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The Wahpeton, North Dakota Near Tornadic Supercell of 28 August 2002 - A Warning Meteorologist's Perspective

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1. Introduction

A supercell thunderstorm developed rapidly near Wahpeton, North Dakota during the afternoon of 28 August 2002. This storm was extremely challenging from a warning perspective. The supercell had visual signatures of a classic wall cloud, with radar imagery also indicating the potential for a tornadic supercell. The storm produced golfball size hail, along with flash flooding, but no tornadoes. Numerous reports of wall clouds over the city of Wahpeton were received for up to one hour, along with radar signatures indicating a possible tornado. This prompted several tornado warnings for multiple counties, as the supercell developed near the Richland County, North Dakota and Wilkin County, Minnesota line. The black dot in Figure1a shows the area of concern.

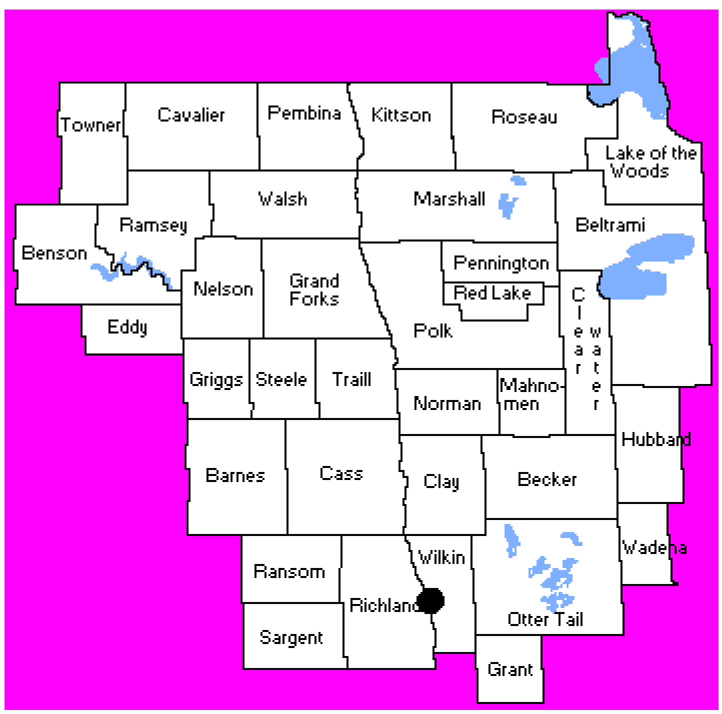


Figure 1a. County warning area map for Grand Forks with black dot indicating area of concern

This paper will examine why tornadogenesis did not occur on this day, even though many clues indicated that a tornado could form during the supercell's lifecycle.

2. Synoptic Overview

A broad and rather light westerly flow was present in the upper troposphere, and this was evident in the 500 hPa and 700 hPa analysis on 29 August 00 UTC in Fig. 1c. and Fig. 1d. A weak shortwave trough at 500 hPa (Fig. 1d) was moving from southwest to northeast through the area of concern around the time the supercell developed, possibly aiding destabilization via cooling from ascent on the synoptic scale. The right entrance region of a weak 15 m s^{-1} speed max at 250 hPa on 29 Aug at 0000 UTC (Fig. 1e) and upper level diffluence were present over southeastern North Dakota near the area of concern.

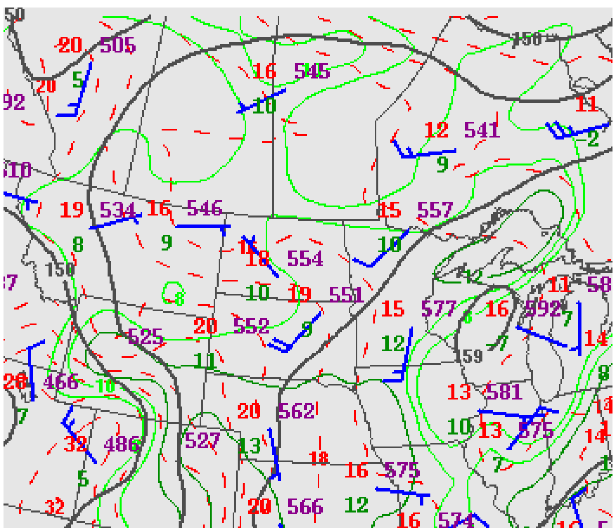


Figure 1b. 850 hPa height contours (dm), dewpoint (°C) and temperature (°C) analysis at 0000 UTC on 29 August 2002

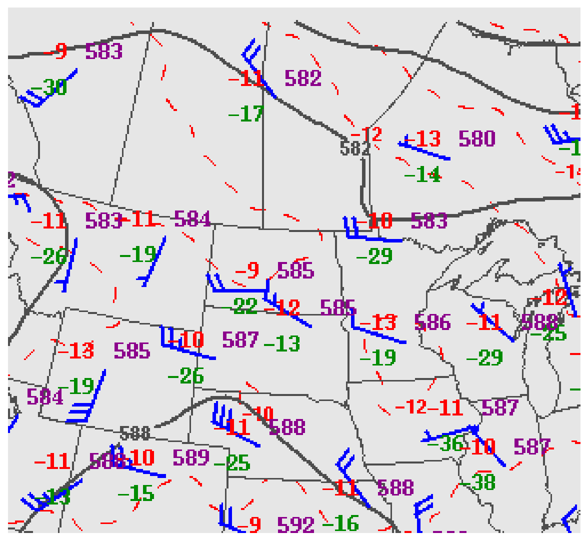


Figure 1d. 500 hPa height contours (dm), dewpoint (°C) and temperature (°C) analysis at 0000 UTC on 29 August 2002

