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THE EVOLUTION OF WIND PROFILE DERIVED HELICITY DURING A SEVERE WEATHER EVENT ACROSS SOUTH DAKOTA

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1. Introduction

On the evening of July 2, 1993, a mesoscale convective complex developed over western South Dakota, northwestern Nebraska, and northeastern Wyoming. This feature produced severe thunderstorms and a few tornadoes over the area. Figure 1 shows the locations of severe weather reports for this event.

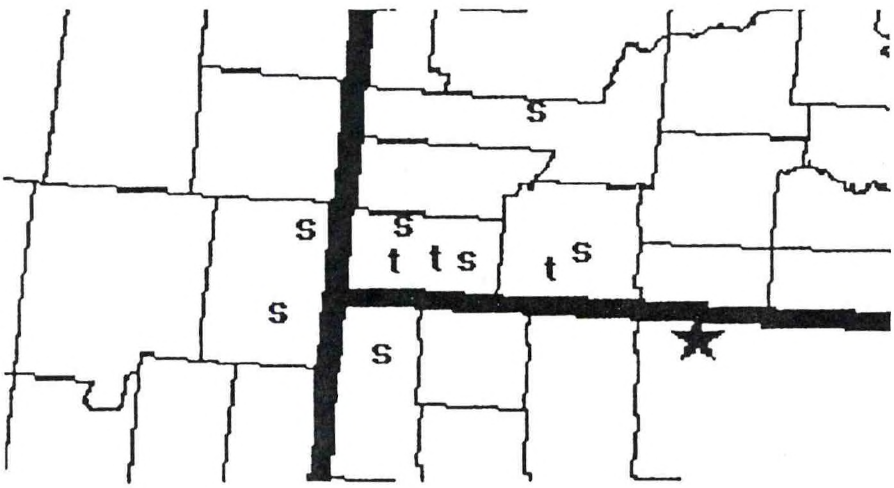

Figure 1. Location of severe weather events for the evening of July 2, 1993 (s denotes severe thunderstorms t denotes tornadoes star denotes the location of the Merrimen profiler).

Storm-relative helicity (s-r helicity) has proven to be a valuable tool in diagnosing an environment's potential for producing severe thunderstorms and, especially, tornadoes (Davies-Jones et al 1990). With recent advancements in software, the wind profiler network can now determine s-r helicities in real-time (Battel et al 1991). Since the Merrimen, Nebraska wind profiler was near this particular severe weather event, this study was undertaken to examine how profiler helicity values evolved during the episode.

2. Synoptic Scale Environment

There were reasons to believe that significant synoptic scale upward vertical motion was present during the event. Figure 2 shows the 50 kPa analysis which was performed by the Foster (1988) upper air analysis program. Observationally, there was little, if any, cyclonic vorticity advection occurring over the Northern Plains of the United States in the mid levels of the troposphere. Southwest flow occurred over the area, but the best lift due to cyclonic vorticity advection appeared to be over the western Rockies where a trough had moved. However, as depicted by the 70 kPa analysis shown by Figure 3, significant lower tropospheric warm air advection was implied. The strong warm air advection may have been the most important contributor to synoptic scale rising motion. This lift was revealed by the Q vector analysis which is shown in Figure 4.

