P11.10 INITIAL EXAMINATION OF THE TORNADIC AND NON-TORNADIC SUPERCELLS ON 20 SEPTEMBER 2000: INCLUDES THE F4 XENIA TORNADO

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1. Introduction

During the late afternoon and evening hours of 20 September 2000, a fast moving, low-topped convective squall line developed across western Indiana and moved east into Ohio. Across the Wilmington, OH County Warning Area (CWA), the squall line produced widespread, straight-line wind damage, as well as two tornadoes; one F2 and a short-lived, but intense F4 (most damage was F2-F3; F4 damage was extremely localized). Both tornadoes were spawned by what appears to have been a low-topped, HP supercell within the squall line. In western Ohio, ahead of the line, two isolated storms developed and exhibited persistent supercell characteristics. Neither of these storms, however, produced a tornado.

The F4 tornado occurred in Xenia, Ohio, in rather close proximity to the Wilmington, Ohio WSR-88D (KILN) radar. This location afforded an excellent perspective for diagnosing the radar features associated with this rapidly developing, strong tornado. The F2 tornado occurred 65 nm northeast of the KILN radar, and did not provide as favorable a radar perspective for assessing its features. Due to the low-topped nature of this convective event, the effect and variability of radar distance on the relative strengths and appearances of severe convective storms is discussed.

The overall purpose of this study was to assess, from a radar perspective, the storm scale characteristics of both the tornadic as well as the non-tornadic supercells that were observed during this event. The WSR-88D Algorithm Testing and Display System (WATADS) was utilized for this purpose (WATADS 2000).

2. Synoptic and Thermodynamic Environment

A progressive upper-level trough was forecast by the 1200 UTC September 20 Eta model to move across the lower Great Lakes by 0000 UTC on September 21. This was to be accompanied by a strong 300 mb jet rotating through the base of the trough, leaving the Ohio Valley in the favored right rear entrance region, where a broad area of upper-level divergence was forecast. As analyzed by the 2100 UTC surface RUC-2, strong linear forcing in association with a well-defined cold front as it approached Ohio would help enhance deep upward vertical motion across the region. Figure 1 depicts the surface front at 2100 UTC, with its associated forecast upper-level wind field. An area of moderate boundary layer instability, from which convection would feed, is also noted.

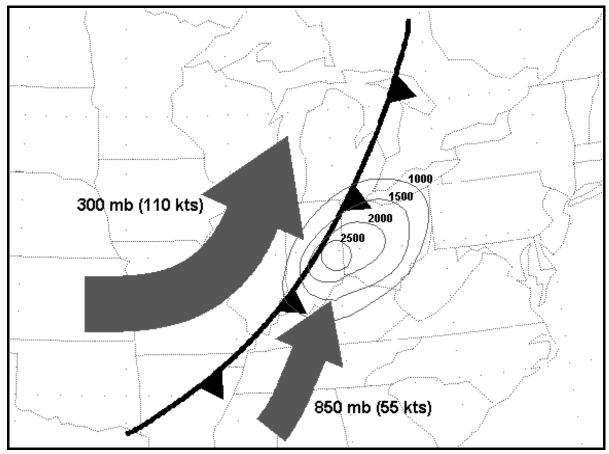

Figure 1. Composite chart valid at 2100 UTC on 20 September 2000. Surface front, upper- and lower-level jets, and boundary layer CAPE are shown.

Forecast Eta soundings for near 0000 UTC on September 21 indicated moderate instability (~1900 Jkg^{-1} CAPE), and strong shear profiles. Storm-relative helicity values approaching 400 m^2s^{-2} suggested the potential for strong mesocyclone development as noted by Davies-Jones et al. (1990). Other parameters such as EHI (Hart and Korotky 1991) and BRN (Weisman and Klemp 1984) were also indicating the potential for supercell development with strong mesocyclones. An 1800 UTC sounding released from Wilmington, OH correlated well with the forecast soundings. The 0000 UTC sounding was released at 2310 UTC (about six minutes prior to touchdown of the Xenia tornado) from NWS Wilmington, which is located about 18 miles south-southeast of Xenia. The squall line that produced the Xenia tornado reached Wilmington at 2355 UTC. Thus this 0000 UTC sounding was released just ahead of the squall line and provided an accurate representation of the pre-squall line environment, especially pertaining to the shear profile. This sounding

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denoted a weak to moderately unstable and highly sheared environment (0-3 km SRH of 1035 m^2s^{-2}).