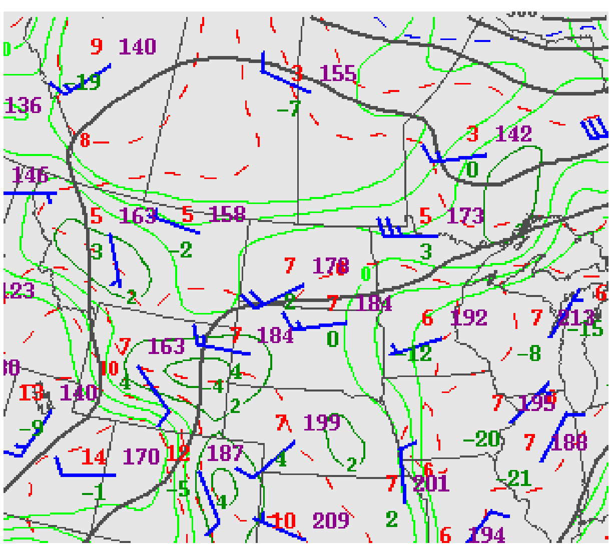


Figure 1c. 700 hPa height contours (dm), dewpoint (°C) and temperature (°C) analysis at 0000 UTC on 29 August 2002

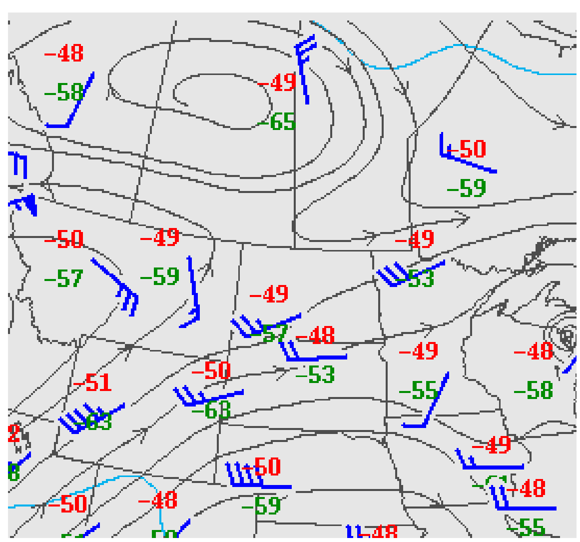


Figure 1e. 250 hPa streamlines, dewpoint (°C) and temperature (°C) analysis at 0000 UTC on 29 August 2002

At 850 hPa (Fig. 1b), a weak 10 ms^{-1} low-level jet transported abundant low-level moisture into the region. Surface dewpoints were also relatively high for the Northern Plains, with upper 60s to around 70 degrees Fahrenheit present. In addition, deep layered moisture was also sufficient for supercells, and precipitable water values of 1.68 inches were noted on a model sounding (Fig 1f.) from the RUC during the afternoon. Deep layer shear was rather weak, with about 25 kt of 0-6km shear. Storm relative helicity (SRH) values were in the weak to moderate category, with 0-3 km SRH values around 80 $m^2 s^{-2}$. Energy helicity index values of around 2 were also present in the 0-3 km layer, which indicate tornado formation was possible. The model sounding near the supercell also shows a veering wind profile in the lowest 500 hPa which likely enhanced storm inflow and helicity values. These parameters would favor supercell development if a storm could develop.

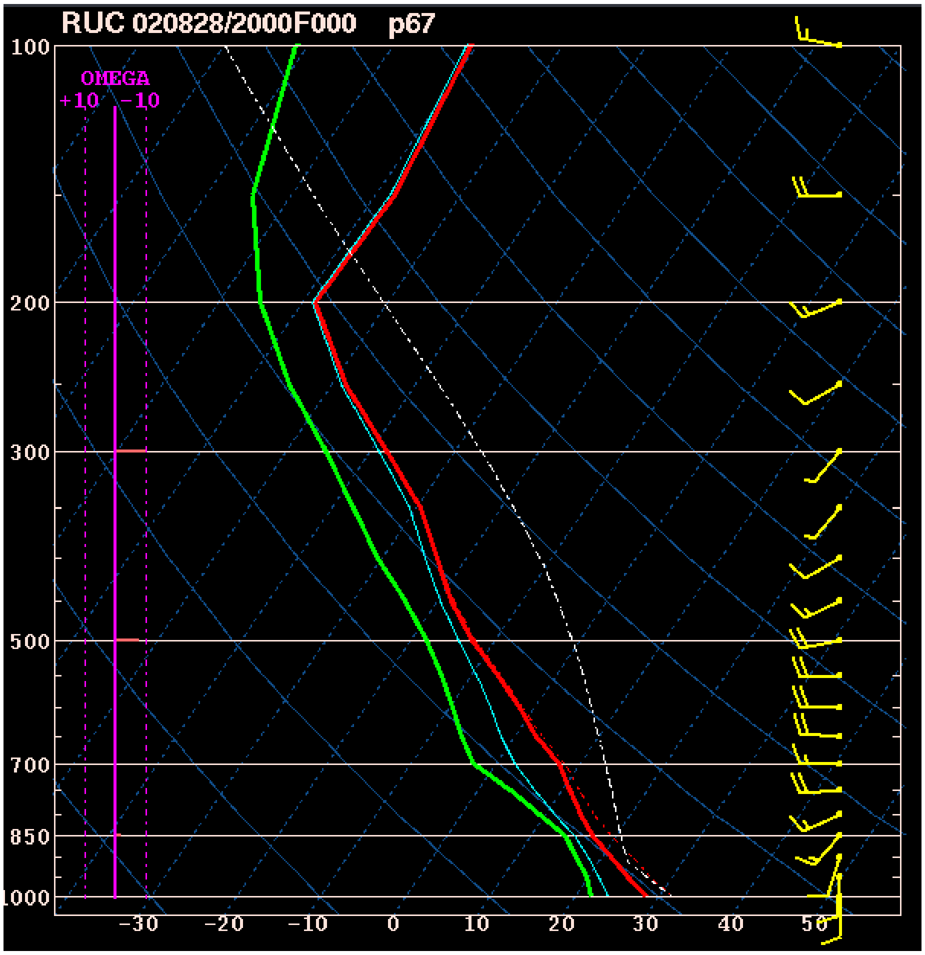


Figure 1f. RUC analysis sounding in Wahpeton, North Dakota at 2000 UTC on 28 August 2005

3. Mesoscale Analysis

Weak surface low pressure moved from northeastern South Dakota, into southeastern North Dakota between 2000 UTC and 2300 UTC, and was located near Wahpeton (denoted by red dot in Fig. 2) at 2300 UTC.