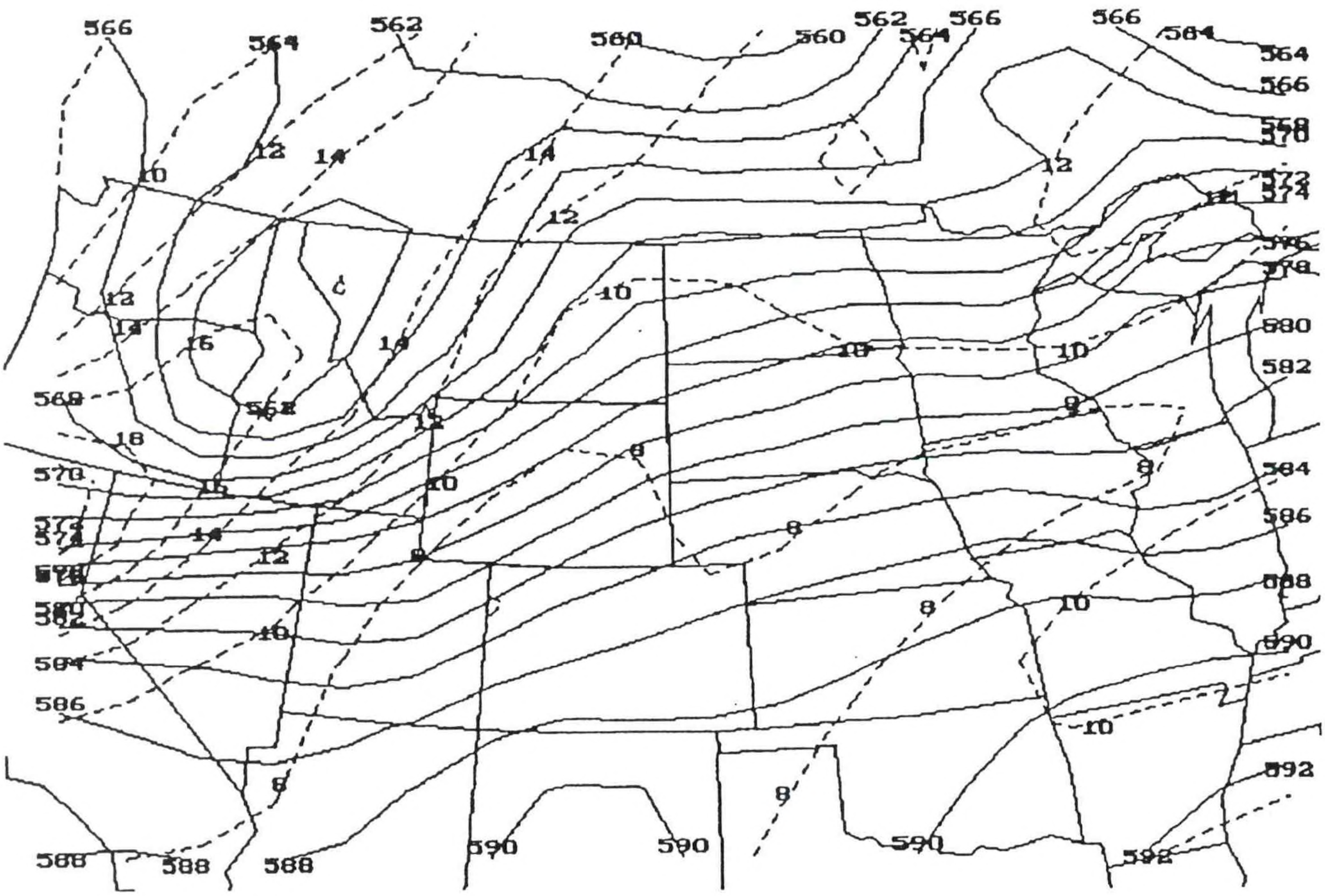

Figure 2. 50 kPa heights and vorticity (7/3/93 - 0000 UTC).

