14.4 # THE 24 OCTOBER 2001 TORNADO OUTBREAK

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1. INTRODUCTION

On 24 October 2001, the second largest tornado outbreak on record (tied with the Palm Sunday Outbreak of 11 April 1965) occurred in the Northern Indiana National Weather Service Forecast Office's (WFO IWX) County Warning and Forecast Area (CWFA). Ten distinct tornadoes (*Storm Data*, 2001) touched down (see Fig. 1 below), including two rated F3. These tornadoes were on the ground for a total of 186.5 miles causing two fatalities, approximately 20 injuries and over $20 million damage. Only the Super Outbreak of 3 April 1974 (16 tornadoes) ranks higher in the number of tornadoes for a single event in this area.

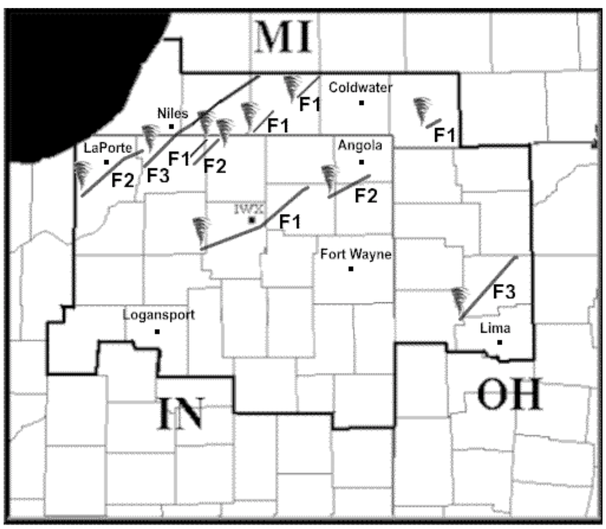

Fig 1. Plot of tornado tracks over WFO IWX CWFA for 24 October 2001.

The outbreak of tornadoes, along with widespread straight-line wind damage that occurred that day, resulted as a line echo wave pattern (LEWP) (Nolen, 1959) formed within a squall line over the CWFA. Two strong bow echoes forming within the LEWP was responsible for 9 of the 10 tornadoes as they formed in the cyclonically rotating comma head northwest of the apex of the bow (Fujita, 1978). One additional tornado occurred later over northwest Ohio as a portion of the squall line merged with a developing mini-supercell ahead of the line and transitioned into a small bow echo.

This paper will examine the 24 October 2001 outbreak from an operational forecaster perspective. A brief description of the synoptic and mesoscale environments will first be presented. This will be followed by a detailed analysis of WSR-88D radar data to examine the storm structures that produced tornadoes and identify signatures crucial to the detection of tornadoes.

2. SYNOPTIC AND MESOSCALE OVERVIEW

Plots of upper air observations from 1200 UTC 24 October 2001 and 0000 UTC 25 October 2001, indicated that the CWFA was under the right entrance region of a 110kt jet at 300mb and the left exit region of a 130kt jet at 200mb. This was combined with the development of a strong low level jet at 700mb, with a 65kt speed max over central Illinois as indicated by the 1800 UTC sounding from Lincoln Illinois (ILX). This coupling of upper and lower level jets has been noted by Uccellini (1996) to destabilize the pre-convective environment and aid in the initiation of convective storm systems.

Surface plots from 24 October 2001 indicated that by 1800 UTC the main surface low was located over northern Minnesota with an occluded front extending down to a weak surface wave in southeast Wisconsin and a cold front extending down through Illinois. As a line of thunderstorms organized ahead of the front, surface observations indicated a 993.8mb mesoscale low in east central Illinois, just southwest of Champaign.

The mesoscale low intensified as it moved north along the front, aided by intensifying thunderstorms and a strong baroclinic zone associated with the cold front. By 2100 UTC, the mesoscale low deepened to 990.4mb as it moved into northwest Indiana near South Bend (SBN) (see Fig. 2).

