P12.8 LOW-TOPPED SUPERCELL EVOLUTION IN ASSOCIATION WITH A MESOSCALE CONVECTIVE VORTEX ACROSS NORTHERN ILLINOIS, AUGUST 24TH, 2004

Nathan Marsili*, William Wilson
NOAA/NWS/WFO Chicago

1. INTRODUCTION

Four F0 tornadoes occurred on August 24th, 2004 across northern Illinois. The synoptic and mesoscale factors which contributed to thunderstorm initiation during the late afternoon hours will be investigated. A mesoscale convective vortex (MCV) developed across northeast Missouri in the stratiform precipitation region of a decaying mesoscale convective system (MCS), and a wide array of case studies and numerical simulations have shown that this is a common genesis region for MCVs (Menard and Fritsch 1989, Fritsch et al. 1994, Bartels et al. 1997). This MCV moved into north-central Illinois by late afternoon. Although direct observation of the MCV was not possible through the radiosonde network or profiler data, radar and satellite suggested the presence of the MCV. Thunderstorms redeveloped in the vicinity of the center of the MCV, and the convective mode quickly became supercellular as this renewed convection encountered an old outflow boundary across northern Illinois which originated from late morning thunderstorms across northeast Illinois. A brief examination of the radar evolution will also be explored, along with changes in the near-storm environment as the supercells moved into extreme northeast Illinois.

2. AUGUST 24th, 2004 CASE STUDY

2.1 Synoptic Overview

Analyses of the 500-hPa and 700-hPa geopotential height field from the 1200 UTC August 24th, 2004 radiosonde data (not shown) indicated a broad negatively tilted mid- and upper-level short wave trough from southwest Minnesota into west-central Illinois. An examination of the National Center for Environmental Prediction's 1800 UTC ETA model initialization fields indicated an eastward progression of the main synoptic features with the 500-hPa trough axis situated from northeast Iowa into central Illinois at 1800 UTC, with an 18 m/s 700-hPa speed maximum progressing through the base of the mid-level trough across northern Missouri (Figure 1). A low-level warm front extending from eastern Iowa into northern Indiana was also noted from the 1800 UTC ETA initialization data at 850 hPa with a modest southerly low-level jet of 15 m/s from southeast Missouri into northern Illinois. Comparison of the 1800 UTC ETA initialization and 1200 UTC radiosonde data suggested the northward movement of the 850-hPa warm front. An axis of positive low-level theta-e advection at 850 hPa also extended from southeast Missouri into northern Illinois in the 1800 UTC ETA initialization. A surface dew point analysis indicated that the 21° C isodrosotherm reached as far north as north-central Illinois to approximately the position of the surface warm frontal boundary at 1800 UTC.

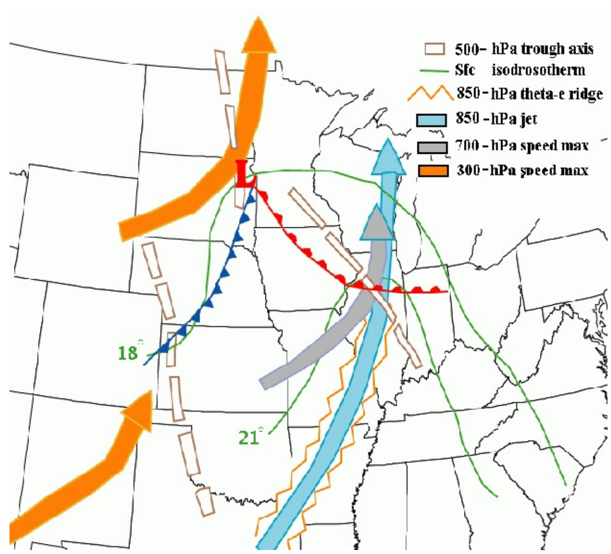

Figure 1. Miller diagram valid for 1800 UTC August 24th, 2004. 500-hPa trough axis (dashed open lines), surface isodrosotherms (green sold lines), 850-hPa jet (solid cyan lines), 700-hPa jet (solid gray lines), 850-hPa theta-e ridge (jagged orange open lines), 300-hPa jet (solid orange lines).

The 500-hPa vorticity initialization from the 1800 UTC ETA indicated a maximum in vorticity across northeast Missouri (Figure 2). Inspection of radar and satellite data (not shown) suggested that

* *Corresponding author address:* Nathan Marsili, National Weather Service Chicago, 333 West University Drive, Romeoville, Illinois 60446

this maximum in vorticity was likely the location of the MCV at 1800 UTC. This feature would play a significant role in convective initiation which will be discussed in a later section.