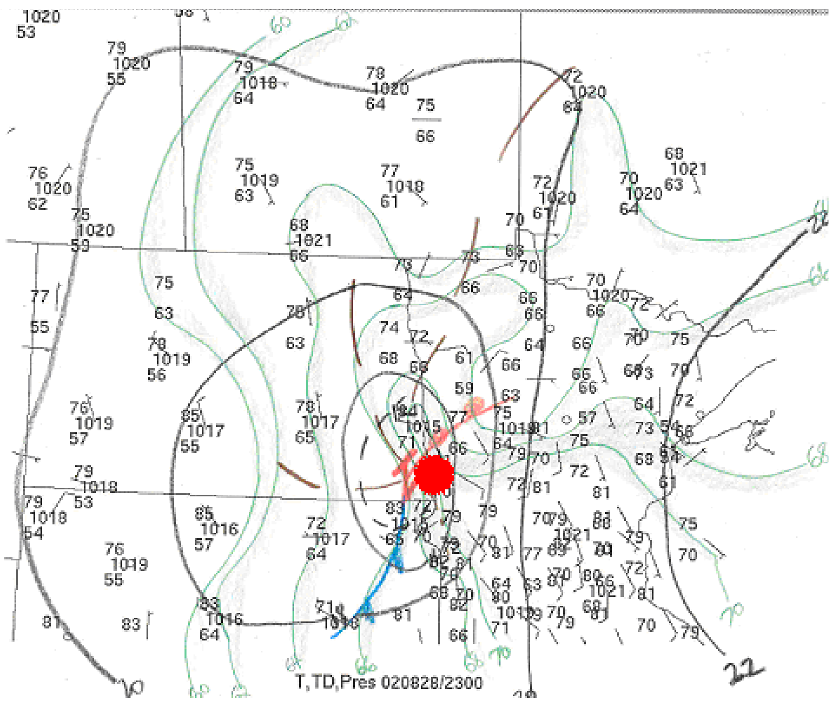
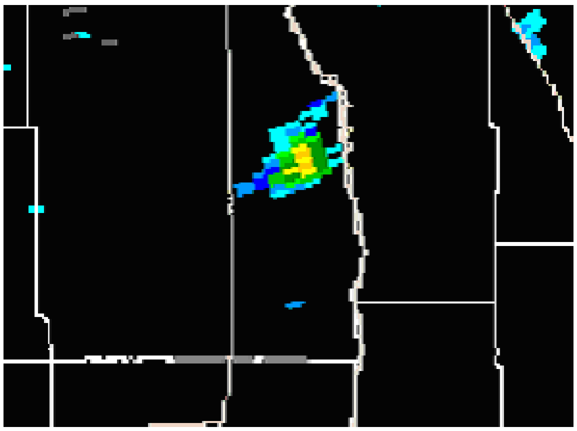


Figure 2. Surface analysis at 2300 UTC on 28 August 2002.

The low pressure area enhanced low-level convergence in the area of concern. This aided mesoscale lift in the vicinity of the supercell. The 2000 UTC surface wind direction at the Wahpeton AWOS site was 170 degrees at 10 kts. By 2300 UTC, the surface wind direction had backed to 100 degrees and increased to 18 kts. This increased the local inflow to the supercell as it tracked slowly to the east-northeast. The calculated 0-3km SRH increased from 49 $m^2 s^{-2}$ at 2000 UTC to 79 $m^2 s^{-2}$ at 2300 UTC. There were no surface boundaries, horizontal convective roles or other discontinuity gradients evident with the KMVX and KABR WSR-88D imagery. The KMVX radar beam at 0.5 degree reflectivity slice was 8,693 feet above ground level (AGL) near the supercell, while the KABR 0.5 degree reflectivity slice was higher about 10,377 feet AGL near the storm. It is possible that the radar was over shooting the surface boundaries and other low-level features, so it's not known how many surface boundaries were present. Surface boundaries have been noted with several other tornado cases in the Northern Plains over the past several years. These surface boundaries can enhance 0-1km SRH and the tilting and stretching of horizontal vorticity to vertical vorticity given a strong updraft (Markowski et al. 1998). The possible lack of numerous, intersecting surface boundaries enhancing horizontal vorticity in this case may have been one reason for tornadogenesis failure. This is purely speculation though, with the lack of detailed surface data near the supercell.

4. A Warning Meteorologist's Perspective of the Supercell From Radar and Real Time Spotter Reports

Convection explosively developed from a weak echo on radar at 2118 UTC, into a thunderstorm by 2123 UTC (Fig. 3a and Fig. 3b).



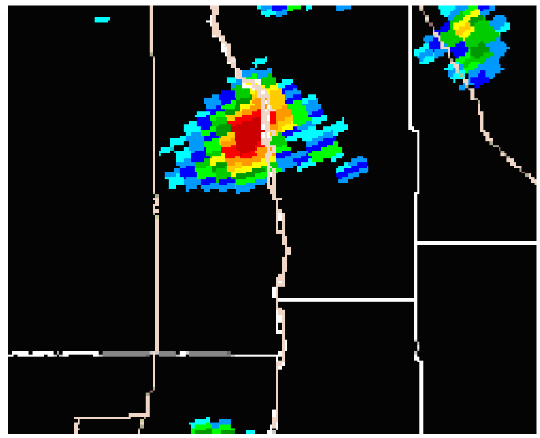


Figure 3a. KMVX 0.5 reflectivity at 2118 UTC Figure 3b. KMVX 0.5 reflectivity at 2123 UTC

Some weak rotation became evident in the mid levels on radar around 2129 UTC (Fig. 3c) in Storm Relative Motion (SRM) imagery. The thunderstorm became a supercell thereafter with persistent rotation in the storm for about an hour. A severe thunderstorm warning was issued at 2129 UTC for Richland and Wilkin counties based on a rapidly increasing elevated core well above the freezing level. Vertically integrated liquid also increased rapidly from 31 kg m^{-2} at 2114 UTC to 62 kg m^{-2} at 2120 UTC. Cross sections showed a dramatic increase in an elevated core from 2114 UTC until 2124 UTC (Fig. 4a and 4b). The freezing level near this area from a RUC sounding at 20Z was around 12,800 feet AGL.