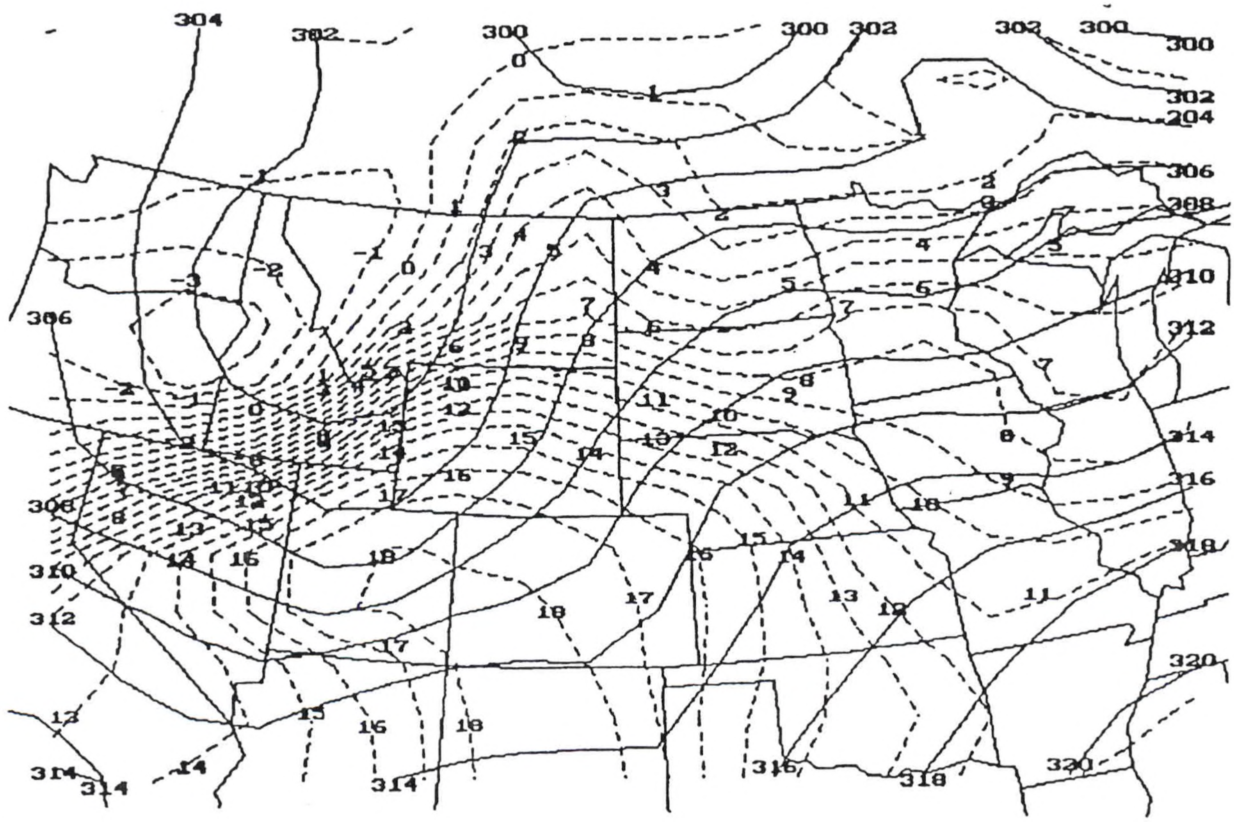

Figure 3. 70 kPa heights and temperature (7/3/93 - 0000 UTC).