Based on the early afternoon sounding data and the 1200 UTC model suite, squall line initiation was anticipated during mid afternoon across western Indiana. The main severe threat appeared to be for straight line wind damage in association with the strong, linear forced squall line development. Given the degree of shear, however, isolated tornadoes would also be possible with those storms that developed apart from the squall line. As evidenced by the 0000 UTC sounding data, the actual instability was a little less than originally anticipated, but the low level shear was significantly greater, leading to an increased probability of tornado development, albeit isolated. The more stable outflow from nearby storms most likely played a significant role in influencing the weaker instability observed at that time.

3. Storm Evolution

Thunderstorms developed across western Indiana during the early afternoon hours of September 20. By 1930 UTC, the storms had evolved into a broken line stretching from north-central Indiana, southwestward through southern Illinois. The storms quickly organized into a solid line and pushed east across Indiana. Between 2100-2230 UTC, as the convective line impacted northwest Ohio and eastern Indiana, widespread wind damage was reported. Movement of the line was east around 20 kts, while individual cells within the line were moving northeast at 40-50 kts.

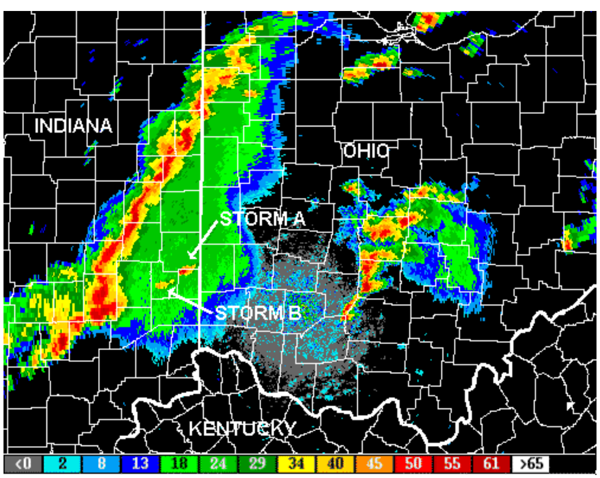

Figure 2. KILN composite reflectivity image from 2115 UTC on 20 September 2000.

At 2115 UTC, two separate storms developed just ahead of the squall line as it moved into eastern Indiana (Fig. 2). These storms moved northeast and remained isolated from the squall line through about 2330 UTC when merger of these storms with the line was observed. Although these two storms took on persistent supercell characteristics, neither produced a tornado.

The squall line continued to produce widespread, straight-line wind damage as it moved across western Ohio. Around 2130 UTC, cell mergers observed over southeast Indiana helped to establish a concentrated area of storm intensification embedded within this convective line. Intensification persisted as the line moved east. It was from this portion of the line that the short-lived F4 Xenia tornado occurred (2316-2324 UTC). From 2330-0300 UTC, the squall line continued its eastward movement across Ohio. Reports of widespread, straight-line wind damage persisted during this time. Between 0031-0050 UTC, the second tornado of the day, an F2, occurred approximately 65 nm northeast of the KILN radar.

4. Tornadic Supercells

As noted above, around 2130 UTC, cell mergers across southeast Indiana aided in storm intensification within the squall line. Between 2130-2150 UTC, the storm developed persistent, tightening rotation of 30-35 kts within the lowest 16 kft AGL (Fig. 3). At 2140 UTC, 25-30 knots of gate-to-gate rotation existed in the lowest two elevation slices. Although no tornado occurred during this period, damaging winds were reported.

At 2205 UTC, this cell began to bow aloft (not shown), and by 2211 UTC, the bowing structure became manifest at the surface. As the cell bowed across extreme southeast Indiana, further intensification was observed. During the bowing phase, a convergent pattern developed in the lowest 12 kft AGL, while weak rotation continued aloft. Damaging straight-lined winds persisted through this period as well. Through 2246 UTC, as this storm moved into southwest Ohio, rotation of 25-35 kts within 3-4 nm was noted. Figure 4 depicts what was perceived as a meso-low structure accompanying this storm. DeWald and Funk (2000) observed a similar small-scale frontal structure in the 20 April 1996 damaging squall line event that impacted portions of Indiana and Kentucky. At 2251 UTC, rotation had strengthened to 30-35 kts at about 10 kft AGL and tightened significantly. By 2256 UTC, the tight rotation lowered to about 5 kft AGL, but had also weakened to about 20 kts. Through 2306 UTC, the rotation once again broadened as the storm moved further into southwest Ohio, and once again took on a bowing appearance. This was short-lived, however, for by 2311 UTC the storm began to take on the characteristics of a High Precipitation (HP) supercell as it moved to within 20 nm of the KILN radar. Moller et al. (1994) defined an HP supercell as a single steady-state cell, which deviates to the right of the mean wind

