P12.7 MESOCYCLONE AND RFD INDUCED DAMAGING WINDS OBSERVED IN THE 27 MAY 2004 SOUTHWEST OHIO SUPERCELL

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1. INTRODUCTION

During the early evening hours of 27 May 2004, in an environment classified by moderate shear and instability, a supercell developed in rather close proximity to the Wilmington, Ohio WSR-88D (KILN) radar. Although this supercell was responsible for producing large hail and two brief, but weak tornadoes, it was the preponderance of damaging winds that marked this storm. Of special interest to this case was the ability to evaluate the storm's low-level mesocyclone and rear flank downdraft (RFD) characteristics using high resolution WSR-88D 8-bit base reflectivity and velocity data at ranges of less than 18.5 km (10 nm) from the KILN radar. Potential correlation between both the low-level mesocyclone and the RFD with areas of non-tornadic damaging winds were evaluated.

Collection of high resolution data by radar systems such as the Doppler On Wheels (DOW) have been instrumental in revealing not only high detailed information pertaining to tornadoes, but also on low-level mesocyclone characteristics (Wurman et al. 1997; Wurman and Alexander 2004). Wurman and Alexander (2004) illustrate the difficulty in determining, at times, whether a multi-scale system was in fact a mesocyclone or 'tornado cyclone' (Agee 1976), primarily because of the limitations inherent in a radar system to resolve such features. An example of exceptionally strong, damaging winds associated with a low-level mesocyclone were measured by a DOW mobile radar in Oklahoma on 29 May 2004 at heights as low as 6 to 91 m (20 to 300 ft) AGL according to J. Wurman (2006, personal communication). While data presented in this study will not show such extreme values, it will illustrate to what degree the WSR-88D radar can resolve certain features at such close ranges.

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2. METEOROLOGICAL ASSESSMENT

During the mid-late afternoon hours of 27 May 2004, a surface frontal zone, attended by weak waves, was aligned SW-NE through MO then northeastward through MI. This placed the Ohio Valley in a broad south-southwesterly flow of very warm, moist and increasingly unstable air. Utilizing RUC data, upper level analysis for this time indicated a quasi-zonal westerly flow pattern across the region, with a 59 ms^{-1} (115 kt) W-E jet oriented through southern IN/OH (not shown). Mid-level forcing was negligible. At 850 mb, an axis of convergence was observed stretching from MO, northeastward into IN, in advance of a rather broad SW-NE oriented pressure trough (not shown).

At 1815 UTC, visible satellite imagery indicated the development of thunderstorms across west-central IN (Fig. 1). It should be noted that several hours prior to this convective development, a strong W-E oriented surface θ_e gradient was observed stretching across the northern half of IN and OH, with surface θ_e advection quite pronounced across west-central IN. Thus it appears that convection initiated on this moisture convergence boundary that extended into OH.

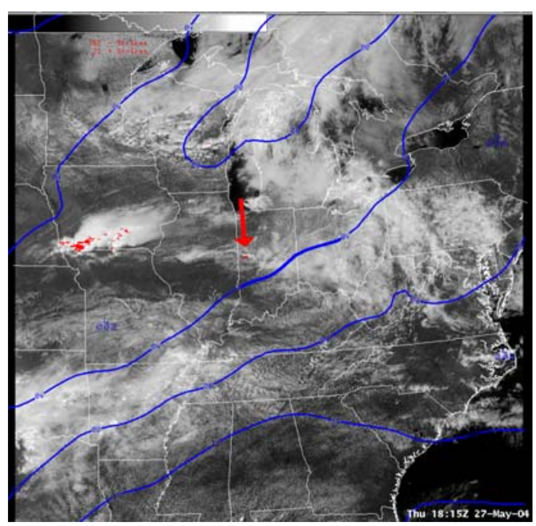

Fig. 1. Visible satellite image and 15 minute lightning data (red dashes and arrow) at 1815 UTC, with 1800 UTC RUC MSL pressure analysis (mb; blue).

By 2200 UTC, an area of 850 mb convergence had developed eastward across central IN and into west-central OH (Fig. 2), apparently aiding the developing convection. At 925 mb, Fig. 2 indicated an axis of instability nosing into southwest OH, where CAPE values approached 2000 J/kg. An area of convergence was also observed at this level, stretching from MO northeastward into western OH. Low level shear, as assessed using the 0-1 km storm-relative helicity (SRH) parameter, indicated values increasing to 125-150 m^2s^{-2} over southwest OH. Values in this range, according to Rasmussen (2003), provide for a better environment for supercells to potentially produce significant tornadoes. Note however that this parameter alone is not a requisite for the generation of significant tornadoes, but was strongly indicative of the potential for rotating storms.

