

Central Region Technical Attachment
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**EVOLUTION OF TWO 13 JUNE 2001 WEST-CENTRAL MINNESOTA TORNADIC
SUPERCELLS ALONG A WARM FRONTAL BOUNDARY**

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1. Introduction

On 13 June 2001, a strong mesoscale convective system formed over the Northern Plains and generated numerous tornadic thunderstorms across the region. A vast majority of the tornadoes occurred ahead of a cold front extending along the Missouri River basin. Two of the most destructive tornadoes, however, were associated with a warm frontal boundary that lifted into west-central Minnesota (Fig. 1).

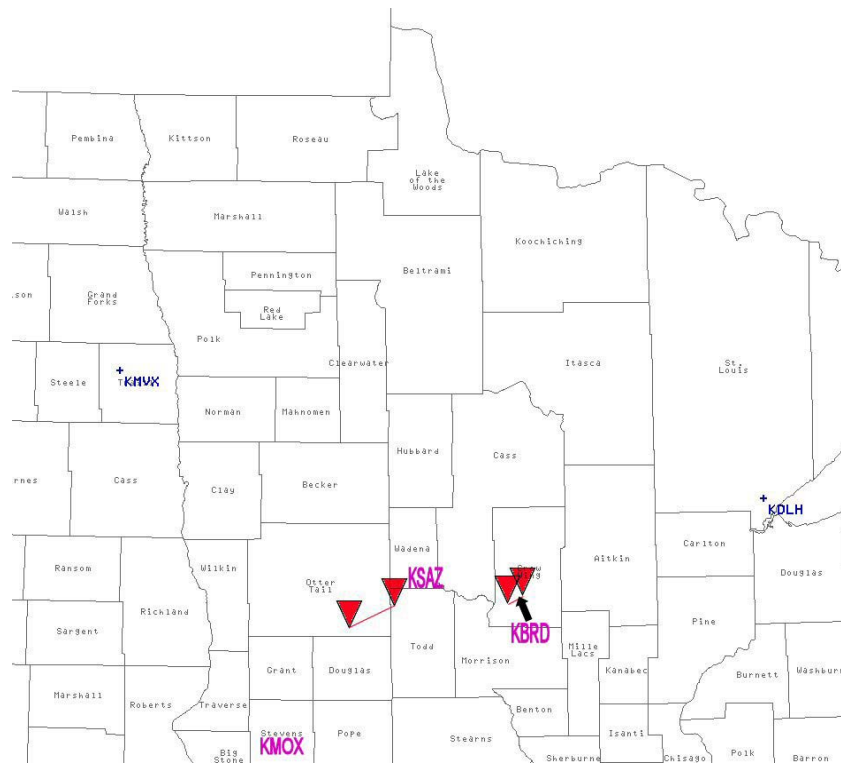


Figure 1. Map of Northern Minnesota with KMXV and KDLH WSR-88D radar locations, county names, the locations of KMOX, KSAZ, KBRD and tornado tracks. The tornado track on the left occurred near Parkers Prairie, MN while the track on the right was near Brainerd, MN.

This paper will deal with two aspects of the event. The first will focus on model performance and how the use of subjective meso-analysis helped provide meteorologists with good situational awareness. The second aspect will

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follow the evolution of the two tornadic high precipitation (HP) supercells as they moved along the surface warm frontal boundary.

2. Synoptic Pattern

At 1200 UTC 13 June 2001, surface features included a broad area of low pressure which extended from central South Dakota and southward into the Southern Plains. An associated warm front extended east-west from near Omaha, Nebraska to La Crosse, Wisconsin. Dewpoints across west-central Minnesota north of the warm front were around 60° F. The +70° F dewpoints were located south of the warm front across southern Iowa while an 850 mb equivalent potential temperature (θ_e) ridge extended into southern Minnesota. At 500 mb, a closed upper-level cyclone over western Wyoming led to southwest flow aloft over the Northern Plains. At 1800 UTC, the primary area of low pressure deepened over Kansas and Oklahoma while a secondary area of low pressure developed over South Dakota with a warm front extending into southern Minnesota. By 2200 UTC, the front reached its farthest northward extent in Minnesota, curving northeast from near Morris (KMOX) to Staples (KSAZ) and Brainerd (KBRD). Good low level moisture advection was present as dewpoints rose into the low 70°s F across central and southern Minnesota. At 0000 UTC, 14 June 2001, the surface warm front retreated back to the southeast resulting in northeasterly winds across northern and west-central Minnesota (Fig. 2). A 40 kt low-level jet advected +18° C 850 mb dewpoints northward and the 850 mb θ_e ridge (Fig. 3) punched into west-central Minnesota. Additional mid-level ascent was promoted by the left exit region of a 500 mb 50-60 kt jet streak.