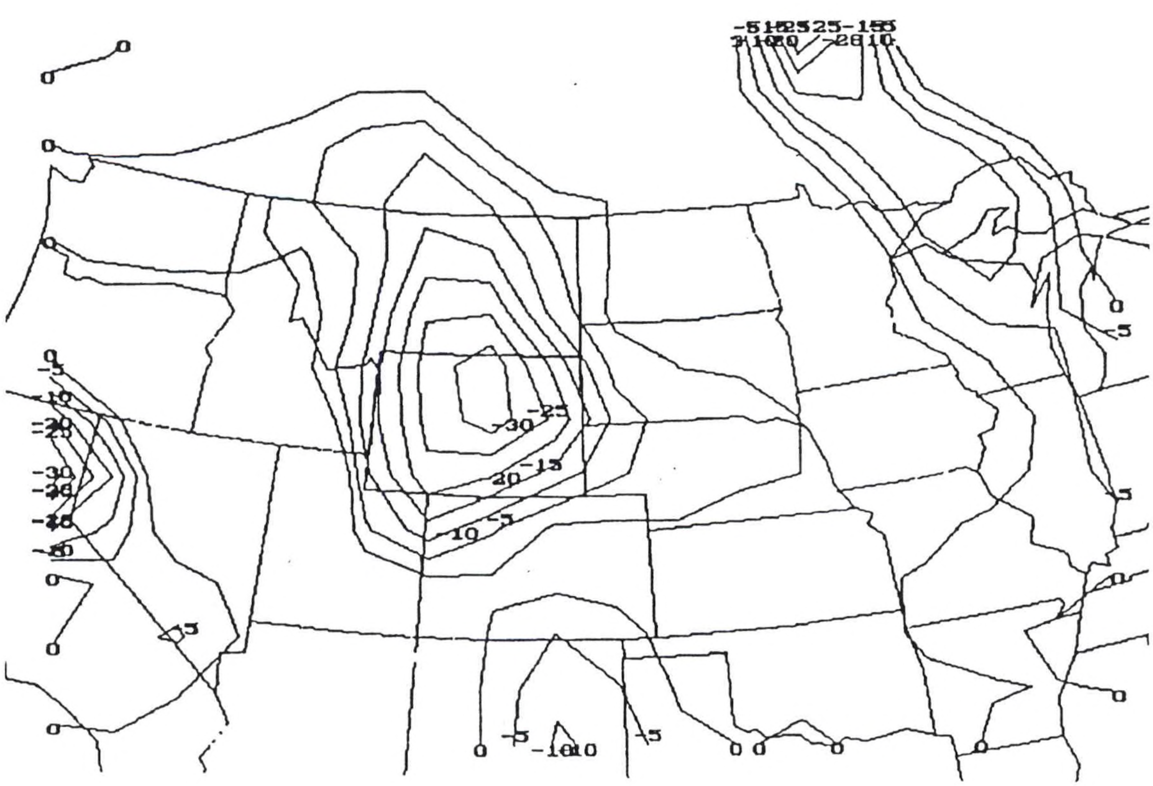

Figure 4. Divergence of Q Vector Analysis (07/03/93 - 0000 UTC). Note: Only areas of rising motion are analyzed on map.

There was also an abundant supply of moisture over southwest South Dakota. Figure 5 shows analyzed dew points over the area. It depicts a moisture tongue extending from central Nebraska to southeast Montana. Low-level wind fields were favorable for moisture convergence (also in Figure 5). Thus, there were additional lower tropospheric parameters favorable for upward vertical motion.