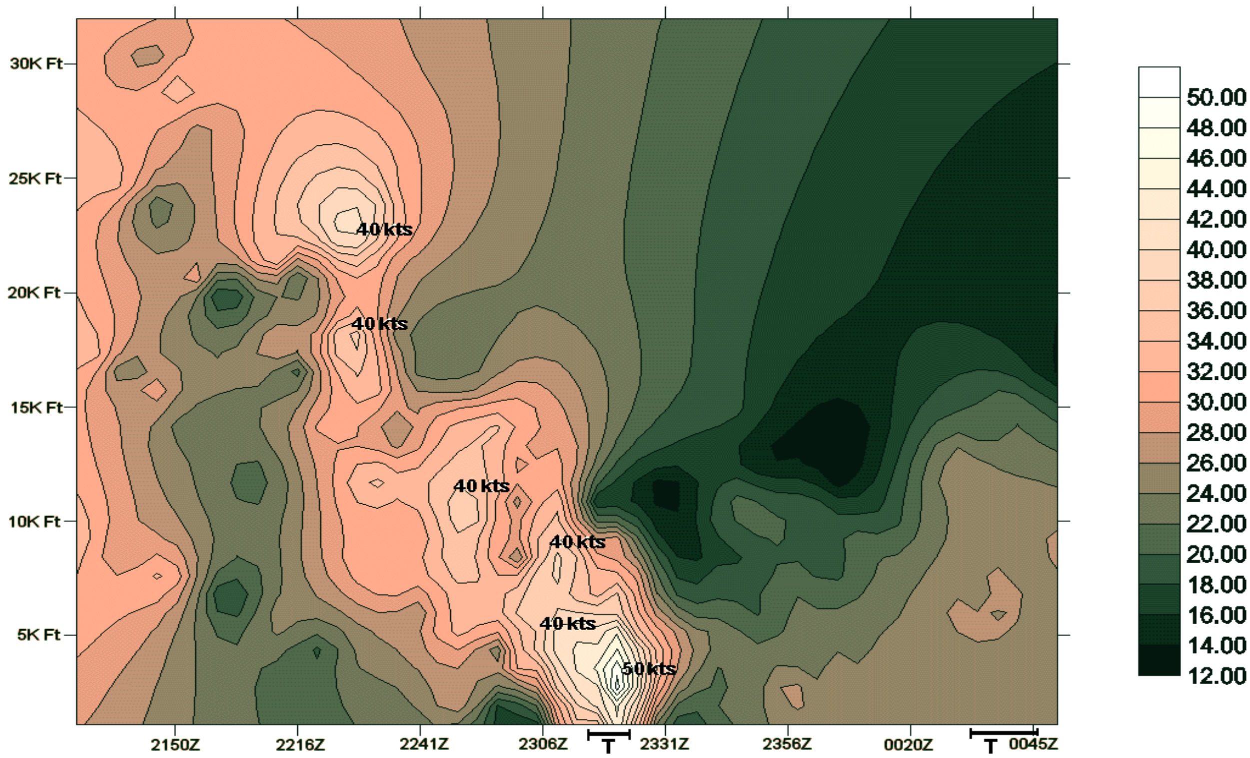

Figure 3. Time-height cross-section showing rotation (kts) from a storm-relative framework for the two tornadic supercells on 20 September 2000. "T" denotes tornado occurrences.

(Northern Hemisphere) and possesses both a mesocyclone, which contains substantial precipitation, and a bounded weak echo region (BWER). At this time, significant tightening of the rotation occurred between 5-8 kft AGL with 40-45 kts of near gate-to-gate rotation.

At 2316 UTC, although the rotation weakened slightly, the tighter circulation began to lower, with 30-40 kts of rotation observed in the lowest 8 kft AGL. The tornado first touched down at 2318 UTC, and by 2321 UTC, gate-to-gate rotation of 35 kts was present at 3.3 kft AGL and 47 kts at 4.9 kft AGL. At 1.1 kft AGL, 33 kts of nearly gate-to-gate rotation was observed. For the duration of tornadic portion of this storm, rotation was restricted to the lowest 10 kft AGL. At 2326 UTC, which corresponded to the end time of the tornado, the rotation had begun to diminish in intensity, although 40 knots of gate-to-gate rotation was still present at 3.2 kft AGL.