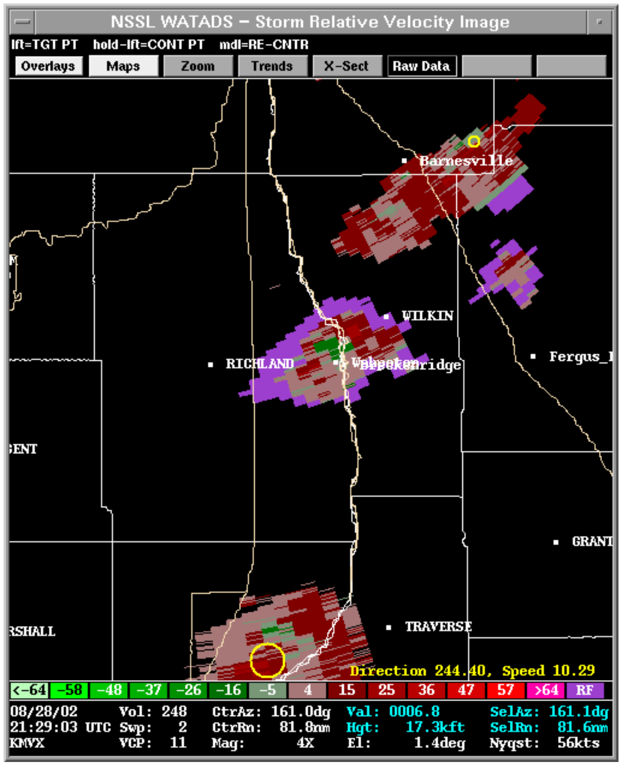


Figure 3c. KMVX 0.5 SRM at 2129 UTC

Weak mid level rotation began to lower into the 0.5 degree elevation angle at 2142 UTC as seen on the SRM image from the KABR WSR-88D (Fig. 5). The supercell continued to develop a stronger deep (about 3 km) rotation over the next 5 minutes with a tornadic vortex signature (TVS) detected at 2149 UTC over Wahpeton. A developing inflow notch, near the TVS, was also observed in the 0.5 degree elevation angle reflectivity imagery at 2149 UTC (Fig. 6).

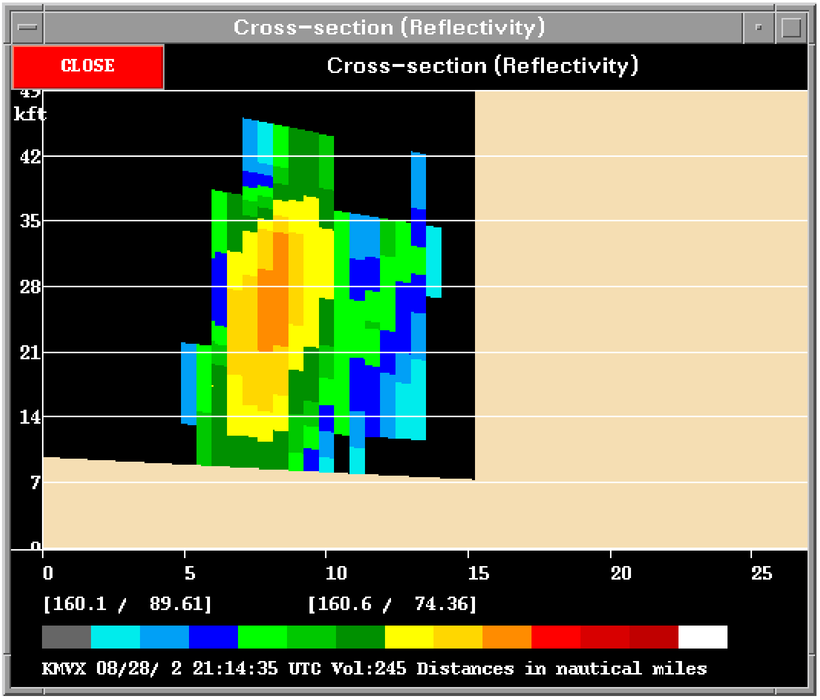


Figure 4a. KMVX 2114 UTC Reflectivity Cross Section with a developing mid level core

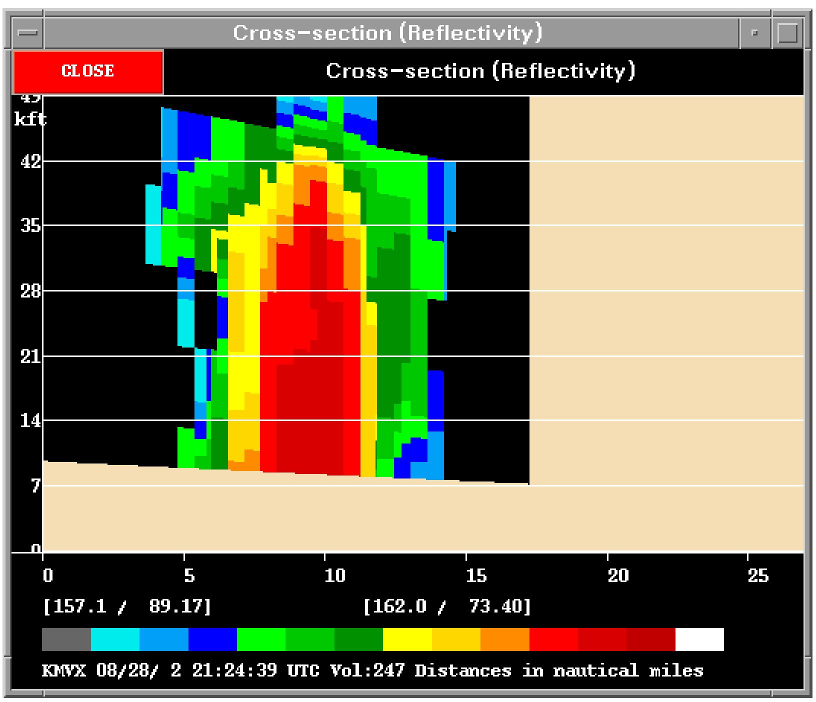


Figure 4b. KMVX 2124 UTC Reflectivity Cross Section showing explosive development of thunderstorm core.

