Central Region Technical Attachment
Number 05-01
March 2005

Rapid Tornadogenesis in Nelson County, ND - 18 July 2001

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1. INTRODUCTION

A supercell thunderstorm developed rapidly in southwest Nelson County, North Dakota during the afternoon of 18 July 2001, and produced a long lived tornado which produced weak F3 damage. The tornado occurred in an area with numerous intersecting surface boundaries. The tornadic supercell's mid level rotation persisted for only 10-15 minutes before producing the tornado. Research done by Burgess et. al (1993) on supercell thunderstorms have shown mesocylones were present on average at least 36 minutes prior to tornadogenesis. The Nelson county tornado also occurred very close to three distinct boundaries. Research by Atkins et al. (1999) revealed that mesocylonic low level circulations were "stronger and more persistent" in the vicinity of boundaries, than when boundaries were not present. During Project VORTEX, 70% of F2 or greater tornadoes occurred near low level boundaries (Markowski et al. 1998a). In addition, the tornado occurred on the cool side of a boundary, which could have led to lower lifted condensation levels (LCLs) in the local tornadogenesis region. Recent research has indicated that lower LCLs may aid in tornadogenesis, which occurs often on the cool side of boundaries (Markowski 2003).

This paper will examine the rapid tornadogenesis as seen from the WSR-88D and mesoanalysis perspective. In addition, hypotheses are presented as to why tornadogenesis occurred so quickly, and if this tornado could have been anticipated sooner with the environmental conditions that were present.

2. SYNOPTIC OVERVIEW

A broad west to southwest flow was present in the upper troposphere, as a 30 m/s speed max was approaching the Northern Plains at 300 hPa, along with divergence at 300 hPa (Fig. 1). Dry air was being advected into the region in the mid levels, as 700mb dewpoint depressions rose around 2 degrees C from 1200 UTC to 0000 UTC near Bismarck, ND (KBIS). A very unstable low-level environment was present with convective available potential energy (CAPE) values around 6,000 J/Kg noted in northeastern North Dakota during the afternoon hours. Storm relative helicity (SRH) and shear values were in the moderate category with 0-3km SRH values around 200 m^2/s^2, and around 35kts of bulk shear in the 0-6 km layer. Abundant moisture was available as well, with surface dewpoints in the low and middle 70s and precipitable water amounts around 1.50 inches.