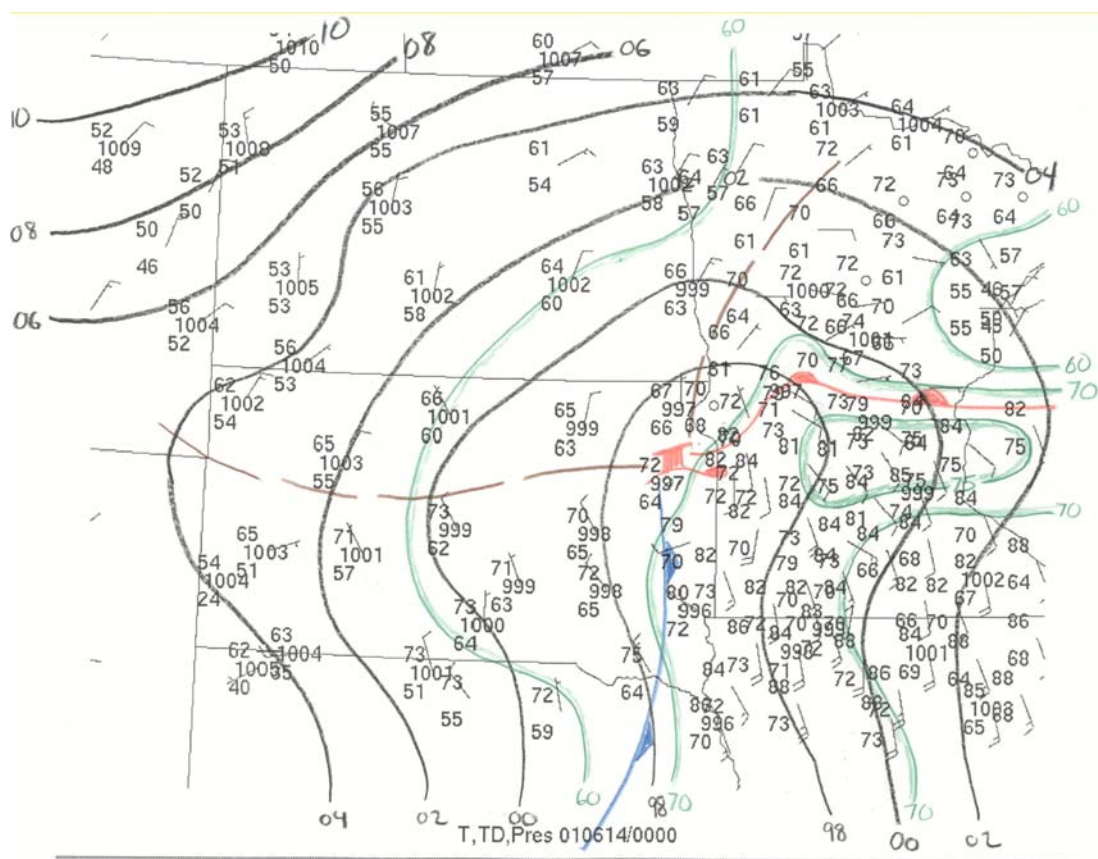


Figure 2. Surface Analysis for 0000 UTC 14 June 2001.