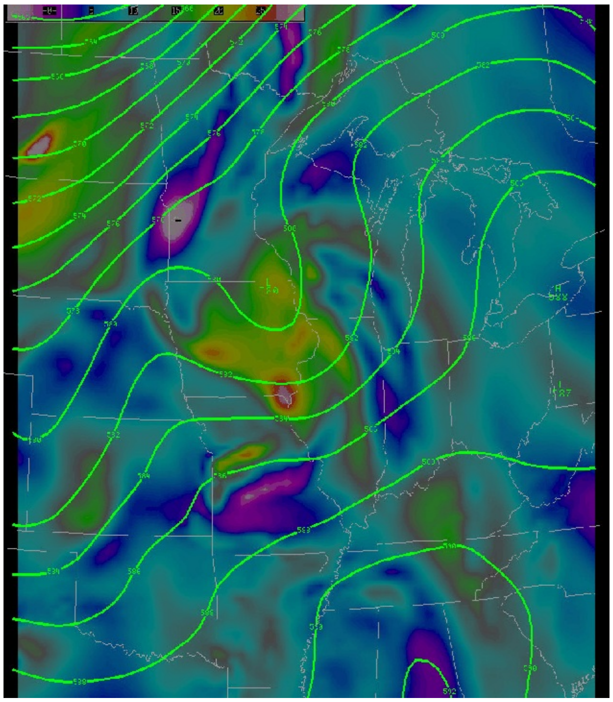

Figure 2. 500-hPa vorticity (color shaded) 00h forecast from 1800 UTC ETA model. 500-hPa geopotential height 00h forecast from the 1800 UTC ETA model (solid green lines).

2.2 Mesoscale Convective Vortex

Two areas of thunderstorms occurred during the morning. One cluster of thunderstorms moved across northeast Illinois which would produce an outflow boundary by late morning. Another larger MCS dissipated by early afternoon across west-central Illinois. Radar data from Lincoln, Illinois (not shown) indicated evidence of an MCV emanating from the stratiform precipitation area of the decaying MCS across west-central Illinois. This MCV became evident in satellite imagery by late afternoon as the cirrus shield associated with the decaying MCS began to thin. By 2145 UTC, some cyclonic rotation in the mid-level clouds was inferred from visible satellite imagery on the northern periphery of the MCV (Figure 3). Closer to the center of the MCV, a convective tower developed embedded in a widespread mid-level cloud deck (Figure 3). This convective tower would eventually become the thunderstorm that produced the first F0 tornado. Further to the east, cumulus streets developed in the relatively unstable air mass just downstream of the MCV. Just to the northeast of the cloud streets, towering cumulus were noted along an old outflow boundary downstream of the MCV (Figure 3).

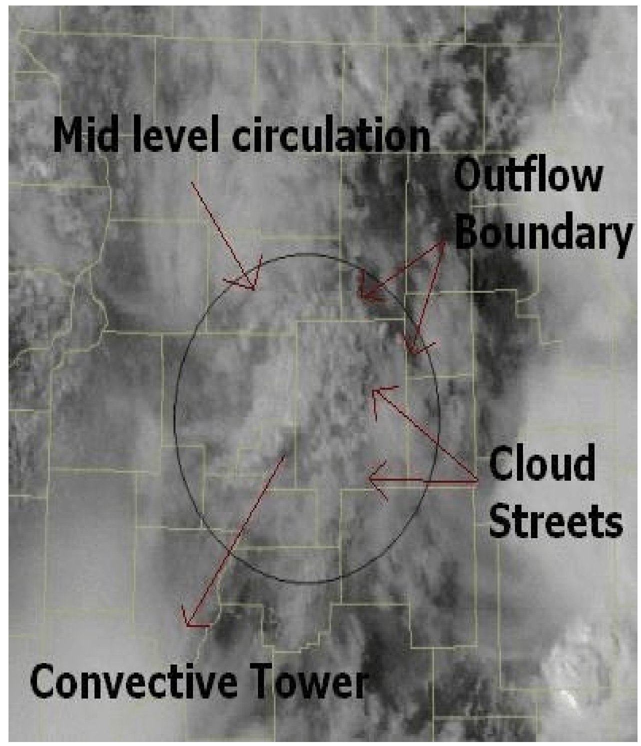

Figure 3. Visible satellite imagery from 2145 UTC.

Local Analysis and Prediction System (LAPS) soundings were analyzed to assess the instability downstream of the MCV, primarily in the vicinity of the pre-existing outflow boundary. A LAPS sounding from 2200 UTC (Figure 4) near the outflow boundary indicated surface based convective available potential energy (CAPE) of approximately 1400 J/kg indicating moderate instability.