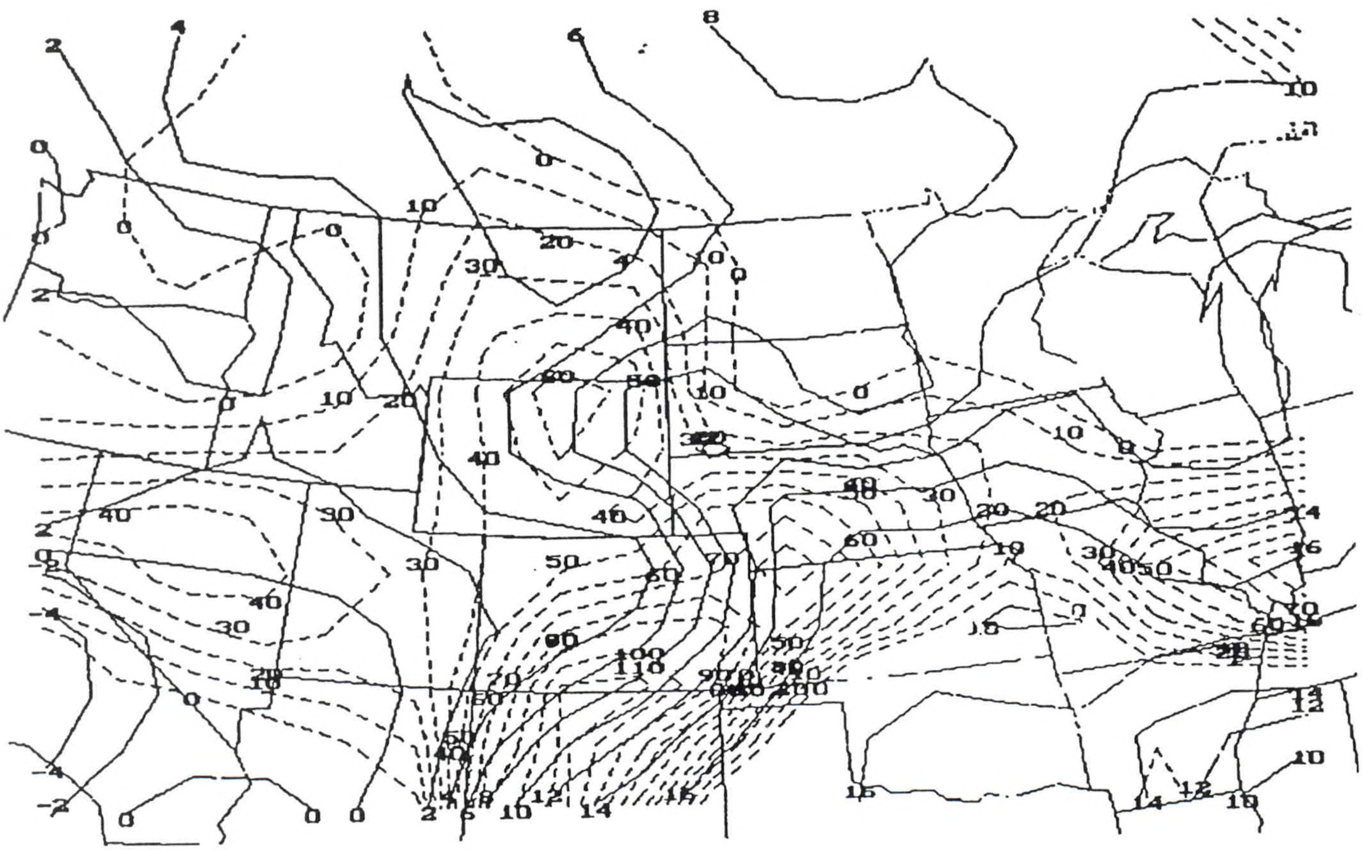

Figure 5. 85 kPa dew point (solid) and Moisture Convergence (dashed) Analysis (7/03/93 - 0000 UTC).

3. Thermodynamic Environment

The Rapid City (RAP), South Dakota upper air sounding for 3 July 1993 at 0000 UTC showed considerable instability (Figure 6). The Convective Available Potential Energy (CAPE), as calculated by the SHARP workstation (Hart and Korotky 1991), was approximately 2000 J/kg while the 50 kPa lifted index was -6°C. The combination of synoptic support, unstable air, and strengthening mesoscale lift due to increasing low level convergence set the stage for strong convective development.

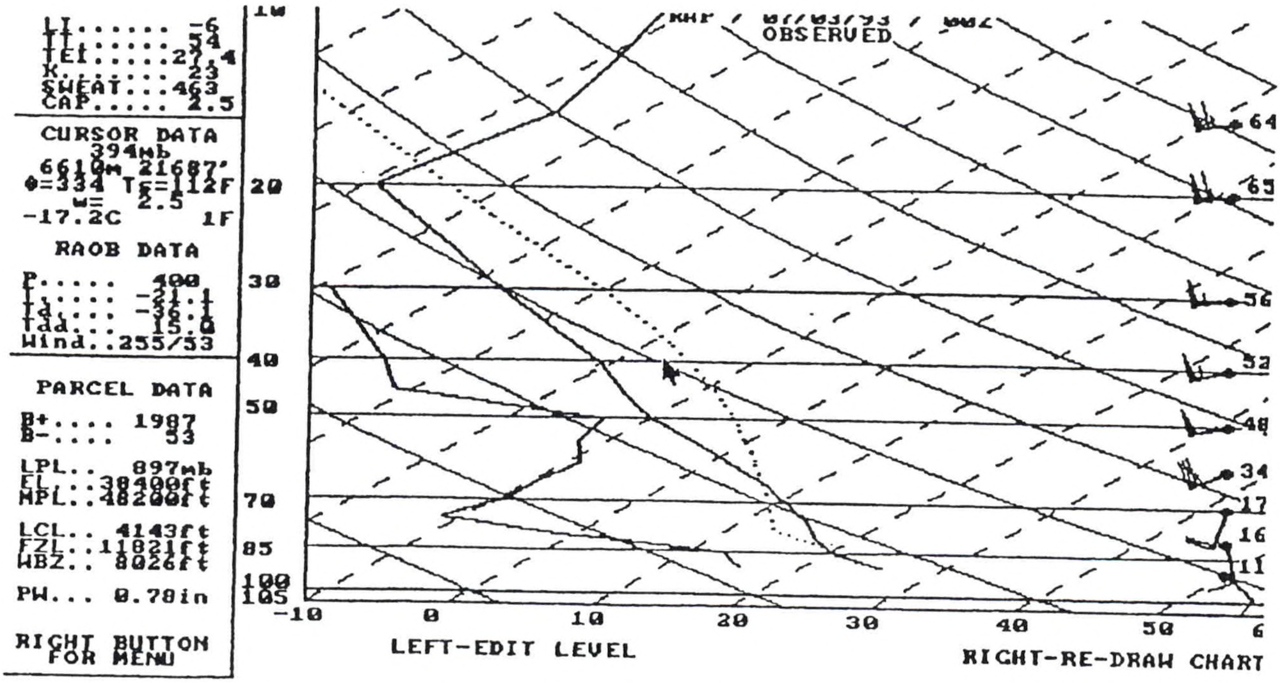

Figure 6. RAP Sounding (July 3, 1993 - 0000 UTC).