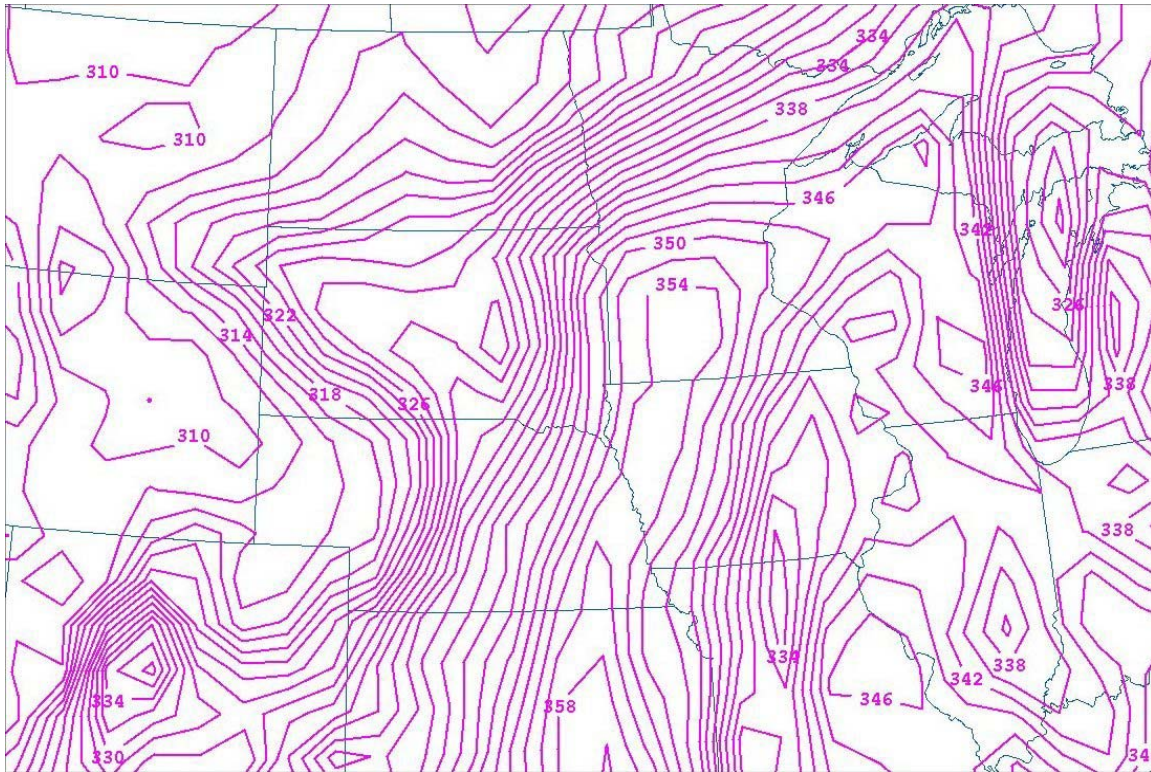


Figure 3. Rapid Update Cycle (RUC) 0000 UTC 14 June 2001 initialization of the 850 mb θ_e field.

3. Model Overview

The intensification of low pressure across South Dakota and the subsequent position of the surface warm front were vital to the evolution of the severe weather on 13 June 2001. The 0000 UTC and 1200 UTC 13 June 2001 operational model runs, with the exception of the 1200 UTC RUC (Fig. 4), did not handle the low pressure development across the northern plains and the northward propagation of the warm front and triple point into west-central Minnesota. Operational models strengthened the southern portion of the low pressure trough and suggested an inverted trough would extend northward into north central Minnesota (Fig. 5). The 1200 UTC ETA forecast 700 mb temperatures valid at 0000 UTC were 2°C to 4°C low compared to the 0000 UTC Aberdeen and Minneapolis soundings. With the 700 mb temperatures forecast too low, the ETA initiated convection prematurely due to a weak cap. The 1800 UTC to 2400 UTC ETA 6 hour QPF forecast of 2 to 4 inches (51 to 102 mm) across the area supports this. Such a scenario would likely have focused severe weather farther south across eastern Nebraska and northwest Iowa.