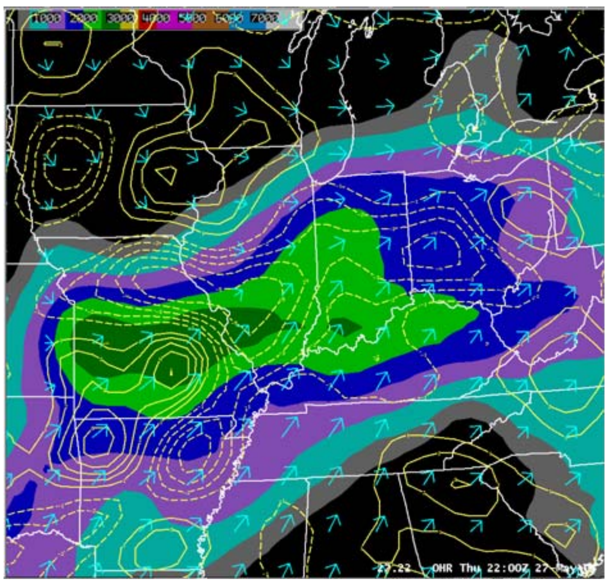

Fig. 2. Analyzed 925 mb CAPE (J/kg) and winds (arrows) from the RUC at 2200 UTC on 27 May 2004. 850 mb convergence (dashed) also shown.

In addition, Local Analysis and Prediction System (LAPS) sounding data which were generated in AWIPS for a point in southwest OH at 2200 UTC (Fig. 3) indicated that thermodynamic conditions were not only favorable for rotating storms (BRN = 24), but also for strong updrafts (mean layer CAPE ~2300 J/kg) and the potential for large hail (WBZ ~3.1 km (10.3 kft) AGL). Organized storms were also a possibility given the moderately sheared (17 ms^{-1} sfc-6 km mean wind) and unstable environment. Damaging winds likewise were a possibility, as indicated by: (1) the well-defined inverted-V thermal profile which supports enhanced downdraft strength through evaporative processes, and (2) observed dry air aloft indicative of a convectively unstable environment where θ_e decreases with height (Atkins and Wakimoto 1991).

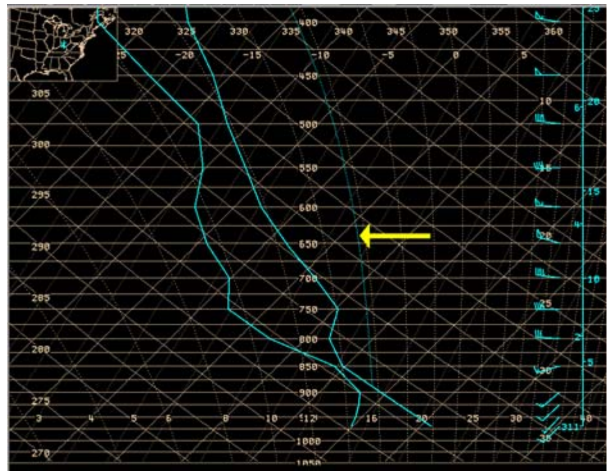

Fig. 3. LAPS sounding displayed from 2200 UTC on 27 May 2004 for a point in SW Ohio. Lowest 50 mb mean layer lifted parcel (dotted line) indicated by arrow.

3. RADAR ANALYSIS

Isolated convection developed around 1800 UTC over east-central IL and west-central IN, as observed by the WSR-88D Indianapolis, IN (KIND) and Lincoln, IL (KILX) radars. By 1900 UTC, this convection had filled in and became oriented into a quasi WSW-ESE line of thunderstorms. As these storms moved east, convection along the leading edge of the line interacted with a boundary left behind by some weak convection that had developed ahead of the line about 30 minutes prior. This led to the development of an enhanced/deeper storm at the leading edge of the line between 1930 and 2000 UTC.

After 2000 UTC, this leading edge storm became more discrete, and by 2030 UTC had experienced a split, with clear intensification of the right-mover (Fig. 4). Lightning activity increased dramatically as well at this time. By 2200 UTC, this same storm, now having entered southwest OH, experienced yet another split, with another dramatic spike in lightning activity associated with the right-mover. This right-moving storm continued to intensify as it moved to the southeast, passing within 18.5 km (10 nm) of the KILN radar, allowing for a high-resolution storm-scale assessment of its' low level features.