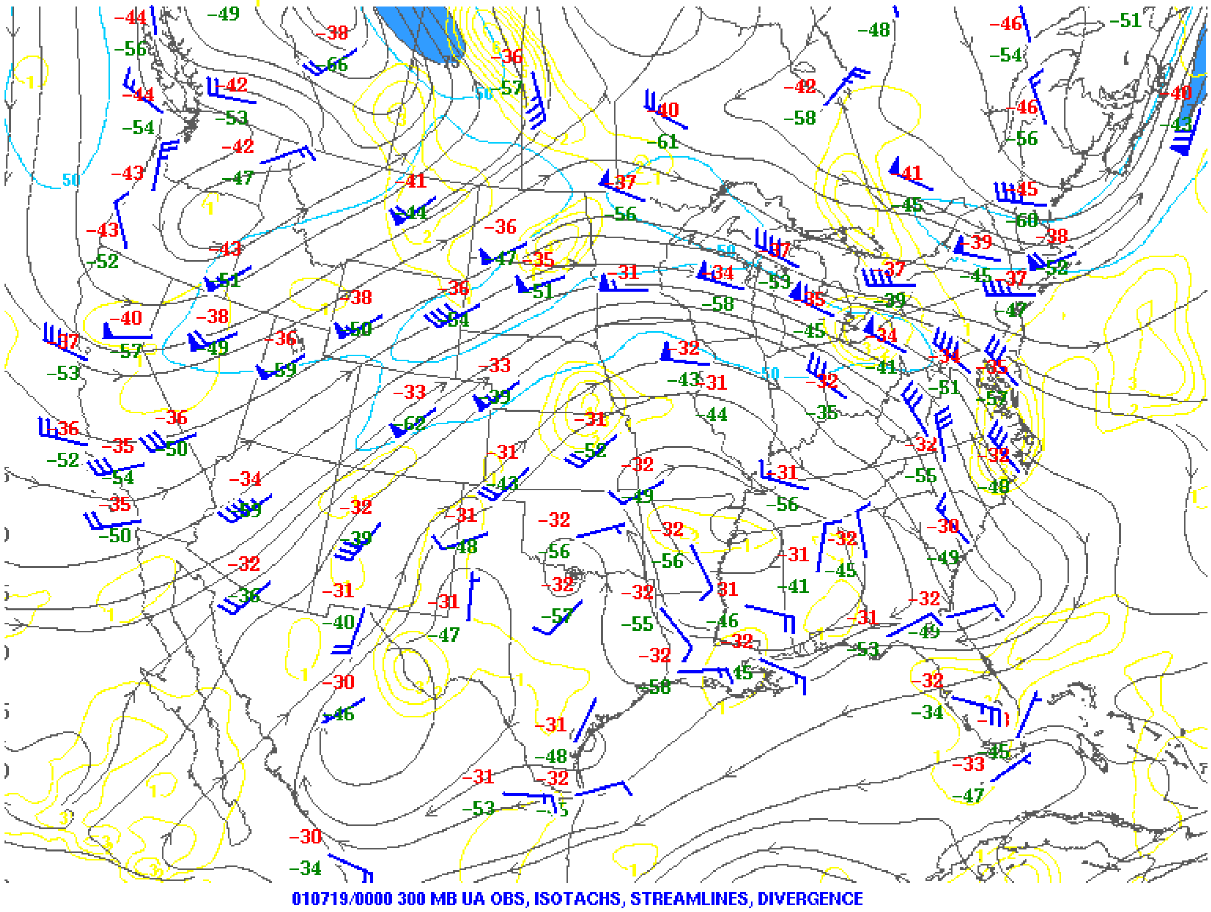

Figure 1. 300 hPa analysis for 00 UTC 19 July 2001 (figure courtesy of the SPC).

3. MESOSCALE ANALYSIS

Numerous surface boundaries and a meso-low were present on the surface analysis near the eventual tornadogenesis region around tornadogenesis time at 2300 UTC (Fig. 2).
The boundaries intersected over northeastern North Dakota. These discontinuity lines were also seen on the KMVX WSR-88D base reflectivity imagery oriented from south-southwest to north-northeast and from south-southeast to north-northwest. Additionally, horizontal convective rolls were oriented southeast to northwest at 2238 UTC in the base reflectivity imagery (Fig. 3).

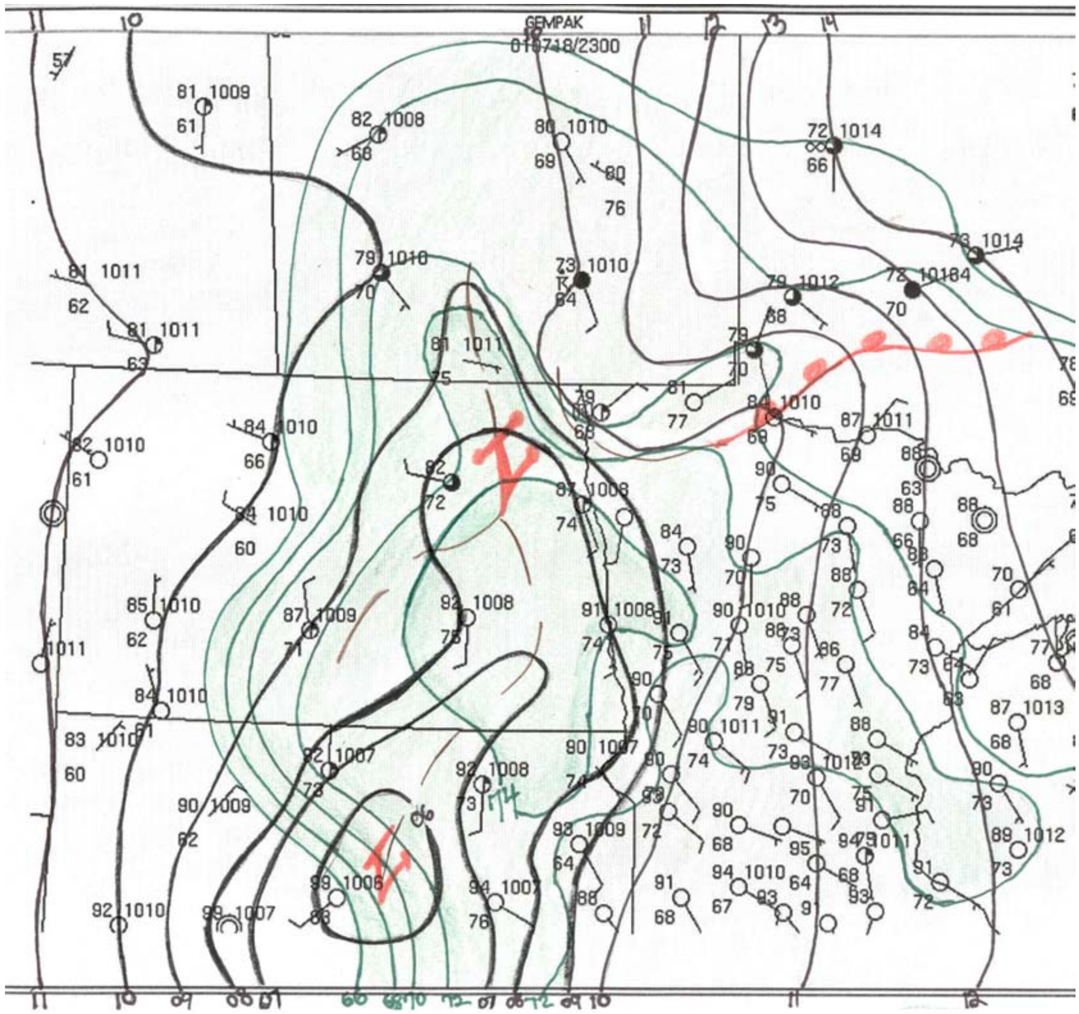

Figure 2. Surface analysis for 2300 UTC 18 July 2001.