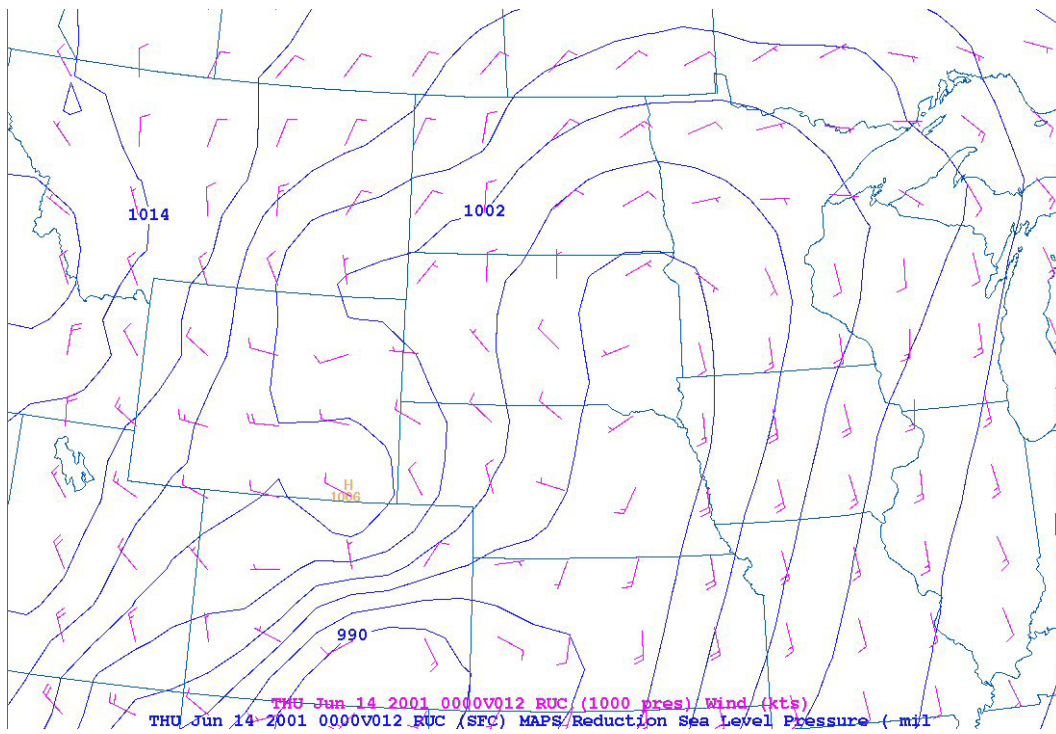


Figure 4. RUC twelve hour forecast valid at 0000 UTC 14 Jun for surface wind and mean sea level pressure.

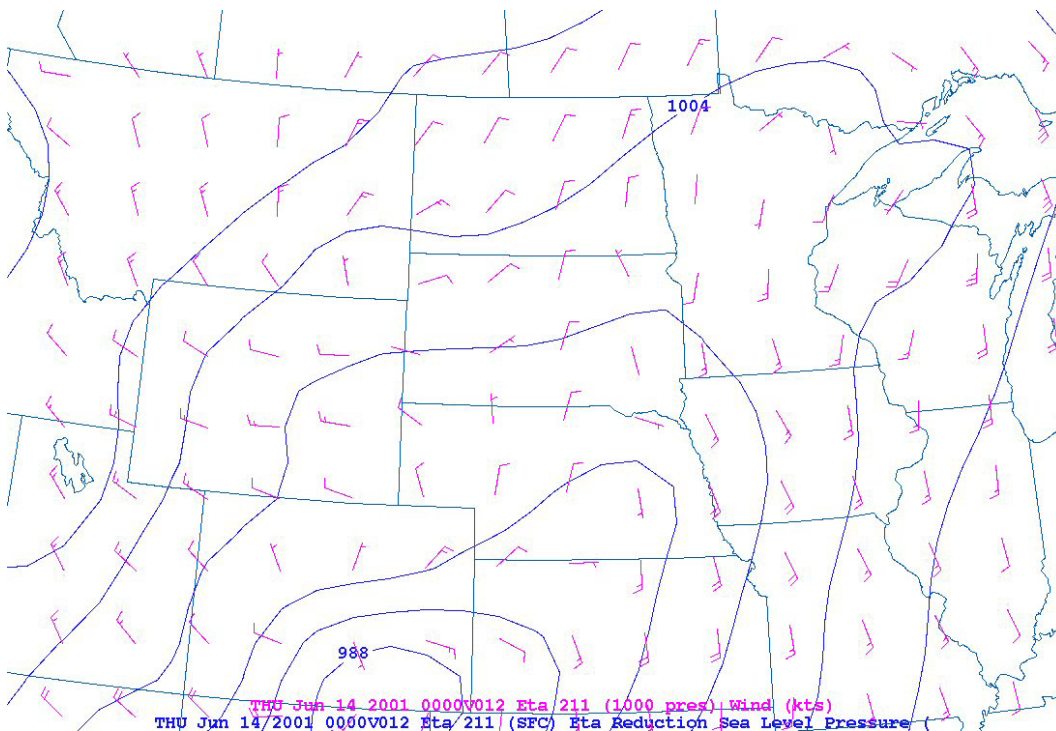


Figure 5. ETA twelve hour forecast valid at 0000 UTC 14 Jun for surface wind and mean sea level pressure.