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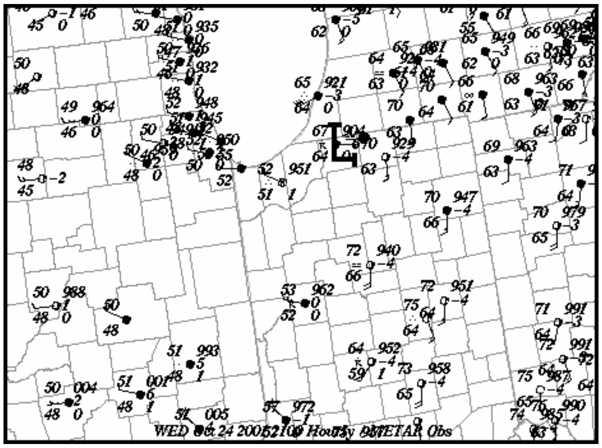

Fig 2. Surface plot from 2100 UTC 24 October 2001 (meso-low indicated by "L").

Surface winds just east of the mesoscale low backed significantly, becoming easterly at SBN at 2054 UTC. This lead to a significant increase in the storm relative helicity (SRH) in the near-storm environment and thereby increasing the potential for tornado formation (Davies-Jones, 1993).

The 0000 UTC sounding from Detroit (DTX) for 25 October 2001 gave a good representation of the pre-storm environment that existed as the line of storms entered the CWFA that afternoon. This sounding revealed a moderately unstable atmosphere with CAPE values near 1000J/kg and LI of -6. Strong directional and speed shear was also present in the low levels with 0-3km SRH values of $350 m^2 s^{-2}$.

3. RADAR ANALYSIS

The ten tornadoes that occurred this day will be divided into three groups: Bow Echo #1, which produced six tornadoes over the northwest portion of the CWFA, Bow Echo #2, where three tornadoes occurred over the central portion of the CWFA, and Cell/Line Merger, where one tornado occurred as the result of a merger of a mini-supercell and the squall line. Base reflectivity and storm relative velocity (SRM) data from the North Webster Indiana (KIWX) WSR-88D radar was used in the analysis. A more complete set of color images of the radar data can be found on the World Wide Web at www.crh.noaa.gov/iwx/24oct01/radardata.html.

3.1 Bow Echo #1

This group consists of two bow echoes, an initial small bow echo which is then quickly overtaken by a second larger bow echo, both of which developed on the northern end of the squall line. At 2010 UTC, 0.5 degree reflectivity data showed a weak echo channel just west of LaPorte county in Indiana indicating the rear inflow jet (RIJ) (Przybylinski, 1995) of the first small bow echo. 0.5 degree SRM data also indicated cyclonic rotation just north of this feature with both the National Severe Storms Laboratory (NSSL) and WSR-88D algorithms detecting a mesocyclone. By 2015 UTC, the mesocyclone was positioned just northwest of the apex of the bow echo within the comma head. Rotational velocities continued to increase and a tornado occurred at this time in western LaPorte county Indiana.

At the same time that the small bow echo was producing the first tornado, another larger bow echo just to the southwest was moving up into the same area. By 2025 UTC, the larger bow echo had overtaken the southern end of the first tornadic bow. The 0.5 degree reflectivity and SRM data for 2025 UTC (see Fig. 4a and 4b) suggests this merger enhanced the RIJ and associated rear flank downdraft in the vicinity of the tornado and strengthened the bookend vortex (Weisman, 1990) of the smaller bow echo.

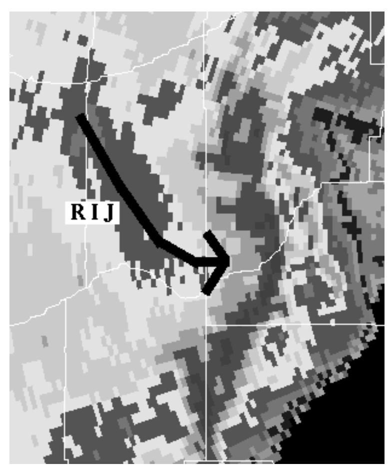

Fig 4a. 0.5 degree reflectivity from 2025 UTC. Black arrow indicates position of rear inflow jet.