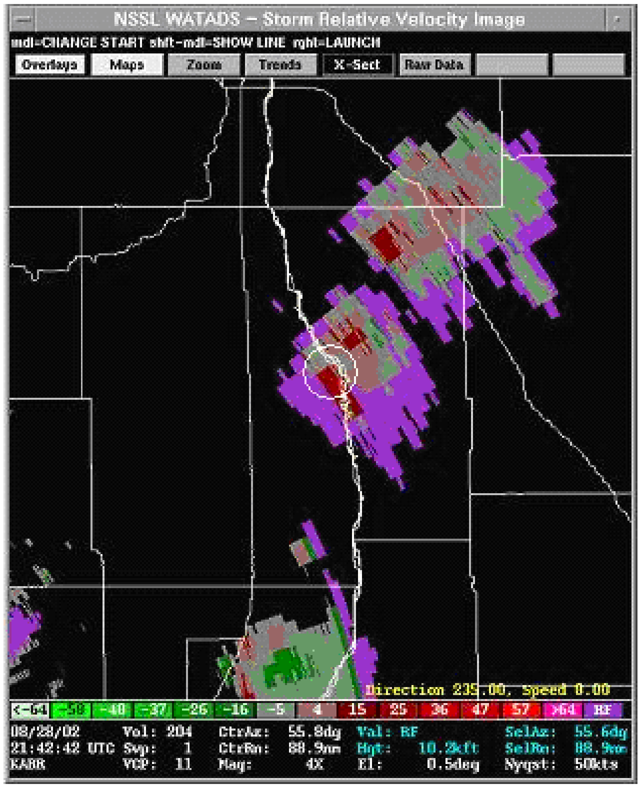


Figure 5. KABR 2142 UTC 0.5 degree Storm Relative Motion over Wahpeton, ND.

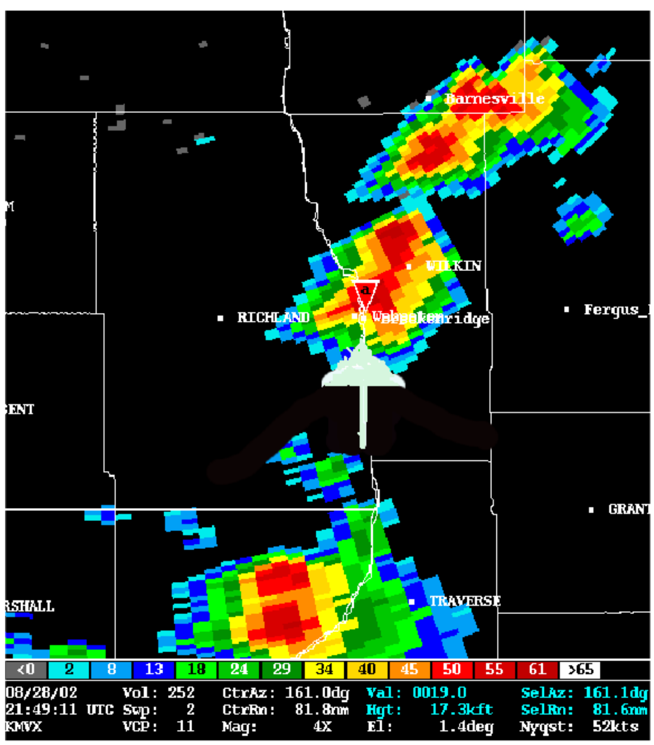


Figure 6. KMVX 2149 UTC 0.5 Reflectivity indicating a TVS and inflow notch.

The first report of a wall cloud from a spotter in Wahpeton came at 2155 UTC. This spotter reported that a wall cloud was beginning to form with scud lifting rapidly into the updraft. A tornado warning was issued at 2200 UTC based on spotter reports and radar signatures previously discussed, which indicated the likelihood of a tornado. An inflow notch began to form in base reflectivity imagery at 2208 UTC, (Fig. 7) indicating a strong updraft.

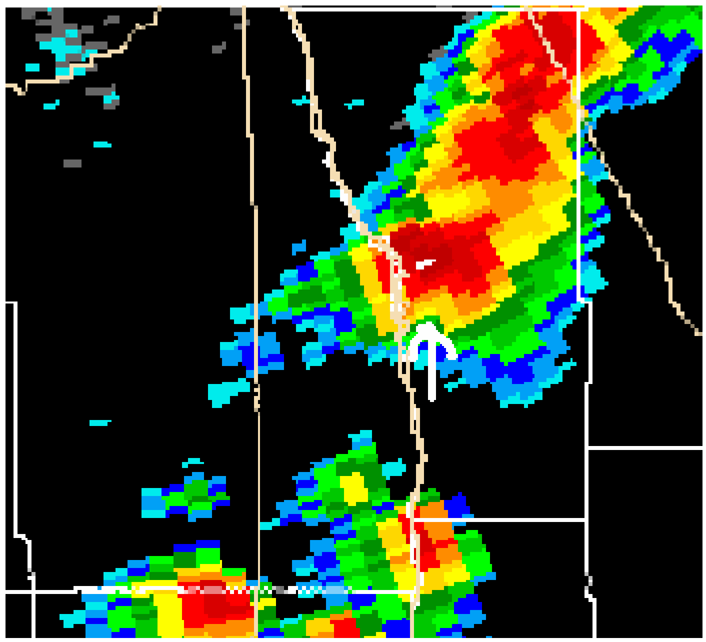


Figure 7. KMVX 0.5 degree base reflectivity image at 2208 UTC indicating developing inflow notch and strong updraft.

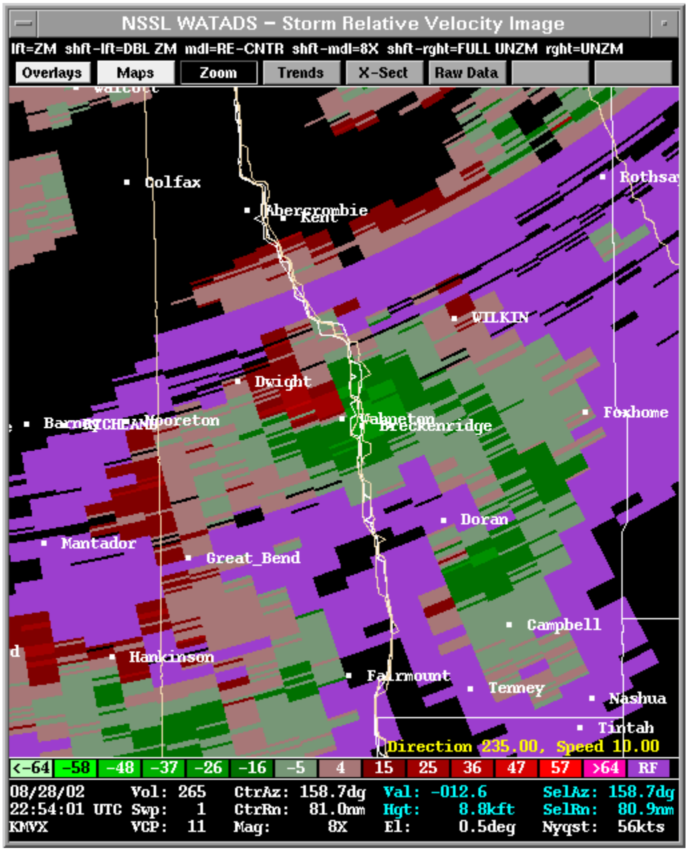


Figure 7a. KMVX 0.5 degree SRM base reflectivity image at 2254 UTC indicating persistent strong updraft and gate to gate shear.