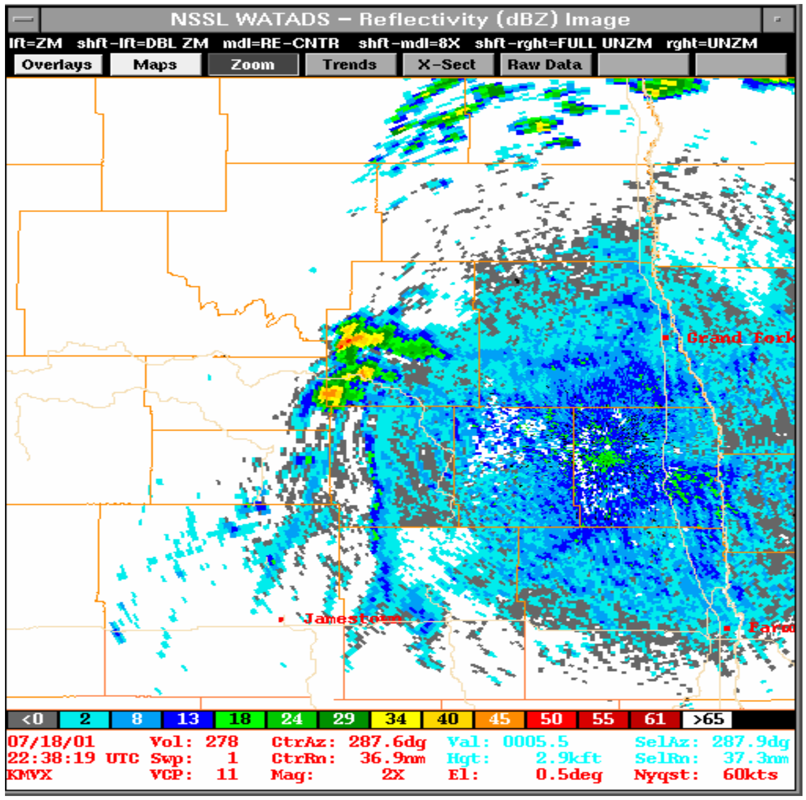

Figure 3. KMVX WSR-88D 0.5 degree base reflectivity image at 2238 UTC on 18 July 2001.

The movement of the surface boundaries throughout the afternoon was seen in the surface analyses, as well as in the radar reflectivity imagery. A meso-low circulation developed around 2200 UTC in northeastern North Dakota, shortly before tornadogenesis commenced around 2300 UTC. This focused boundary layer convergence near the intersection of the mesoscale boundaries. At 2100 UTC, the 0-3km SRH near Grand Forks from the 1200 UTC Eta showed values around 200 m^2/s^2. Locally enhanced SRH likely occurred in the vicinity of the supercells interacting with surface boundaries over Nelson and surrounding counties similar to observations noted by Rasmussen and Markowski (2000). The hodograph from the Dimmitt, TX tornado of 2 June 1995 revealed an SRH of 1100 m^2/s^2. It is hypothesized that augmentation of the local SRH occurred in the vicinity of the tornado, which was near numerous surface boundary intersections. In addition, the rapid tilting and stretching of horizontal vorticity into vertical vorticity from the powerful updraft likely led to rapid tornado formation once the supercell crossed onto the "cold" side of the boundary (Markowski et al. 1998a).

4. RADAR ANALYSIS OF THE TORNADIC SUPERCELL

Horizontal convective rolls, along with N-S and SW-NE oriented boundaries were present in southwestern Nelson County before convective initiation occurred around 2213 UTC . A cross section of reflectivity imagery (Figs. 4 and 5) shows the rapid growth of the supercell from 2246 UTC until 2323 UTC, and the attendant strong updraft with a pronounced Bounded Weak Echo Region (BWER).

