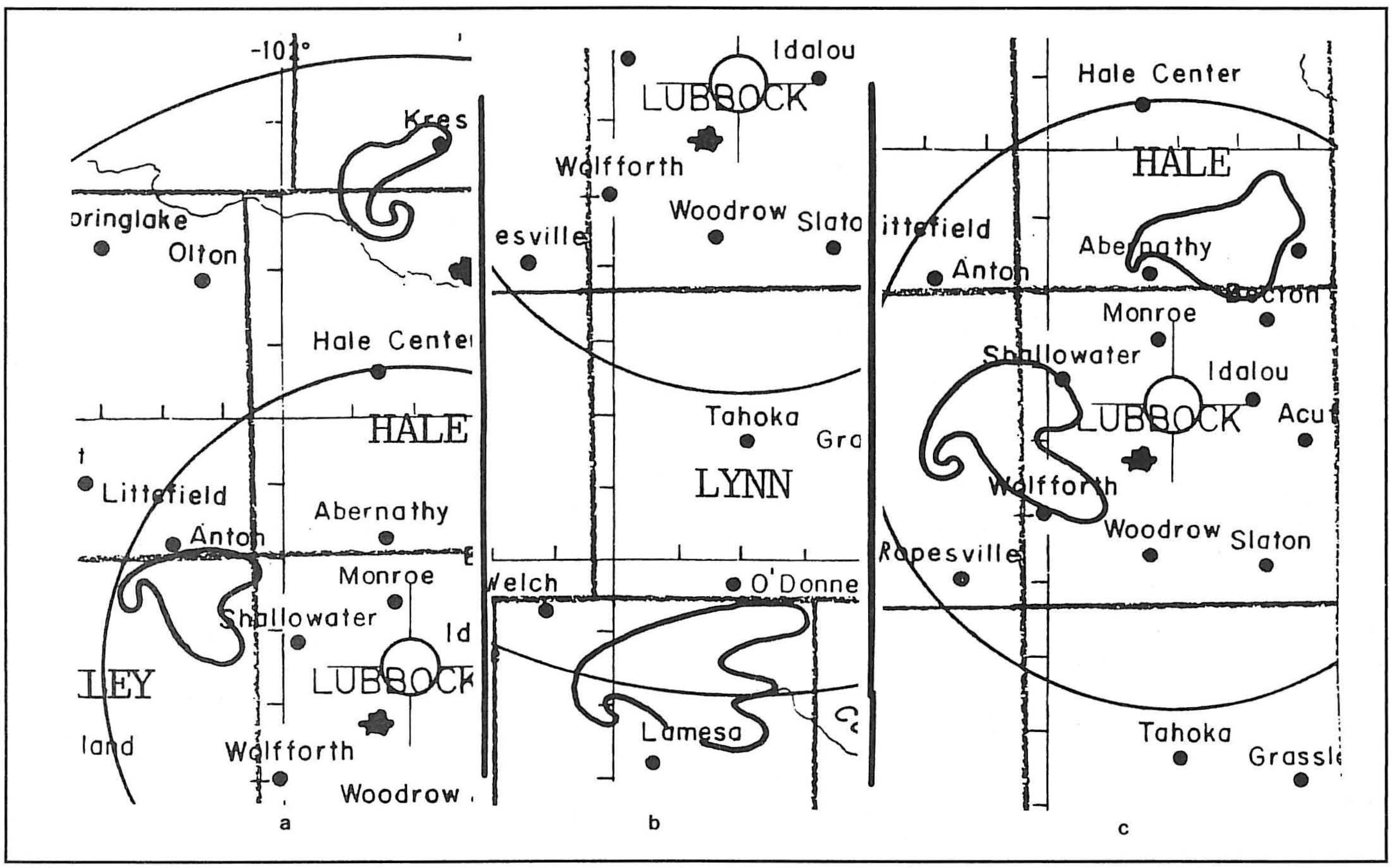

Fig. 7. Overlays from the Lubbock WSR-74C radar. Radar was in linear amplification mode with 18-24 dB signal attenuation selected. (a) 0012 UTC. (b) 0020 UTC. (c) 0055 UTC.