4. The Evolution of Storm Relative Helicity and Wind Shear through Profiler Data

The Merrimen, Nebraska profiler is located in the northern portion of the Nebraska panhandle (Figure 1). This profiler, like all others, not only offers a forecaster real-time wind data, but can also provide information on derived wind fields. Wind shear, helicity, storm inflow, and storm movement are all parameters that are calculated by the AFOS wind profiler software. Since the Merrimen profiler was close to the severe weather reported on the evening of July 2, 1993, an examination on how some of these parameters performed was undertaken.

The first severe thunderstorm of the evening occurred over east central Wyoming at 0130 UTC. This storm produced 1.75 inch diameter hail at Redbird, Wyoming, which is approximately 70 miles north of Cheyenne, Wyoming.

Figure 7 shows the Merrimen hodograph for July 3, 1993, at 0000 UTC, or about 90 minutes before the first reported severe weather. The estimated low level storm inflow was respectable with speeds between 25 and 30 knots. Net positive wind shear in the lower 2 km near the surface was 4.9 x 10 -3 s-1. This relatively low shear did not approach the lower limits for tornadic storms with CAPES near 2000j/kg as defined by Johns et al (1990). Helicity, too, was not impressive with a lower 3 km value of 107 m2/s2. By 0100 UTC, however, a dramatic increase in helicity was noted in the hodograph (Figure 8). The 0-3 km layer helicity increased to 174 m2/s2 which was an increase of 67 m2/s2 in an hour. This value was above the 150 m2/s2 rough helicity threshold for mesocyclone formation defined in the literature (Davies-Jones et al 1990). This increase in helicity implied an increased probability for tornadic thunderstorms to develop.

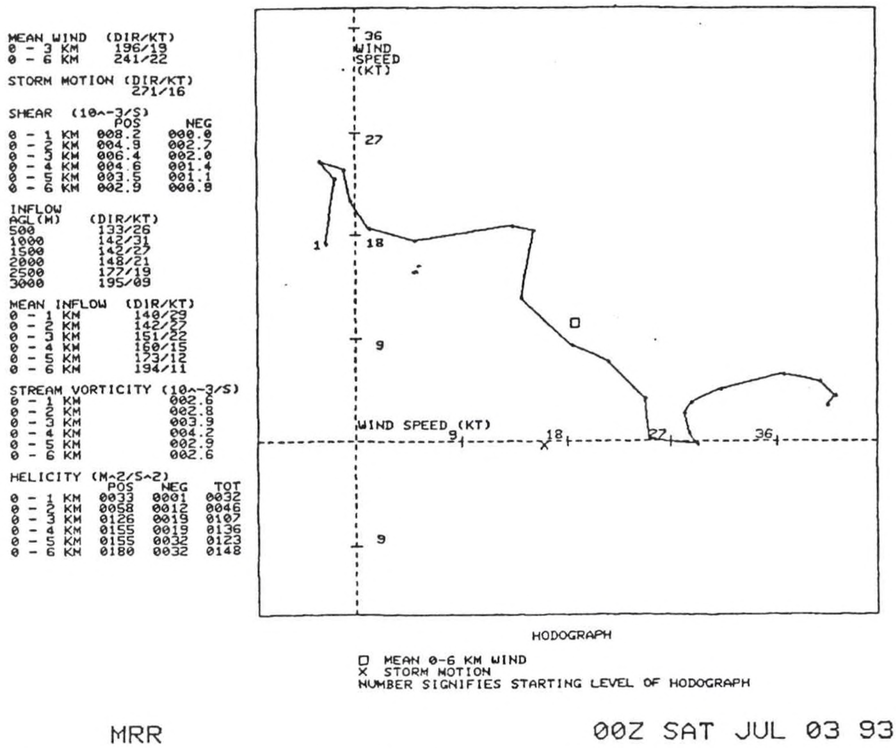

Figure 7. Merrimen Hodograph (7/3/93 - 0000 UTC).