A brief comparison between 1200 UTC ETA and RUC parameters near KSAZ showed significant differences. The severe weather risk parameters generated by the RUC indicated a higher risk for severe weather than those of the ETA. For the twelve hour forecast valid at 0000 UTC 14 June, three severe weather parameters were highlighted. From the RUC sounding (Fig. 6) convective available potential energy (CAPE) was 3890 J/Kg, 0-3 km storm relative helicity (SRH) was 111 m^2/s^2 and an energy helicity index (EHI) of 2.9. The ETA sounding (Fig. 7) forecast CAPE was 785 J/Kg, 0-3 km SRH was -12 m^2/s^2 and an EHI of -0.1. The ETA sounding profile suggests the model had initiated convection by 0000 UTC which drastically reduced the instability.

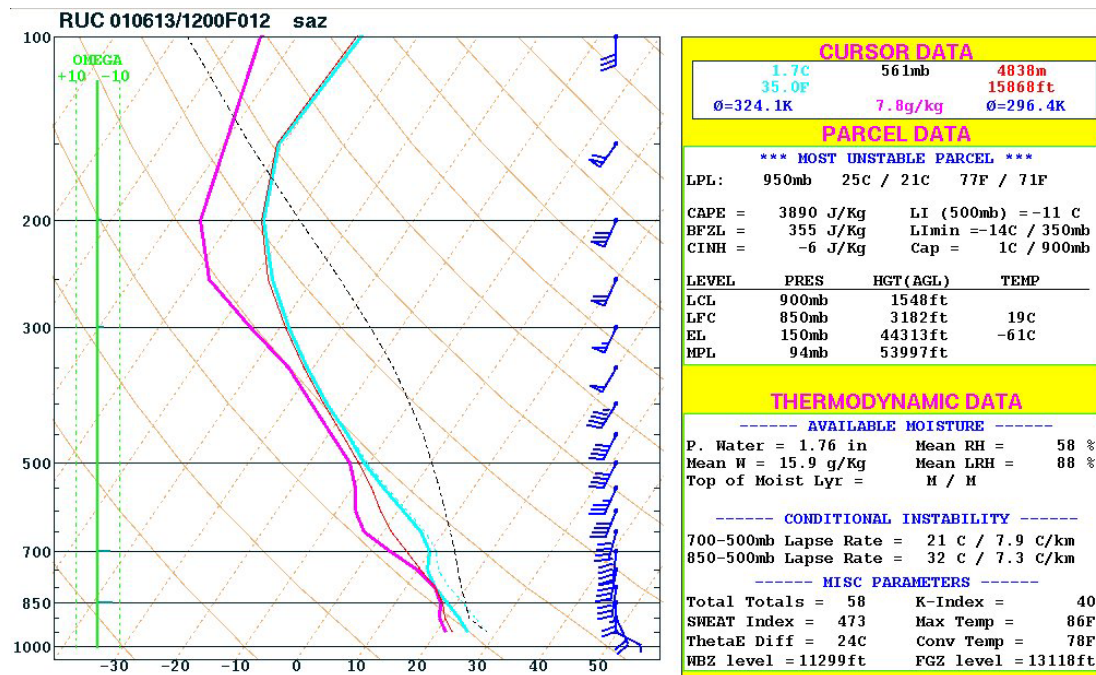


Figure 6. RUC twelve hour sounding for KSAZ valid at 0000 UTC 14 June 2001.