The vertical shear profiles were mainly unidirectional with 2-6 km bulk shear magnitudes around 10 m/s. Trier et al. (2000) studied a subset of 16 MCV cases from 1998 in which a vast majority of these examples exhibited 2-6 km bulk shear magnitudes less than 6.5 m/s. A midtropospheric ridge also accompanied most of these cases. In the August 24th, 2004 case, shear values were significantly higher and the synoptic pattern was characterized by a broad weak mid-level trough. This higher sheared environment likely played some role in limiting the horizontal scale of the MCV. Figure 3 suggested that the horizontal scale of the MCV was only on the order of 50 km. A deep low and mid-level moisture profile also characterized the 2200 UTC LAPS sounding (Figure 4) with precipitable water values of about 5.0 cm. Given the warm core, moist characteristics of MCVs, this deep moisture profile was likely a favorable factor in sustaining the MCV as it tracked into north-central Illinois by late afternoon despite the lack of deep convection through mid-afternoon.

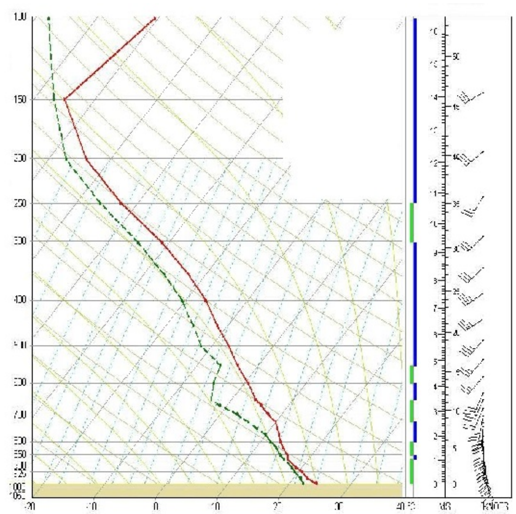

Figure 4. LAPS sounding from 2200 UTC.

A narrow axis of moderate instability with surface based CAPE of 1000-1500 J/kg was also noted from the 2200 UTC Storm Prediction Center (SPC) Rapid Update Cycle (RUC) mesoscale analysis (Figure 5). This instability axis was aligned just downstream of the MCV and to the north of the well-pronounced cold pool across west-central Illinois associated with the decaying MCS. Convection quickly transitioned to a supercellular mode as the MCV approached the outflow boundary across north-central Illinois. Reflectivity cross sections (not shown) indicated storm tops of approximately only 6 km as a supercell structure evolved. The report of the first tornado during this event occurred at 2255 UTC as the supercell began to track to the northeast of the outflow boundary as this boundary began to slowly retreat to the north. The WSR-88D from Romeoville, Illinois (KLOT) detected a broad mid-level cyclonic convergent signature to the northeast of the supercell in a more stratified region of reflectivity (Figure 6) likely indicative of the broad mid-level circulation at the northeast periphery of the MCV. This rotation was most pronounced at the 3.4 degree elevation scan (~ 3 km AGL). The combination of radar and satellite data suggested that this supercell developed very close to the center of the MCV circulation. This is consistent with the findings of Trier et al. (2000) in which secondary convection developing near the MCV center apparently aided in maintaining the MCV circulation through time.

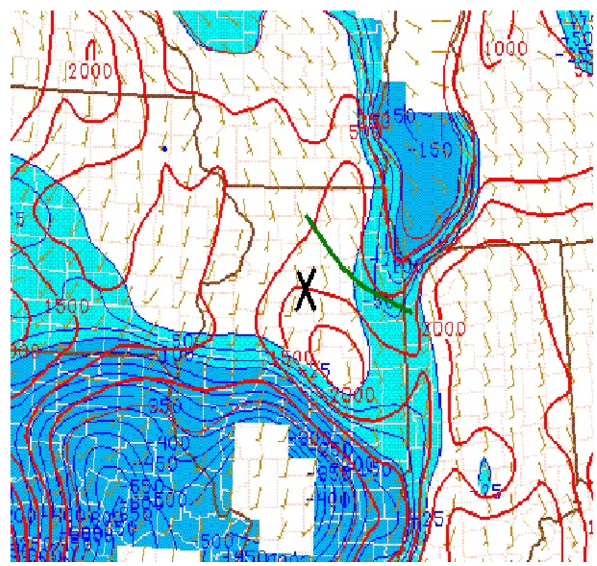

Figure 5. SPC RUC analysis graphics for 2200 UTC. Surface based CAPE (red contours), CIN (blue contours), X represents approximate MCV location, outflow boundary (green solid line).