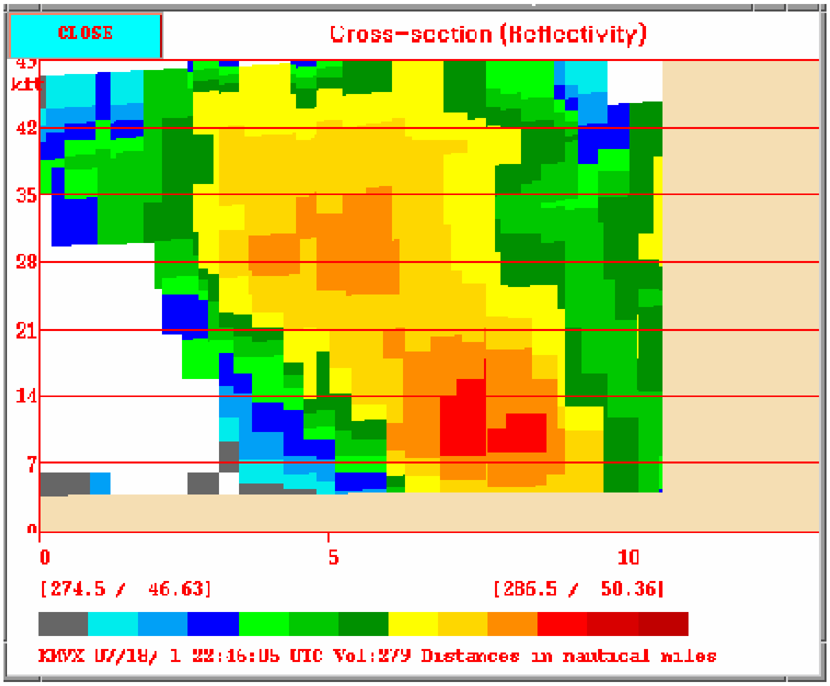

Figure 4. KMVX WSR-88D reflectivity cross section at 2246 UTC 18 July 2001.

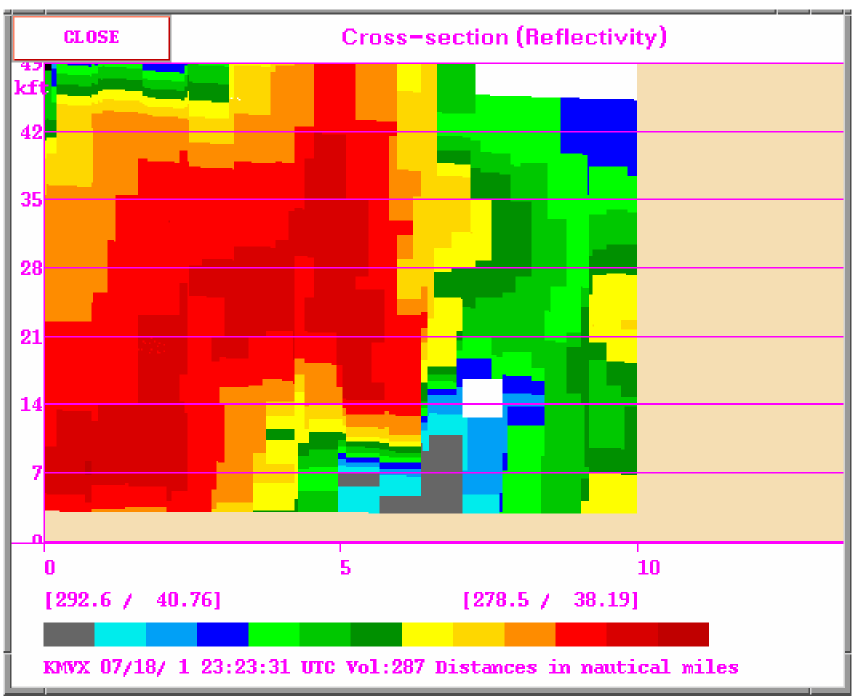

Figure 5. KMVX reflectivity cross section at 2323 UTC on 18 July 2001 with pronounced bounded weak echo region.

Mid level rotation in the KMVX WSR-88D storm relative motion (SRM) data increased from a very weak circulation at 2240 UTC (Fig. 6), to a moderate intensity mesocyclone fifteen minutes later at 2255 UTC near the southernmost supercell (Fig. 7). The circulation aloft rapidly translated to the surface, with the first tornado reported around 2255 UTC. Therefore, the mesocyclone formed approximately fifteen minutes before producing a tornado. Research done by Burgess et al. (1993) indicate mesocylones formed approximately 36 minutes before tornadogenesis. This tornado developed shortly after a mesocyclonic circulation in the mid-levels was first detected. Furthermore, using data from 52 tornadic storms, Trapp et al. (1999) found that 48% of the tornado vortex signatures (TVS's) either (1) were first detected near the ground and grew upward or (2) appeared nearly simultaneously over a significant depth of the storm. The present case fits the latter scenario. The mean tornado lead time for these "nondescending" TVS's was 5 minutes (Trapp et al. 1999).