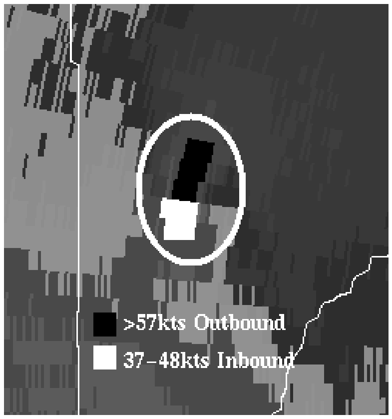

Fig 4b. 0.5 degree SRM from 2025 UTC Circle indicates position of mesocyclone, maximum inbound and outbound velocities highlighted.

The rotational velocity in the lowest elevation reached 56kts, a strong mesocyclone as determined using the NSSL and Operational Support Facility (OSF) Tornado Warning Guidance (1999) criteria and nomograms. It was also at this time that the Tornado Detection Algorithm (TDA) first detected a Tornado Vortex Signature (TVS) with maximum delta velocity of 111kts at 4600ft, ten minutes after the initial tornado touchdown.

The strongest rotational velocities before and during this tornado were in the lowest elevation scans, suggesting non-descending (mode II) tornadogenesis as described by Trapp et al (1999). This intensification caused by the larger bow echo is likely what enabled the tornado to reach F2 intensity. This tornado remained on the ground for 33 miles and resulted in one fatality and $1 million in property damage.

Four subsequent tornadic mesocyclones formed with this bow echo, producing a total of five tornadoes, including an F3 tornado that remained on the ground for 47 miles resulting in one fatality and nearly $9 million in property damage. All but one formed in similar fashion to the first tornado, just northwest of the apex of the bow echo, in the southeast portion of the comma head, and in close proximity to the RIJ.

3.2 Bow Echo #2

At 2030 UTC, 15 minutes after the first tornado touchdown with Bow Echo #1, another bowing segment began to form along the squall line about 40 miles south of the first bow echo. By 2100 UTC, a well-defined weak echo channel representing the RIJ could be seen in the 0.5 degree reflectivity pushing into the apex of what had become Bow Echo #2. SRM data at 0.5 degrees also showed an accompanying mesocyclone just north of the apex. The mesocyclone continued to intensify over the next few volume scans as it wrapped back into the comma head of the bow echo.

Rotational velocities increased at all levels from the base up to around 13kft, with the strongest occurring just above of the base by 2120 UTC. Base reflectivity and SRM data at 2115 UTC (just prior to tornado touching down) shows that the mesocyclone is located just northwest of the apex of the bow echo, in the southeast portion of the comma head and in close proximity to the descending RIJ (see Fig 5a and 5b). This again indicates mode II tornadogenesis.

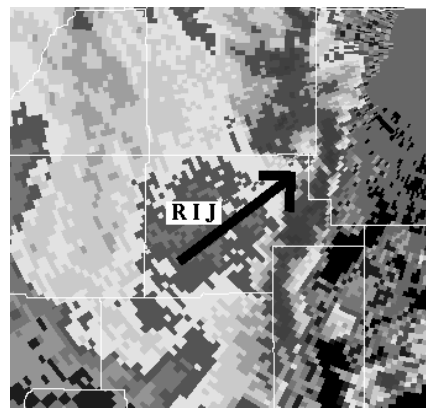

Fig 5a. 0.5 degree reflectivity from 2115 UTC. Black arrow indicates position of rear inflow jet.

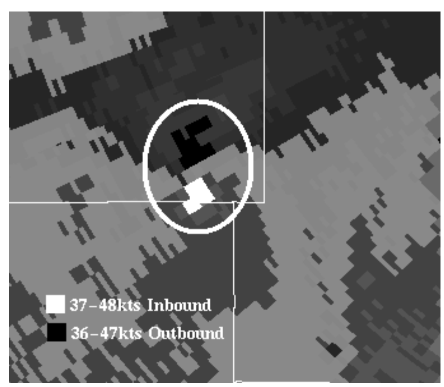

Fig 5b. 1.5 degree SRM (height 3.5kft). Circle indicates position of mesocyclone, maximum inbound and outbound velocities highlighted.