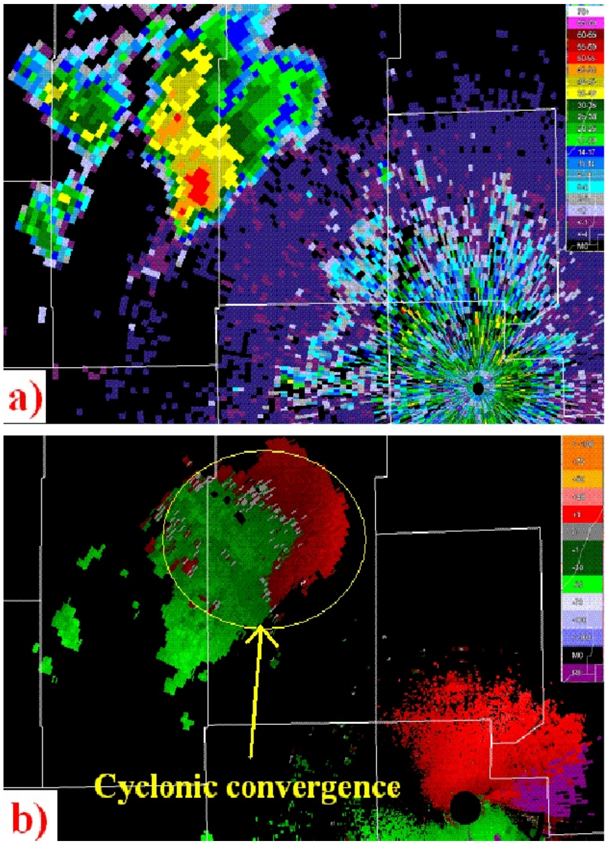

Figure 6. Radar imagery from KLOT WSR–88D at 2248 UTC. 0.5 degree base reflectivity is shown in Figure 6a, and 3.4 degree base velocity is shown in Figure 6b.

2.3 Radar Evolution/Near-storm Environment

The initial supercell that developed near the MCV center began to split as it continued into northeast Illinois. Half degree base reflectivity and velocity data at 2313 UTC showed the presence of the right- and left-moving supercells which resulted from this first storm split (Figure 7). The right-moving supercell produced two more F0 tornadoes, but it is the evolution of the left-mover and changes in the near-storm environment which will be the focus of the remainder of this paper. As the left-moving supercell tracked across far northern Illinois in the 2300-0100 UTC time frame, it encountered an environment characterized by slightly cooler surface temperatures and lower lifting condensation level (LCL) heights to the north of the slowly retreating outflow boundary. The left-moving supercell would split again, and it would be the right-mover from this second split that produced the last of the four F0 tornadoes.

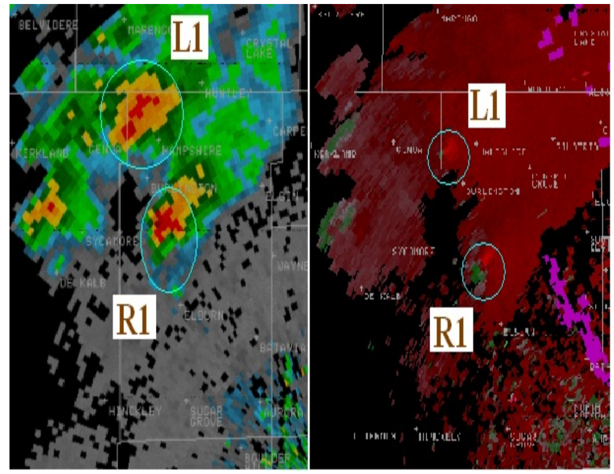

Figure 7. 0.5 base reflectivity (left) and 0.5 base velocity from KLOT WSR-88D at 2313 UTC. L1 and R1 represent the left- and right-moving supercells respectively from the first storm split.

SPC RUC mesoscale analysis graphics from 0100 UTC depicted a north-south gradient in 0-3 km CAPE with the greatest values across extreme southern Wisconsin (Figure 8). A more favorable low-level CAPE distribution further to the north may have enhanced the potential for tornadogenesis as explored by McCaul (1991) through the process of vortex stretching. An examination of radar data from Milwaukee-Sullivan (KMKX) also lends some support to the possible role of vortex stretching in tornadogenesis. In Figure 9a, a 40 dBZ core is present in the 3.4 degree elevation scan (~ 4 km AGL) with the cell labeled R2 (the right-moving supercell associated with the split of the initial left-moving supercell). The 0.5 degree base velocity product from KMKX showed little in the way of any rotational signatures at 2355 UTC. By 0011 UTC August 25th (Figure 9b), the time of the last reported tornado, the small core noted at 2355 UTC had diminished, but a low-level rotational couplet was evident in the 0.5 degree elevation scan. The emergence of this rotational couplet shortly after the stronger core/updraft was noted at 2355 UTC suggests that vortex stretching may have played a role in tornadogenesis. The warm front which had been reinforced by the outflow boundary also may have provided a source of low-level vorticity as suggested by Figure 8.