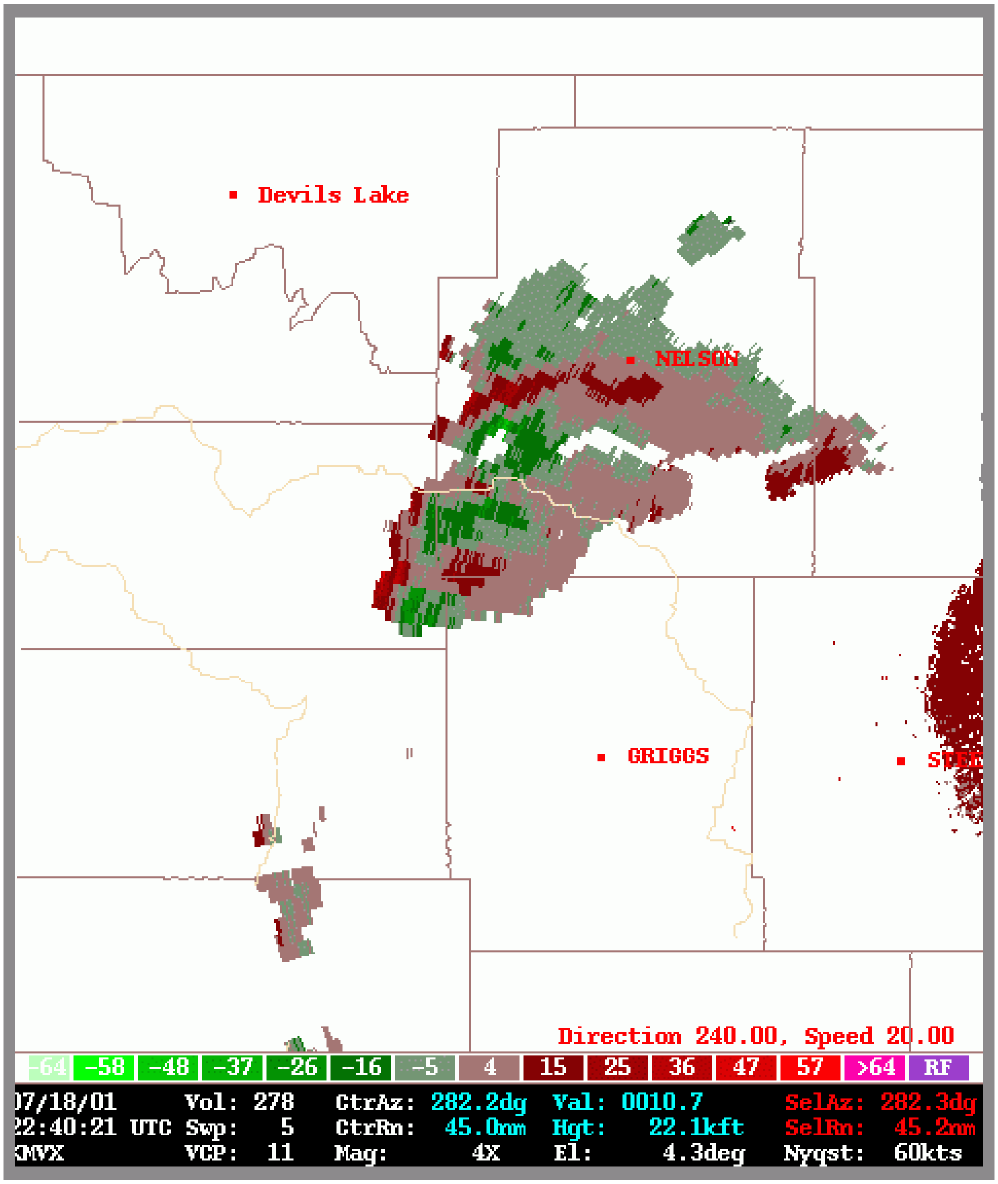

Figure 6. KMVX 4.3 degree Storm Relative Motion image at 2240 UTC 18 July 2001.