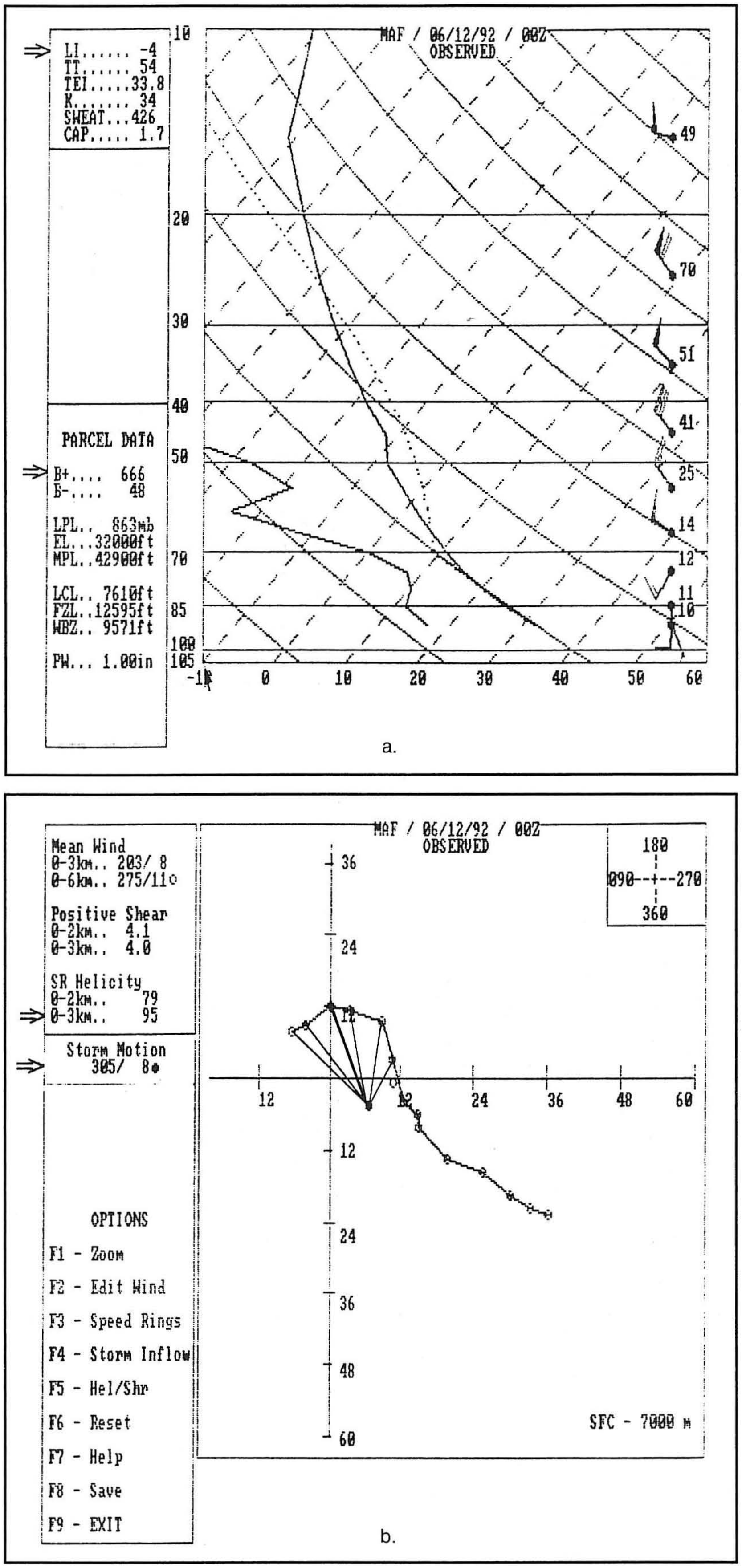

Fig. 8. Midland, Texas sounding taken 0000 UTC 12 June 1992. (a) Skew-T log-p diagram. Arrows point to pertinent stability indices. (b) Hodograph. Arrows point to cell motion and helicity.