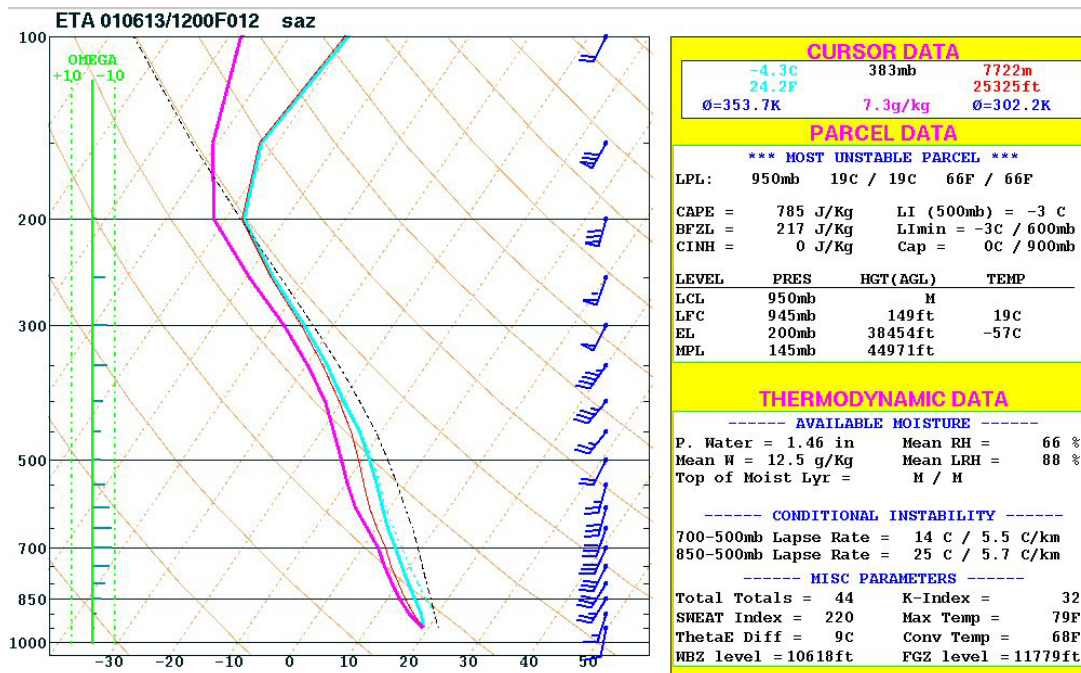


Figure 7. ETA twelve hour sounding for KSAZ valid at 0000 UTC 14 June 2001.

By 1800 UTC, surface subjective meso-analysis revealed a strengthening low pressure center over eastern South Dakota with the best pressure falls across west-central Minnesota. In addition, detailed hand analysis indicated that the warm front had moved into southern Minnesota and had begun to push north of the low pressure center. It became evident that of all the operational models, the RUC had the best overall handle on the mesoscale situation.

4. Supercell Evolution Along The Warm Frontal Boundary

A challenging aspect to the first thunderstorm (T1) was its path through four Minnesota counties and three National Weather Service (NWS) offices' county warning areas (CWA); Aberdeen (ABR), Grand Forks (FGF) and Chanhassen (MPX). T1 developed near the nose of the 850 mb θ_e ridge and along the surface warm front over Stevens County around 2200 UTC. This development occurred in the northeastern quadrant of the surface low and in a favorable region for intense tornadoes across the Northern Plains as suggested by Guerrero et al. (1998), Johns et al. (2000) and Broyles et al. (2002). T1 then began to move northeast and parallel to the warm front. Initial severe weather reports received included golfball sized hail at 2235 UTC in Stevens County and a brief tornado at 2240 UTC in Grant County. The 2300 UTC subjective meso-analysis indicated that the center of low pressure had moved eastward out of South Dakota and into Minnesota. As the low moved east, the warm front gradually retreated to the southeast. Shortly thereafter, T1 crossed over onto the cold side of the boundary and quickly intensified and acquired supercell characteristics. The Mayville (KMXV) WSR-88D, located 30 miles south of Grand Forks, began to display strong rotation on the 0.5 degree storm relative motion (SRM) product and a tornado warning was issued at 2308 UTC. Between 2353-0015 UTC, a tornado of generally F1-F2 intensity (with sporadic F3 damage) moved along a twelve mile track near Parkers Prairie, Minnesota.

Around 0000 UTC 14 June, another thunderstorm (T2) developed along the warm front over Douglas County and moved northeast. T2 produced two brief tornadoes between 0027-0045 UTC. Like T1, T2 intensified and

became a tornadic supercell as it pulled away from the warm front and passed over to the cold side of the boundary. T2 produced a tornado with F2 damage in the DLH CWA near KBRD around 0100 UTC.