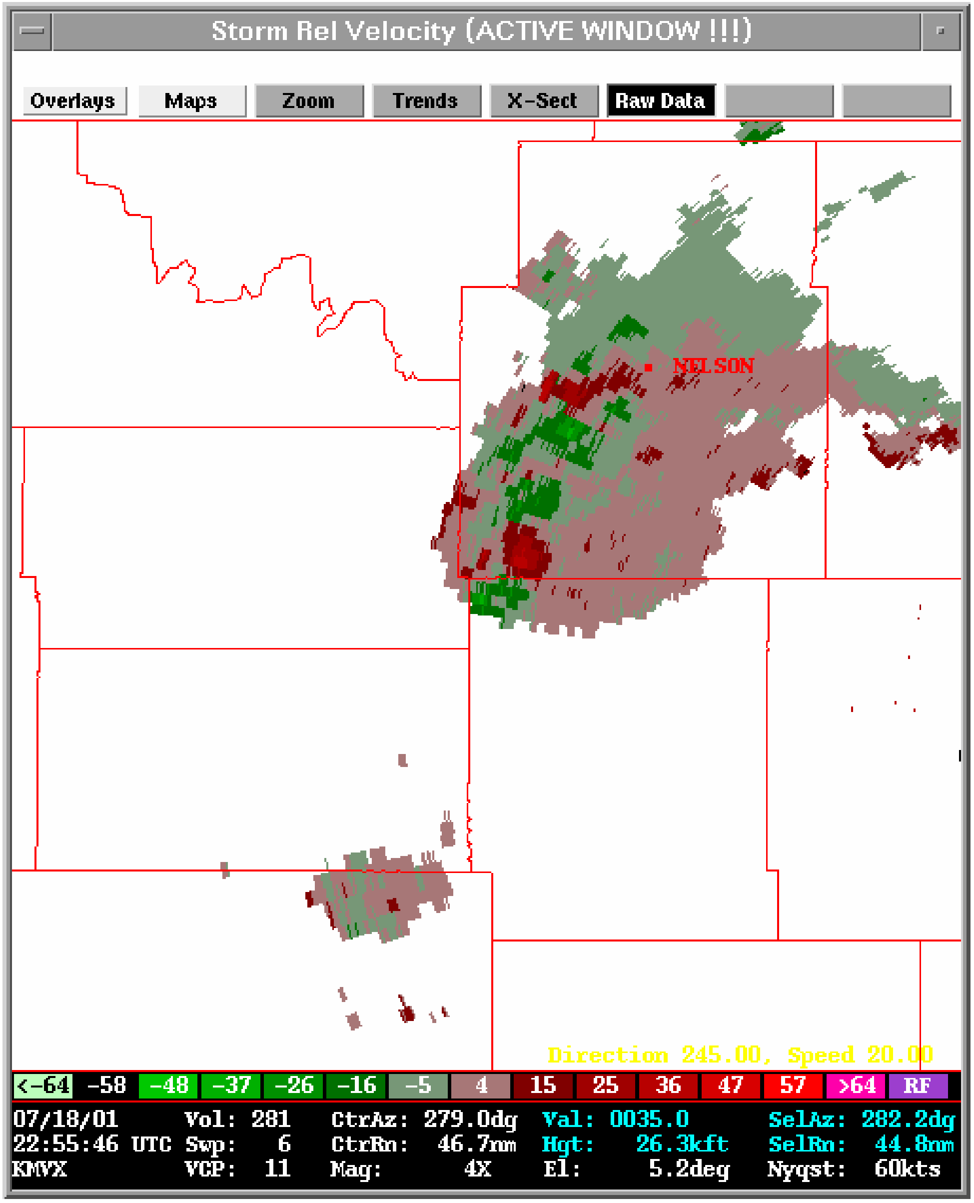

Figure 7. KMVX 5.2 degree Storm Relative Motion image at 2255 UTC 18 July 2001.

At 2253 UTC (Fig. 8), one surface boundary extended from southwest Nelson county through western Griggs county while the westernmost boundary extended from southwest Nelson to northeast Stutsman county. As the supercell crossed the boundary intersection over southwest Nelson county tornadogenesis occurred around 2258 UTC (Fig. 9). The tornado touched down on the cool side of the boundary intersection, which has been linked to persistent and stronger tornadoes than those formed along or on the warm side of boundaries (Houston and Wilhelmson 1998). This may have also led to lower LCLs in a potentially warm-type rear flank downdraft (RFD), which can then be easily ingested into the attendant strong updraft. Visual clues of a notable clear slot with the potential warm-type RFD were also noted by storm chasers following this supercell (Markowski 2003).