Reports of funnel clouds and wall clouds were received from the Wahpeton area until 2255 UTC. In addition, several TVS algorithm alerts appeared on the WSR-88D, as the gate to gate rotation persisted (Fig. 7a). An additional tornado warning was issued at 2245 UTC for Richland and Wilkin counties on the persistent tornado threat.

The supercell never produced a tornado and remained nearly stationary for an hour before slowly dissipating after 2300 UTC as it became downdraft dominated. Spotters provided continuous updates throughout the life cycle of the supercell and indicated they “thought a tornado would form at any minute.” This information, in conjunction with the radar data, provided the radar meteorologist with sound reasoning for issuing the tornado warnings. This one hour event accounted for four tornado false alarms since two county tornado warnings were issued twice from the rotation for Richland and Wilkin counties.

5. Possible Reasons For Tornadogenesis Failure

The supercell had very little tilt in the vertical, therefore enabling the downdraft to choke the moist inflow of the updraft. This was evident in a reflectivity cross section at 2154 UTC (Fig. 8). This caused precipitation to fall into the updraft which resulted in ingestion of rain-cooled air. Since the storm's steering winds in the mid levels were rather weak, the supercell remained nearly stationary. This could have produced a cold type rear flank downdraft (RFD) (Fig. 9), which may have been a factor in tornadogenesis failure (Markowski 2003). Cold type RFDs prohibit the updraft from ingesting warm and unstable air, with the cold air from the RFD promoting divergence at the surface. Deep layer shear was weak and the very slow motion of the storm would tend to cause the SRH to be lower than forecast. This was the case as calculated 0-3km SRH was around 79 $m^2 s^{-2}$, and forecasted SRH was about 100 $m^2 s^{-2}$. This combination thus produced a downdraft dominated supercell, and limited SRH which may have been a factor in tornadogenesis failure. A storm spotter photographed the supercell (Fig. 10) and the rear flank downdraft (RFD) can be seen undercutting the updraft. From visual inspection, it appears that a cold type RFD was at work in this case.

The supercell also appeared to become elevated or detached from the surface inflow, which was evident from visual inspection. This was evident in Fig. 10, even though a lowering of the cloud base was observed, there didn't appear to be a focusing of the lowered base. The supercell also likely produced a cold pool from rain cooled air, which may have further inhibited the tornadogenesis process by limiting warm, moist inflow.

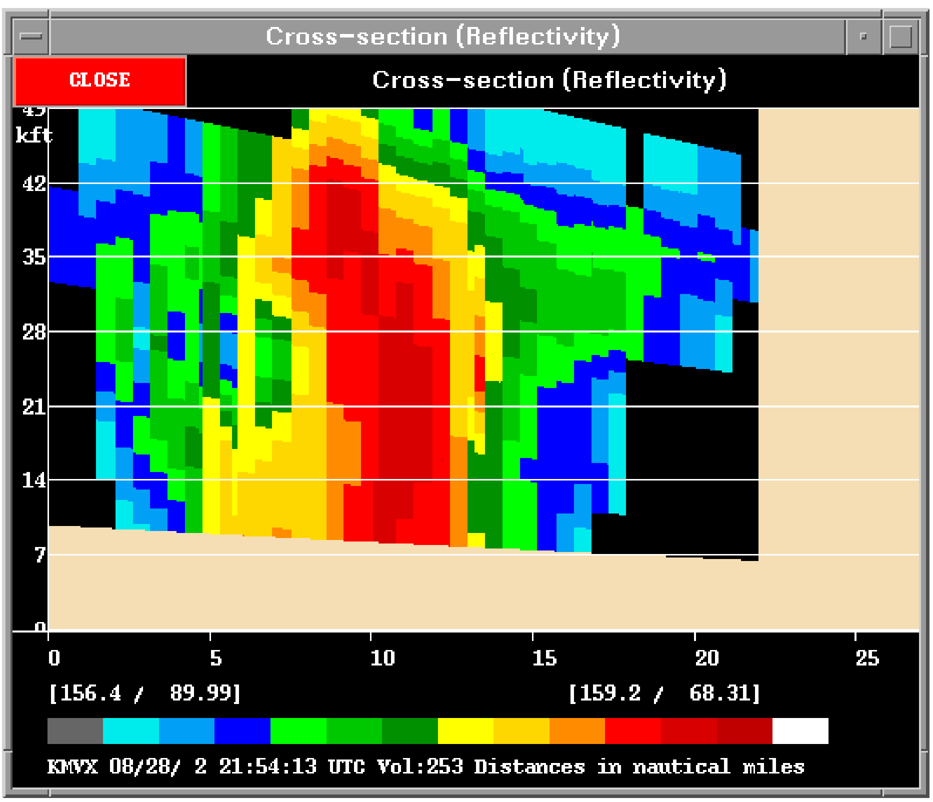


Figure 8. 2154 UTC KMVX Reflectivity Cross Section indicating little tilt in the vertical