An F1 tornado touched down at 2120 UTC, had a 39 mile track, struck two factories in Warsaw Indiana injuring 14 workers and caused nearly $3 million in total damage.

Two additional tornadic mesocylones occurred with the bow echo resulting in two tornadoes. In both of these instances, tornadogenesis again occurred in the favored location of the bow echo and in close proximity to the RIJ.

3.3 Cell/Line Merger

Between 2230 and 2300 UTC, a mini-supercell formed over the southeast corner of the CWFA just ahead of the squall line with rotational velocities in the minimal-moderate mesocyclone range. By 2315 UTC, the cell had merged with the squall line over Van Wert county Ohio in the southeast corner of the CWFA . At the time of the merger, rotational velocities began to rapidly intensify in the lowest levels, reaching 44kts at the lowest scan by 2330 UTC, indicating a strong mesocyclone. Base reflectivity and SRM data at this time (see Fig 6a and 6b) show that a RIJ was impinging on the squall line, forming a small bow echo with the mesocyclone located in the comma head just northwest from the apex of the bow.

Subsequent mode II tornadogenesis occurred shortly after 2330 UTC with a tornado touching down just northwest of Delphos in Van Wert county Ohio. This tornado rated an F3 and was on the ground for 32 miles causing nearly $1 million in damage.

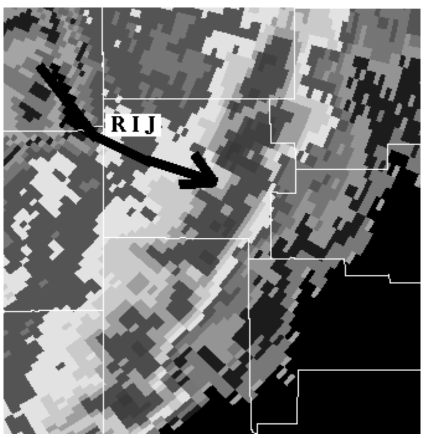

Fig 6a. 0.5 degree reflectivity from 2330 UTC. Black arrow indicates position of rear inflow jet.

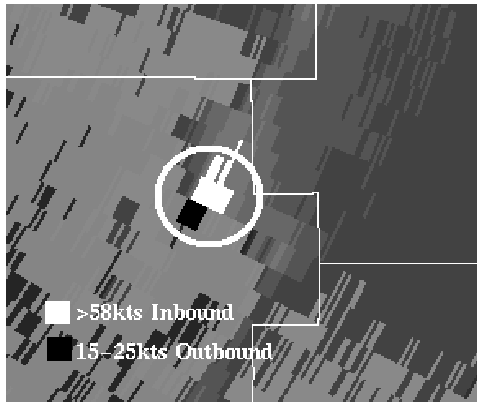

Fig 6b. 0.5 degree SRM from 2330 UTC. Circle indicates position of mesocyclone, maximum inbound and outbound velocities highlighted.

4. Summary

A total of 10 tornadoes occurred across the WFO IWX CWFA on 24 October 2001. Most of the tornadoes resulted from two strong bow echoes associated with an LEWP that moved across the area.

Key signatures associated with the tornadoes included 1) a descending RIJ, 2) tight inbound-outbound velocity couplets in the lowest levels with rotational velocities indicative of at least a moderate mesocylone, 3) location of the tornadic mesocylones with respect to the bow echoes just northwest of the apex and in the southeast portion of the comma head.

In most instances, rotational velocities orginated and were maximized in the lowest levels, indicating non-descending (mode II) tornadogenesis. The mesocyclones that formed exhibited rapid intensification, often forming only 5 to 10 minutes prior to tornado touchdown, which is common with mode II tornadogenesis (Trapp et al 1999). Recognizing the signatures listed above combined with the awareness of the enhanced near-storm SRH values created by the mesoscale low provided forecasters with a heightened situational awareness needed to best anticipate tornadogenesis.

5. References

Available upon request or online at
www.crh.noaa.gov/iwx/24oct01/radardata.html