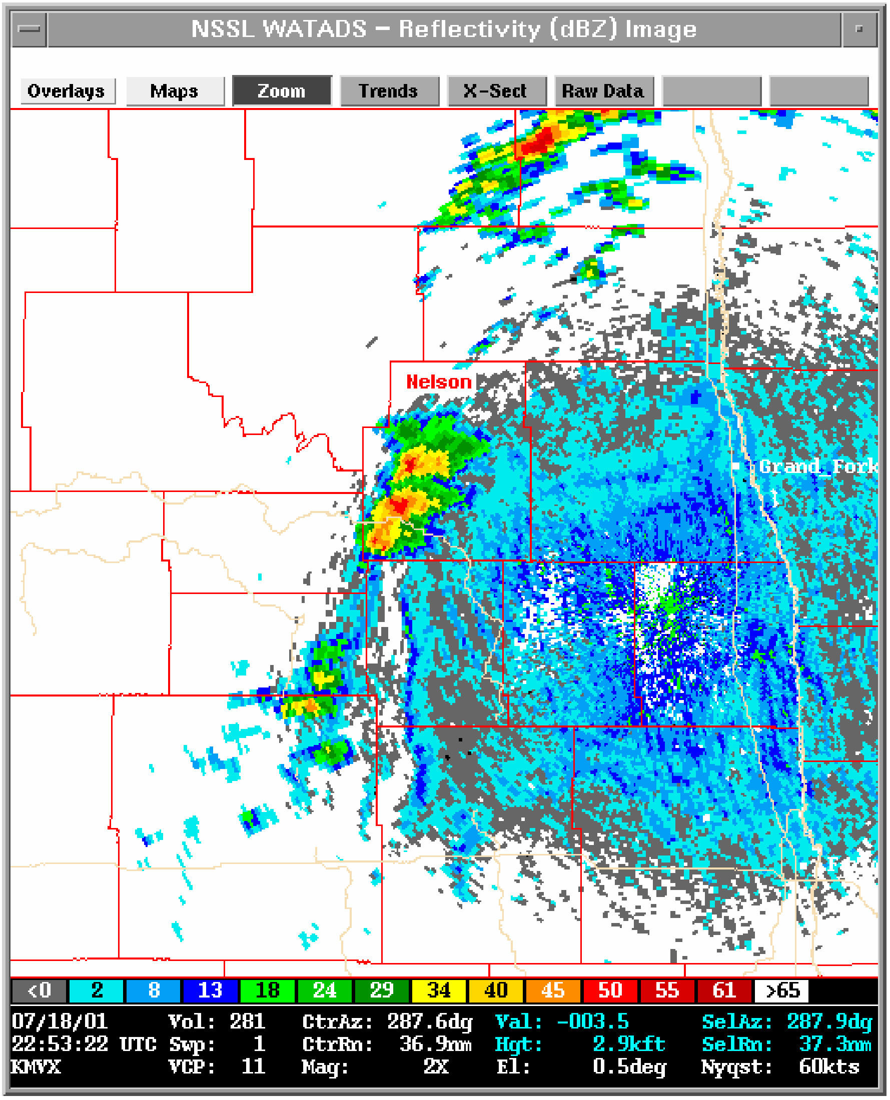

Figure 8. KMVX 0.5 degree base reflectivity image just before tornadogenesis at 2253 UTC 18 July 2001.

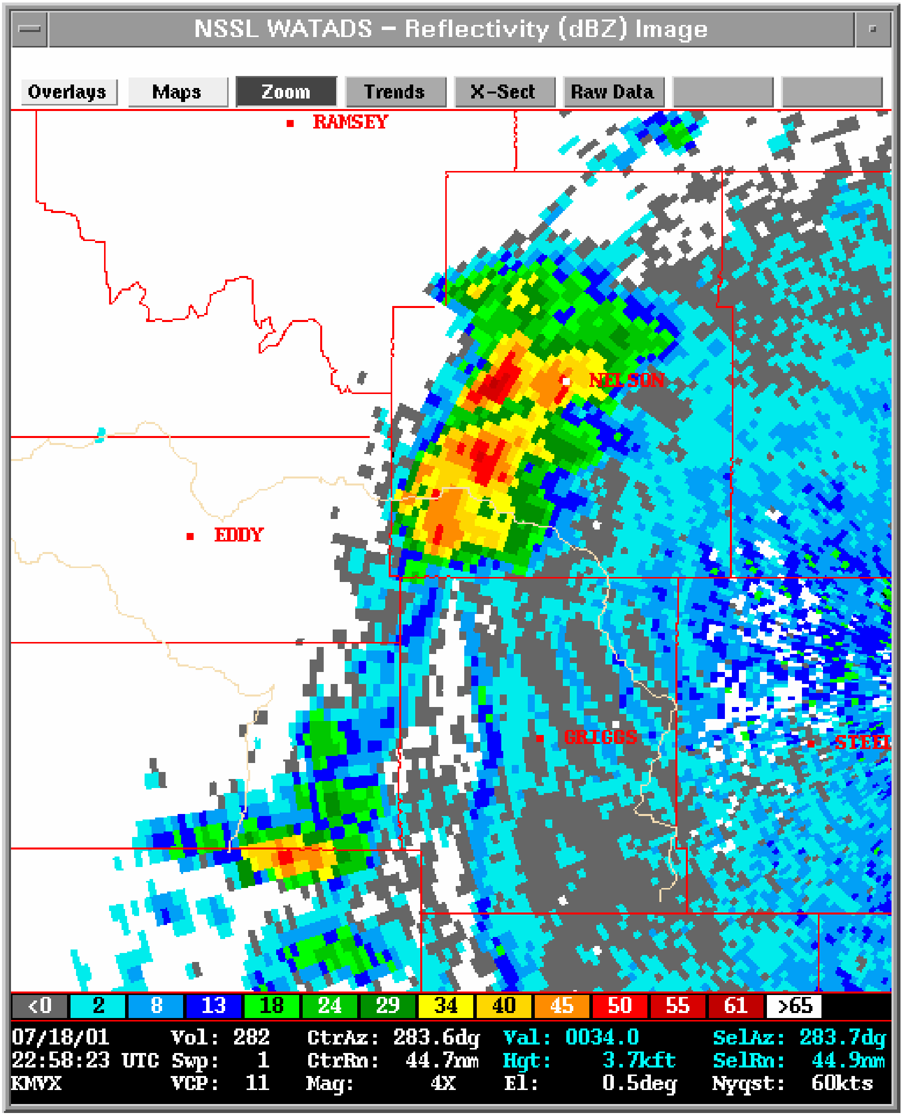

Figure 9. KMVX 0.5 degree base reflectivity image around tornadogenesis time at 2258 UTC 18 July 2001 as boundaries intersect in extreme southwestern Nelson County.