One reason why the storms likely intensified and developed strong rotation and later a significant tornado may be best explained by Markowski et al. (1998). They suggested, through their findings during Project VORTEX, that a storm crossing a boundary would encounter an area of enhanced horizontal vorticity, which could then be ingested and tilted into the storm's updraft. In addition, Rasmussen et al. (2000) hypothesized that boundaries may lead to an environment more conducive to the development of significant tornadoes due to the generation of enhanced SRH in their vicinity. Surface based instability existed on the cold side of the boundary with CAPE of 1000 to 1500 J/Kg present. The instability may have allowed the storms to remain rooted in the boundary layer and more readily able to ingest the low level horizontal vorticity, resulting in rapid mesocyclogenesis. Finally, very low lifted condensation levels (LCL) around 300 m were encountered as the supercells moved onto the cold side of the boundary. Rasmussen and Blanchard (1998) found that tornadic supercells tended to occur in environments with lower LCLs than non-tornadic supercells. Over half of the tornadic supercells in their data set occurred with an LCL lower than 800 m. Rasmussen and Blanchard hypothesized lower relative humidity in the boundary layer would support stronger storm outflow associated with evaporative cooling in the low levels. A larger cold pool would reduce the tornadic threat.

5. Office Response (FGF)

At 1100 UTC 13 June, a Hazardous Weather Outlook (HWO) was issued mentioning a slight risk for severe weather with the main threats being heavy rain, damaging winds and large hail. Subjective meso-analyses throughout the day continued to show a warm front progressing northward through Minnesota and by 2100 UTC, it entered the extreme southeastern part of the FGF CWA. The HWO was updated at 2100 UTC to highlight the increased severe weather threat and the potential for tornadoes. A strongly worded short term forecast, issued at 2150 UTC, said severe thunderstorms would quickly develop across the region and possibly produce isolated tornadoes.

Initially, warning meteorologists used KABR WSR-88D radar to monitor T1 as it drew near Grant County. A tornado warning was issued at 2208 UTC for Grant County with a brief tornado reported at 2240 UTC. T1 crossed into Douglas County (MPX CWA) around 2245 UTC. Despite being 110 nautical miles (177 km) away from the storm, KMX radar became the closest radar to the storm and became the primary data source used as T1 moved through Douglas County and towards southeastern Otter Tail County (FGF CWA). Between 2258-2308 UTC, the storm quickly intensified and developed 45 kts of rotational velocity (V_r shear) at a height of 16,500 ft (5030 m) as seen on the 0.5 degree SRM. A tornado warning was issued for Otter Tail County at 2312 UTC and mentioned the storm would be near Parkers Prairie at 2345 UTC. At 2353 UTC, weather spotters reported a tornado 1 mile northwest of Parkers Prairie. At 0000 UTC 14 June 2001, the tornado warning for Otter Tail County was extended until 0030 UTC. The 0004 UTC 0.5 degree SRM (Fig. 5) image continued to show strong rotation with 55 kts of V_r shear at 15,100 ft (4600 m) as the tornado remained on the ground and moved northeast before dissipating around 0012 UTC.



Figure 5. 0.5 degree KVMX SRM image for 0004 UTC 14 June 2001.

6. Summary and Conclusions

The tornadic event of 13 June 2001 illustrated the importance of situational awareness and how the use of subjective hand analyses alerted meteorologists to a heightened tornadic threat. Once storms developed, warning meteorologists knew the environment was conducive to tornadic development. Tornado warnings were issued aggressively, leading to a 32 minute lead time for the Grant County tornado and a 41 minute lead time for the Otter Tail County tornado. Radar signatures must be interpreted with an understanding of conceptual models that are used in an appropriate context based on meso-analysis of the near storm environment.

Both T1 and T2 developed along the warm front and began to move northeast. Due to the bow shape and retreating nature of the front, both storms began to move onto the cold side of the front and intensified rapidly. A few weak tornadoes touched down with the storms as they traveled along the boundary. Both storms produced significant tornadoes shortly after crossing into the cold air. This is another case that supported Markowski's et al. (1998) hypothesis of the increased tornadic risk as a thunderstorm encountered an enhanced area of horizontal vorticity on the cold side of a surface boundary.

Acknowledgements

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