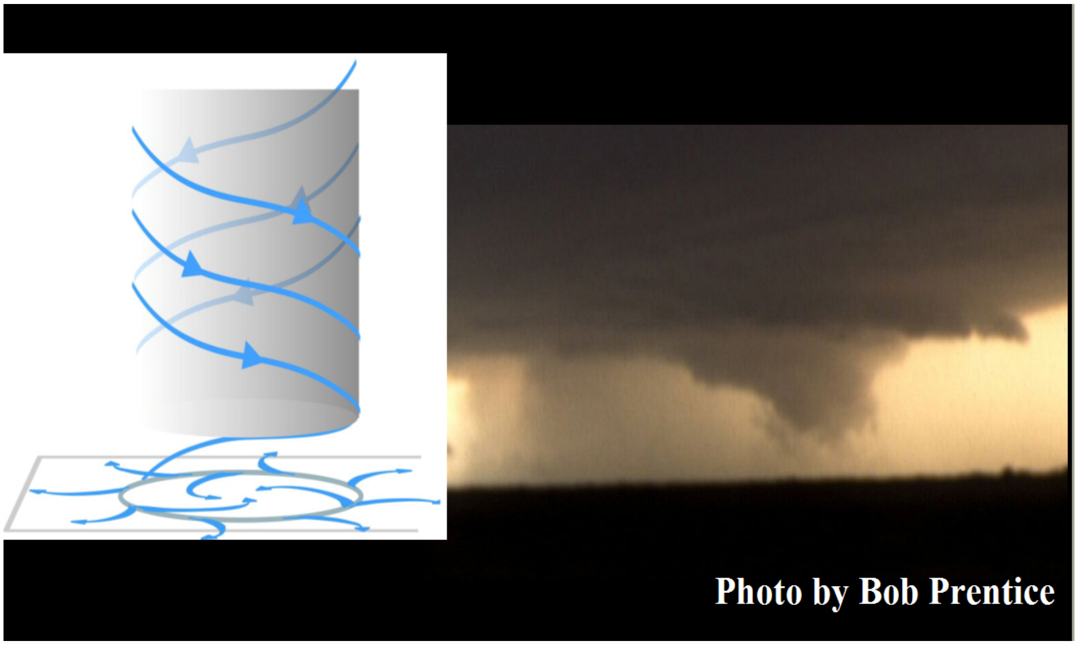


Figure 9. Schematic diagram of a cold type RFD with the downdraft undercutting the updraft with rain cooled air and precipitation (Markowski 2003).

Figure 10. Image taken by storm spotter on 28 Aug 2002 at 2230 UTC showing the possible cold type RFD. Photographer is about 3 miles SSE from the storm, looking towards the WNW Photographed by Mike Hollingshead and used with his permission.

6. Summary and Discussion

Recent research has shown that the height of the Lifted Condensation Level (LCL) and Level of Free Convection (LFC) may play an important role in tornado formation (Edwards and Thompson 2000). The surface parcel LCL height of 831 meters near the supercell, determined from a RUC model sounding, (Fig. 11) fell into the center range of non significant and significant tornadoes, but was also at the bottom range of non tornadic supercells when comparing it to research done by Edwards and Thompson (2000).

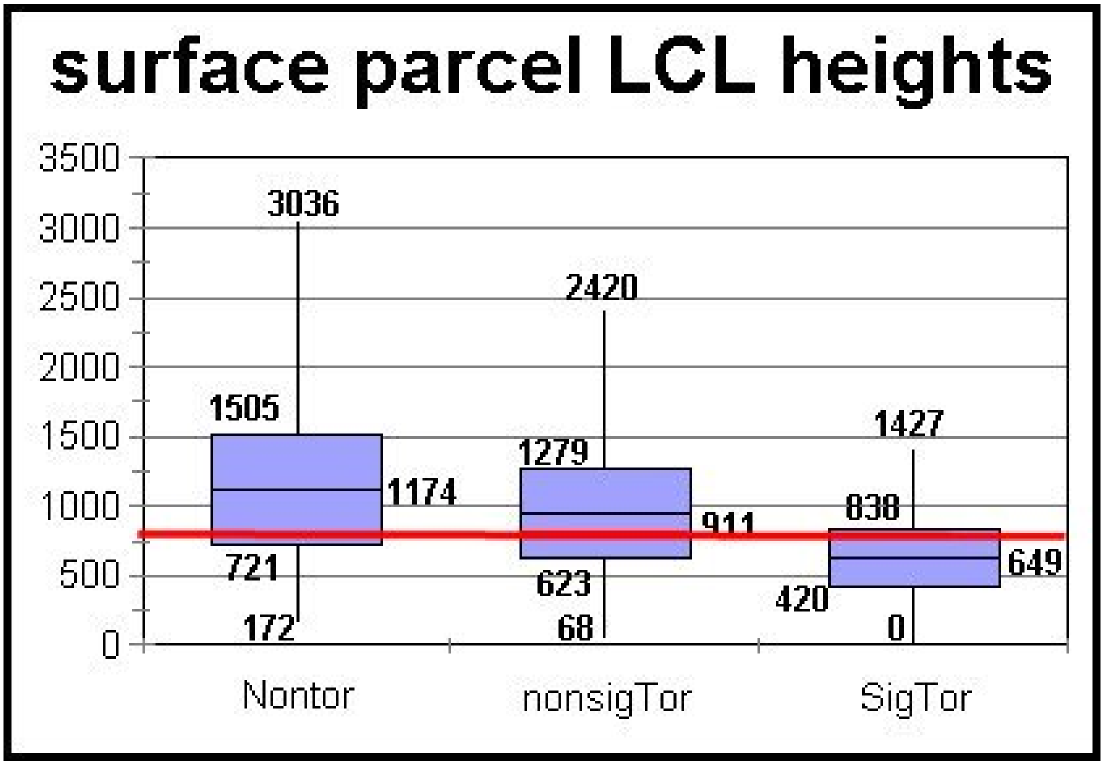


Figure 11. LCL height graph from Edwards and Thompson (2000) and red line indicating approximate surface parcel LCL height of 831 meters from the Wahpeton supercell.

In addition, the LFC height of 1120 m (Fig. 12) fell within the range of both non significant and significant tornadoes from research done by Davies (2004). Lastly, the convective available potential energy (CAPE) around 4000 J kg^{-1} and forecasted SRH of 100 m^2 s^{-2} (actual value was slightly lower) were in range (Fig. 13) with both tornadic and non tornadic supercells when comparing it to the scattergram plot done by Edwards and Thompson (2000). Looking at these parameters, it would appear that it was possible for tornadic development from the supercell that formed.