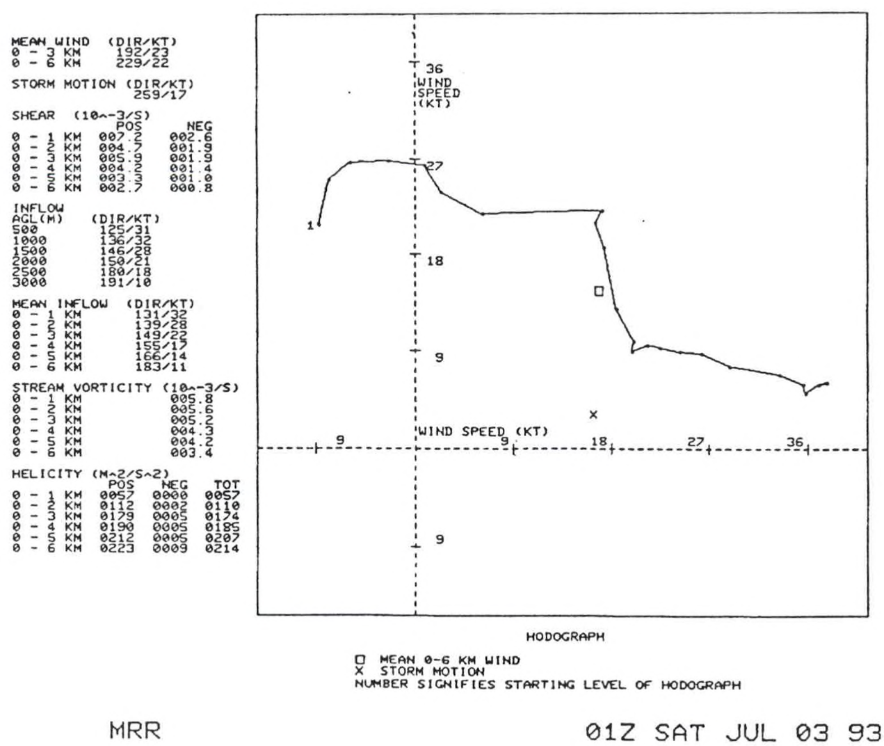

Figure 8. Merrimen Hodograph (7/3/93 - 0100 UTC).

Also, note that Figure 9 indicated a rather large increase in low-level winds. Speeds approached 40 knots. This increase in wind speed, probably due to the development of the nocturnal low level jet, increased low level convergence. This resulted in increased upward vertical motion.