From 2331 UTC through 0050 UTC, the same portion of the squall line from which the Xenia tornado occurred, continued to move northeast into central Ohio, eventually producing an F2 tornado about 65 nm northeast of the KILN radar. The radar signatures associated with this cell were much more subtle than with the Xenia tornado. Much of this appears to be due to the distance from the radar, with most of the storm features being overshot. During the time of the tornado (0031-0050 UTC) the only sign of any rotation was in the lowest two elevation scans, which corresponded to about 8-14 kft AGL. However, the rotation observed was on the order of only 20-25 kts at its strongest, and rather broad. Depicted in Figure 3 is the dramatic difference in rotational velocities observed by radar for both tornadoes. Indications here point to the severe limitations when viewing low-topped severe convection at greater distances from the radar. The only radar feature that represented some similarity between the two tornadic storms was that broken portion of the squall line in the vicinity of where the tornado occurred. This portion of the line was associated with what the authors believe to be a storm-scale, or meso-low feature that was identifiable within the squall line at various times during this event (Fig. 4).

5. Non-Tornadic Supercells

Besides the two tornadic supercells, there were two additional storms that showed supercell characteristics. Both of these storms originated out ahead of the squall line in southeast Indiana at around 2100 UTC, and were separated from each other by only about 10-15 miles (see Figures 2 and 4). They moved northeast in the mean flow within the more unstable airmass out ahead of the squall line until merger with the line occurred over central Ohio between 2330-0000 UTC. On average, the leading storm (Storm A) was much stronger than the trailing storm (Storm B), but at times, both showed strong, deep and persistent rotation.

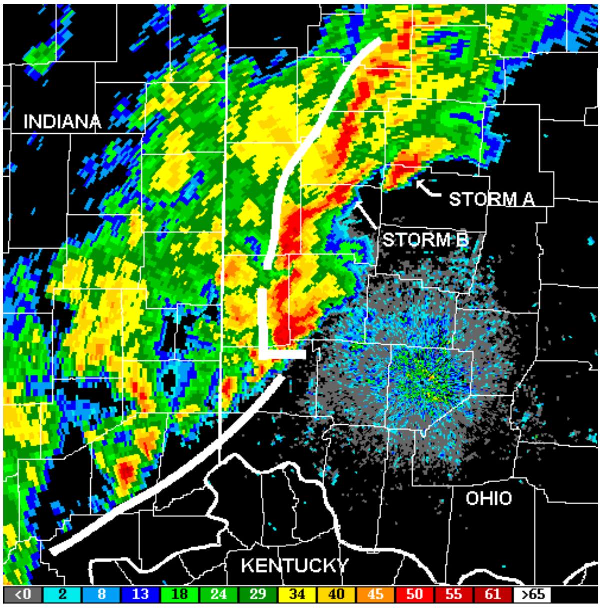

Figure 4. KILN base reflectivity display at 0.5° elevation angle for 2246 UTC on 20 September 2000. Storm-scale low and associated frontal system, along with Storms A and B shown.

As Storm "A" moved across western Ohio between 2205-2331 UTC, dramatic intensification was observed. During this time, many of the classic supercell signatures were noted. This included a BWER, an appendage on its southwest flank, and a strong mesocyclone. It is not understood at this time why this impressive storm did not produce a tornado.

In comparison to Storm "A", trailing Storm "B" showed many similar storm characteristics (mesocyclone, BWER, appendage). Although observed rotational velocities were not as strong as those in Storm "A", values were nonetheless impressive. At 2236 UTC, gate-to-gate rotation of 30-40 kts was present in the lowest two elevation slices (4-9 kft AGL). It is our conjecture that the more stable outflow from Storm "A" had some influence in preventing this storm from fully developing. This may be part of the reason tornadogenesis did not occur.

6. Conclusion

On 20 September 2000, a fast moving, low-topped convective squall line developed across the Midwest, just ahead of an intense cold front in a moderately unstable and highly sheared environment. This convective line produced widespread, straight-line wind damage, as well as two tornadoes (F2 and F4) across the Wilmington, Ohio CWA. Both tornadoes appeared to be generated by a low-topped HP supercell within the squall line. In addition, two isolated supercells developed ahead of the convective line, neither of which produced a tornado.

The area of most concern on this day may have appeared to be associated with the strong rotation observed within the low-topped supercells that formed ahead of the squall line. However, the actual tornado threat turned out to be associated with less persistent and recognizable features within the squall line itself. The storm-scale, or meso low feature present within the squall line during this event pointed to a more favorable area for tornadic development.

Given the low-topped nature of this event, nearly all of the significant rotation occurred below 10 kft AGL in each of the supercells. In this type of event, the ability to thoroughly interrogate a storm's strength and structure is quickly degraded by increased distance from the radar. The HP supercell, which spawned the two tornadoes was a case in point. The first tornadic storm occurred within 20 nm of the KILN radar, and had many recognizable supercell features. The second tornadic storm occurred 65 nm from the radar and showed virtually no supercell features. The only radar feature that represented some similarity between these two storms was the storm-scale, or meso-low structure noted in the reflectivity field.

7. References

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