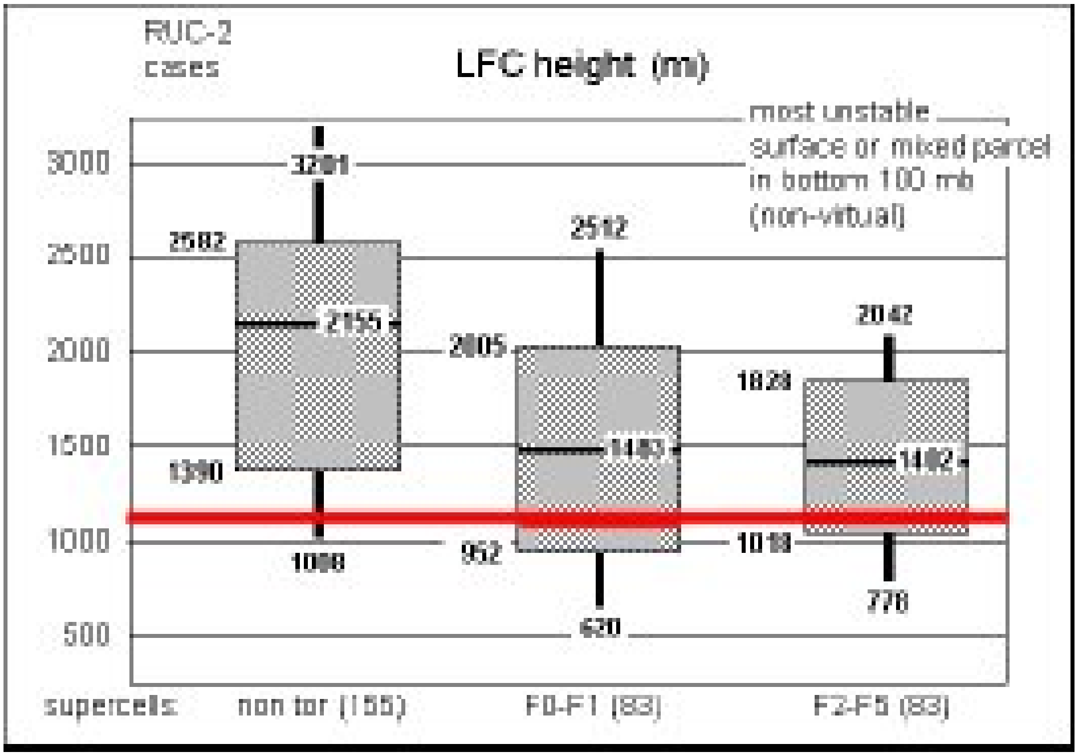


Figure 12. Davies (2002) figure of LFC heights associated with different tornado types. The red line indicates LFC height of 1,120 meters from the Wahpeton supercell.

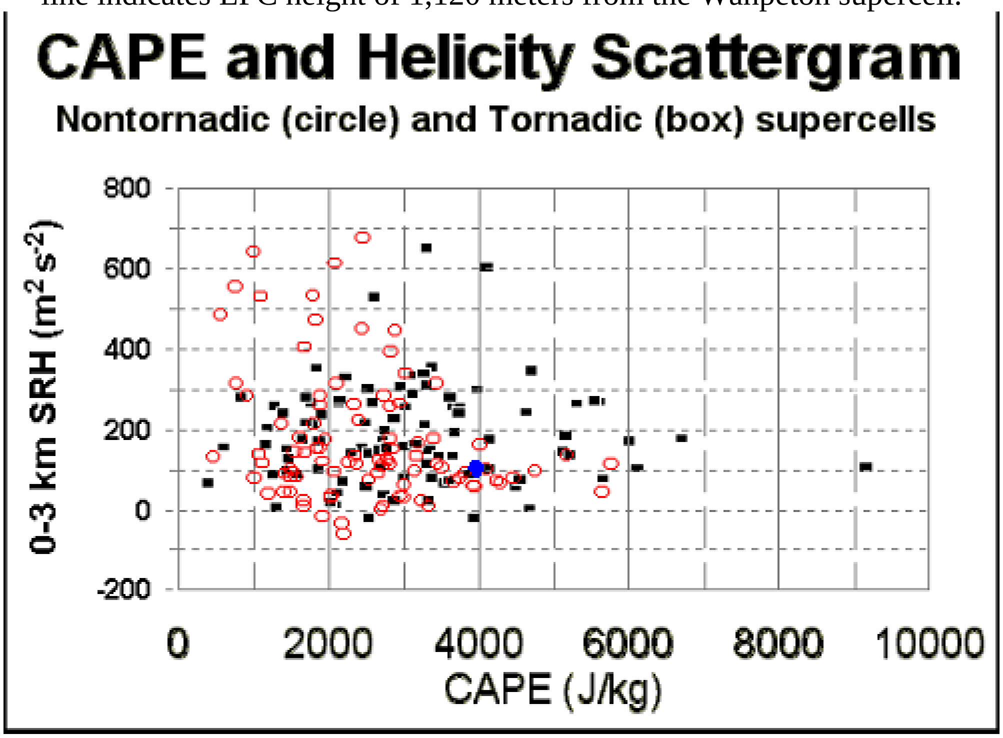


Figure 13. CAPE and Helicity Scattergram plot from Edwards and Thompson (2000). Blue dot indicates forecast values (actual SRH values were a bit lower) where storm of study was (2000).

This case of tornadogensis failure was challenging from a warning perspective. Indications from spotters, radar data, and even some supporting environmental data suggested a significant potential for tornadic development. Although a cold type RFD can not be proven to be the culprit for tornadogenesis failure, circumstantial evidence has led to this conclusion. A real time tool to identify a cold or warm type RFD would be very useful in warning situations before the storm develops. Cloud models in conjunction with proximity soundings and mesonet observations may be useful as a first guess to determine cold versus warm type RFD. The lack of a clear slot wrapping around the supercell could have also been used as a visual clue of the possible cold type RFD. This is because the warm RFD is usually associated with clear slots wrapping around the parent updraft (Markowski 2003). This case illustrated the challenges faced by warning meteorologists during a potential tornadic situation. Information from spotters, radar and the local environment need to be gathered, assimilated and processed in a very short period of time. Therefore, it is important for more research to be conducted on tornadogenesis failure in an effort to identify situations where local environments are not conducive to tornadogenesis.

7. Acknowledgements

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8. References

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