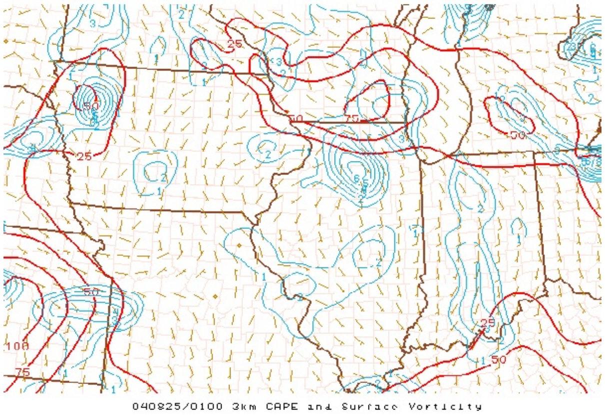

Figure 8. SPC RUC mesoanalysis graphics of 0-3 km CAPE (red contours) and surface vorticity (cyan contours) at 0100 UTC.

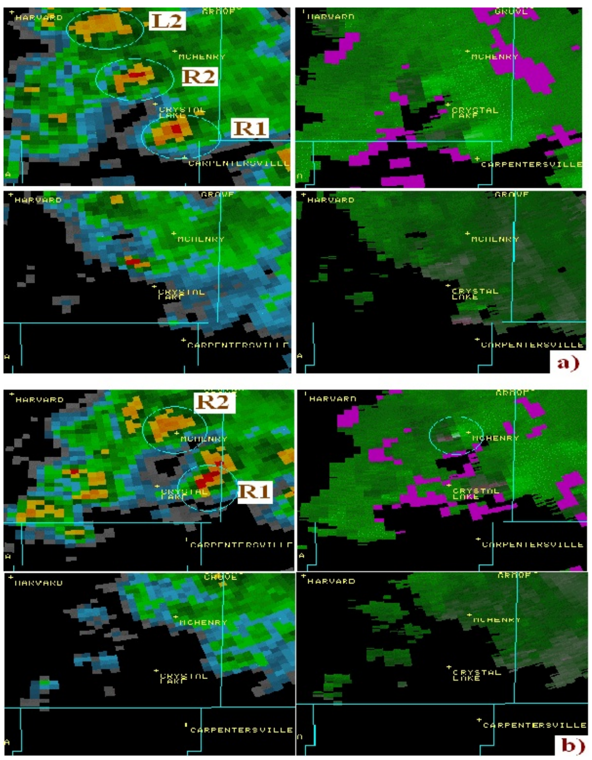

Figure 9. Radar imagery from KMKX WSR-88D. Figure 9a. 0.5 degree base reflectivity (upper left), 0.5 degree base velocity (upper right), 3.4 degree base reflectivity (lower left), 3.4 degree base velocity (lower right) at 2355 UTC. Figure 9b. Same as Figure 9a except for 0011 UTC. R1 represents right-moving supercell with the first storm split, R2 is the right-moving supercell of the split of the initial left-mover, L2 is the left-moving supercell of the split of the initial left-mover.

3. SUMMARY

Mesoscale and synoptic factors came together during the late afternoon of August 24th, 2004 which led to the occurrence of four F0 tornadoes across northern Illinois. The mesoscale features were quite subtle, and identification of these features poses a significant challenge to warning forecasters.

An MCV, which had its origin in the stratiform precipitation region of a decaying MCS across west- central Illinois, was not detected by the profiler or radiosonde network. The presence of the MCV was inferred from analysis of satellite and radar data as it moved northeastward into northern Illinois. Thunderstorms developed near the center of the MCV by mid-afternoon, and the convective mode became supercellular as the old outflow boundary across northern Illinois from morning convection was encountered. Unidirectional shear profiles were conducive to storm splitting, and a left-moving supercell also produced a tornado as convection tracked north of the old outflow boundary. Lower LCL heights and a more favorable distribution of low-level CAPE may have supported tornadogenesis across extreme northern Illinois through vortex stretching.

4. ACKNOWLEDGEMENTS

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