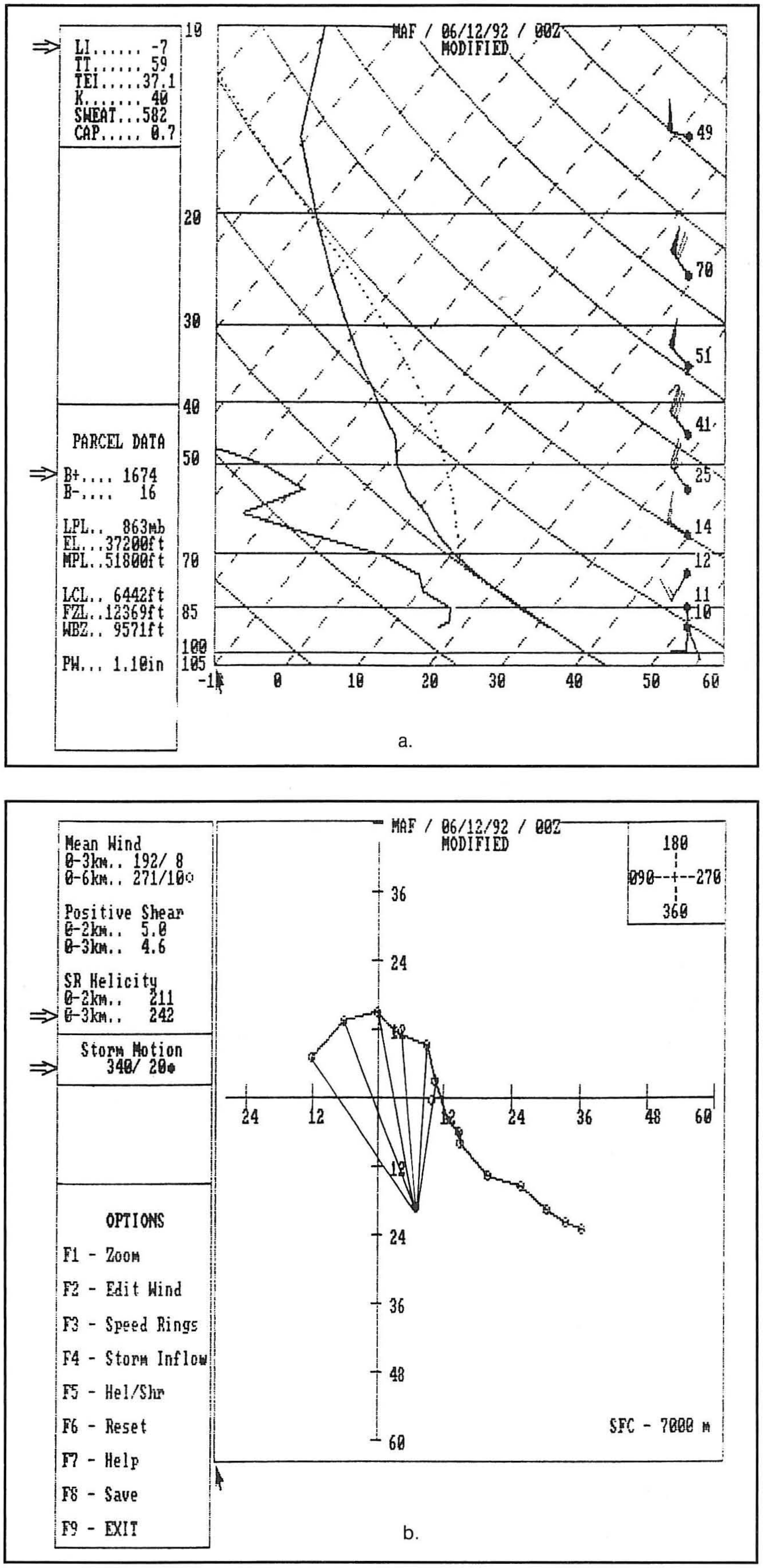

Fig. 9. As in Fig. 8, but sounding has been modified with LBB surface observation, low-level cloud motion observation, and radar-observed cell motion.

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