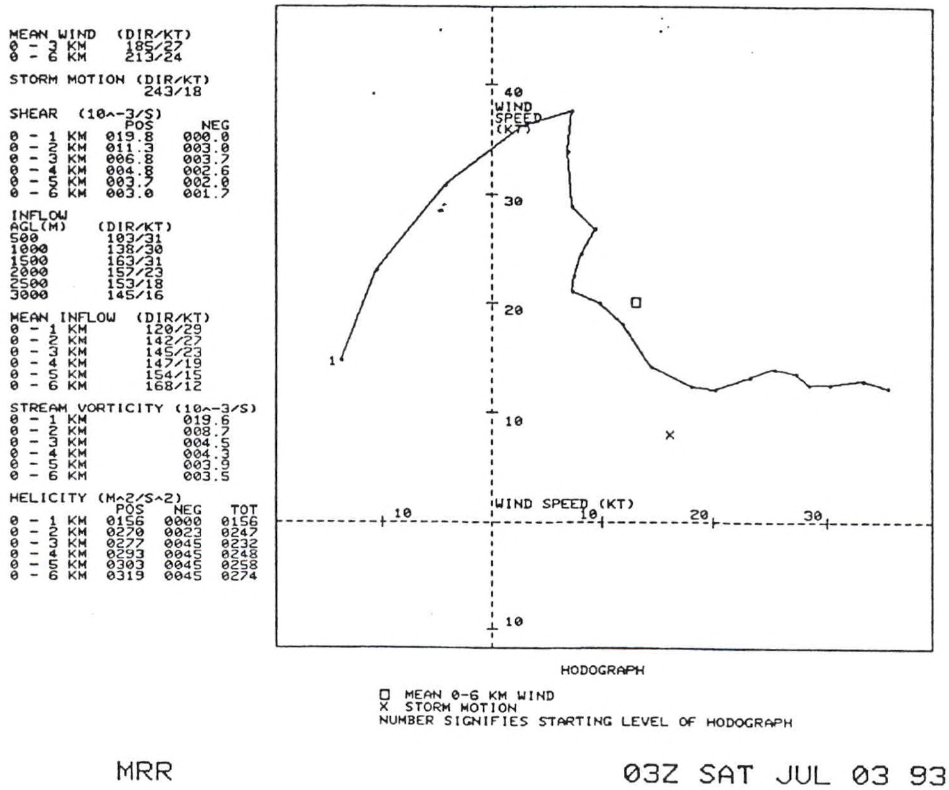

Figure 9. Merrimen Profiler (7/3/93 - 0300 UTC).

By 0156 UTC an F0 tornado was reported in southwest South Dakota two miles south of Provo, about 70 miles southwest of Rapid City. By 0211 UTC, one inch diameter hail occurred in the Nebraska panhandle 12 miles south of Harrison, about 50 miles north of Scottsbluff. Another tornado (F0) was sighted in southwest South Dakota at 0230 UTC, 5 miles north of Ardmore, about 75 miles southwest of Rapid City. Golfball sized hail also occurred at 0230 UTC near New Underwood, South Dakota, which is 20 miles east of Rapid City.

There is a definite diurnal cycle to severe weather over this area. Although thunderstorms occasionally continue past 0600 UTC, most convection dissipates by 0300 UTC (Ryrholm 1989). However, an examination of the Merrimen profiler at 0300 UTC (Figure 9) was even more impressive than in the past three hours. Helicity values had increased to 232 m^2/s^2 over the region which was a gain of 125 m^2/s^2 since 0000 UTC. The low level wind shear was also more impressive at 11 x 10^{-3} s^{-1}. The increase in helicity and wind shear indicated that convection would continue well into the night. The comparison of the wind shear with the Rapid City sounding CAPE continued to show a potential for tornadoes. The helicity also supported this.

Severe weather did continue through the night. Golfball sized hail occurred in east central Wyoming near Lusk, or about 65 miles north of Cheyenne, at 0300 UTC. Severe thunderstorm wind gusts occurred at Edgemont, South Dakota (65 miles southwest of Rapid City) as 0332 UTC. Pine Ridge, South Dakota, reported one inch diameter hail at 0457 UTC and sighted the third tornado (F0) of the event at 0500 UTC. The last reported severe weather of the night over this area occurred at 0522 UTC when golfball sized hail occurred at Oelrichs, South Dakota, about 65 miles south of Rapid City. However, all tornadoes were rated F0. Helicity values indicated that the environment would support weak tornadoes, but not much more than that.

As a side note, the convective complex responsible for the severe weather moved east during the night. It continued to produce more reports of severe weather and flash flooding over southeastern South Dakota from 0900 UTC to 1500 UTC.

5. Conclusions

Profilers obviously provide important wind data in relatively real-time. This is very useful during severe weather events when wind shears become critical. The profiler derived wind fields (including low level wind shears and helicities) provide detailed and valuable information to the operational forecaster. The information can be used to help predict convective intensity, duration, and if the profiler network is dense enough location.

Unfortunately, the wind profiler network is rarely dense enough. Wind profiler data is also not available to field offices until approximately 30 minutes after the hour. This means that forecasters should monitor upstream profiler sites for the latest trends in wind fields. With the advent of WSR-88D wind data, another information source has arrived to the severe weather forecaster and it is real-time. It is hoped that (1) software eventually be developed to calculate helicities using the 88D wind data, or (2) WSR-88D wind data be input into the national profiler program to increase the density of the network.

The monitoring of low level wind fields will provide detailed information on the trends of convective intensification. This leads to an obvious, but valuable, rule-of thumb: in an unstable and sufficiently moist environment, an increase in helicity enhances the potential for rotating updrafts and, therefore, tornadoes. Wind profilers can provide information on this helicity. Although weather office duties increase dramatically during periods of intense convective weather (issuing warnings and disseminating watches, monitoring radar, etc.), a quick glimpse at the derived wind fields from the profilers can provide valuable clues in short term forecasting of convection.

6. Acknowledgments

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