5. SUMMARY AND DISCUSSION

Utilization of surface and radar data played a key role in identifying the many mesoscale boundaries present near the tornadogenesis region. Once the mesocyclone formed, the tornado formed rapidly in 10-15 minutes. Video of the storm from a College of Dupage (IL) chase team showed a classic, well defined tornado, wall cloud and RFD wrapping around the parent mesocyclone, evident in the clear slot behind the parent updraft. This is uncommon as most mesocylones persist for at least 20 to 30 minutes before producing the classic, non-landspout tornado (Trapp et al. 1999).

The strong updraft likely ingested enhanced SRH, which can be augmented by an order of magnitude on the tornado scale. The strong updraft was able to rapidly convert horizontal vorticity into vertical vorticity as it crossed the boundary intersection. The mesoscale boundaries appear to have played a key role in increasing SRH on the mesoscale, so close attention must be paid to them in a region of moist, deep convection. The extreme variability of SRH may explain why some storms in the same mesoscale environment produce tornadoes and some fail. For example, in the present case another supercell was present about 20 km to the north of the tornadic supercell, yet it failed to produce a tornado. This is a topic of ongoing research and will be better understood once the resolution of mesoscale models improve. (Markowski et al. 1998b). Research is now showing that this process from mesocylone to tornadic development can take as little as 10 minutes (Rasmussen 2003). This timescale was comparable to the tornado highlighted in this paper.

There was no lead time for this particular tornadogenesis event. A severe thunderstorm warning was in effect for this supercell before reports of the tornado touchdown were received. An upgrade to a tornado warning occurred when the report of the tornado was received. The local storm-scale 0-1km SRH values were likely greatly enhanced near the boundary intersection at tornadogenesis time. This interaction would have caused a local increase in horizontal vorticity, which was then rapidly tilted and stretched into the vertical with the intense updraft speed of the supercell. A common misconception for warning operations is the required persistence of a long-lived mesocyclone (more than 20 minutes) prior to tornadogenesis. Although this may be true for the majority of F2 or greater tornadoes, this case demonstrates how a supercell can rapidly become tornadic in about 10 minutes. On-going mesoanalysis of boundary intersection in conjunction with the thermodynamic conditions (extreme instability and low LCL heights) and WSR-88D trends may have led to earlier anticipation of tornado formation.

6. ACKNOWLEDGMENTS

The author would like to thank Bradley Bramer (SOO FGF), Mathew Bunkers (SOO UNR), Jeff Manion (CRH) and Ron Przybylinski (SOO LSX) for providing their review, comments and valuable suggestions on the manuscript.

7. REFERENCES

Atkins, N. T, M. L. Weisman, and L. J. Wicker, 1999: The influence of pre-existing boundaries on supercell evolution. *Mon. Wea. Rev.,* **127,** 2910-2927.

Burgess, D. W, R. J. Donaldson, and P. R. Desrochers, 1993: Tornado Detection and Warning by Radar. *The Tornado: Its Structure, Dynamics, Prediction, and Hazards, Geophys. Monogr., No. 79, Amer. Geophys. Union,* 203-221.

Houston, L. A, and R. B. Wilhelmson, 1998: Numerically modeled interactions between supercells and boundaries. *19th Conference on Severe Local Storms Minneapolis MN, Amer. Meteor. Soc.*, 332-333.

Markowski, P. M., E. N. Rasmussen, and J. M. Straka, 1998a: The occurrence of tornadoes in supercells interacting with boundaries during VORTEX-95. *Wea. Forecasting,* **13,** 852-859.

Markowski, P. M., J. M. Straka, and E. N. Rasmussen, D. O. Blanchard, 1998b: Variability of Storm-Relative Helicity during VORTEX. *Mon. Wea. Rev*, **126**, 2959-2971.

Markowski, P. M., 2003: Current Research on RFD/LCL characteristics. URL found at http://www.meteo.psu.edu/~marko/research.html.

Rasmussen E. N. and P. M. Markowski, 2000: Tornado Forecasting. URL found at http://www.nssl.noaa.gov/~erik/www/SSR.

Trapp, R. J., E. D. Mitchell, G. A. Tipton, D. W. Effertz, A. I. Watson, D. L. Andra Jr., and M. A. Magsig, 1999: Descending and nondescending tornadic vortex signatures detected by WSR-88Ds. *Wea. Forecasting,* **14,** 625-639.