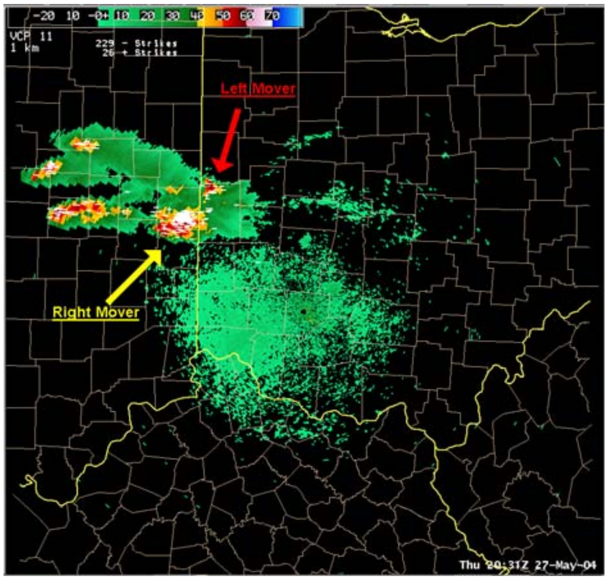

Fig. 4. KILN 0.5° Base Reflectivity image (dBZ) and 5-minute lightning data (white) at 2031 UTC on 27 May 2004.

Between 2210 and 2220 UTC, rotation was observed in association with descending mesocyclone formation. By 2225 UTC, rotation had tightened and was now much better defined at the lowest (0.5°) elevation angle (Fig. 5). Rotational velocity (V_r) of the low level mesocyclone, as identified at the 0.5° elevation slice, had increased to 29 kt. The mesocyclone diameter at this lowest slice was ~1.5 nm, with the center of the beam located at ~191 m (625 ft) AGL. There was also some evidence at this time for a developing tornado cyclone, where a somewhat distinct circulation had begun to form within the broader mesocyclone circulation (Agee 1976), primarily at those elevation angles between 1.5° and 3.4°.

It appeared at this time that the storm was taking on HP supercell characteristics, with development of a BWER in association with the strengthening updraft/mesocyclone (Moller et al. 1994). An appendage in the reflectivity data at the lowest slice had now become evident as well (Fig. 6).

Figure 7 depicts the evolution of this storm as it transitioned from and inflow-dominated HP supercell to outflow/RFD dominated between 2225 and 2235 UTC. By 2230 UTC, there was better evidence within the observed KILN radar data of a tornado cyclone (Fig. 7d). At ~226 m (740 ft) AGL, V_r in association with the low-level mesocyclone had increased to 20 ms^{-1}. In addition, V_r within this tornado cyclone was observed to increase with height, showing 26 ms^{-1} rotation at 1.4 km (4.6 kft) AGL. It was about this time that a brief touchdown of a weak F0 tornado occurred.

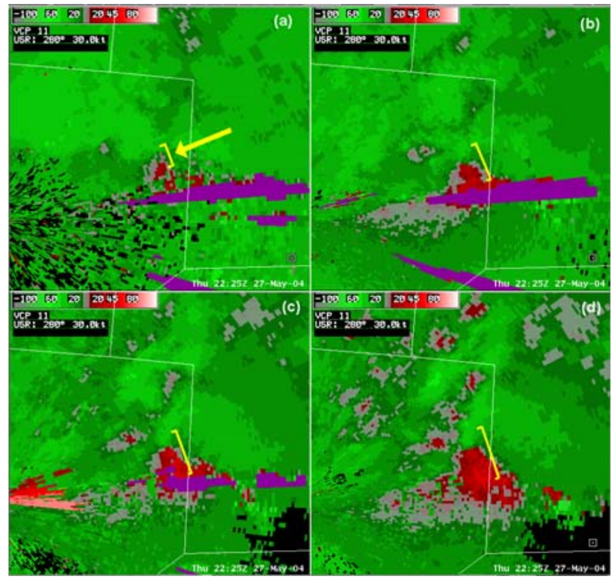

Fig. 5. KILN 4-panel SRM images from 2225 UTC on 27 May 2004 (28 km zoom). Storm motion from 280° at 30 kt. Elevation angles used: (a) 0.5°, (b) 1.5°, (c) 2.4°, and (d) 3.4°. KILN radar located just off the lower left part of each panel.

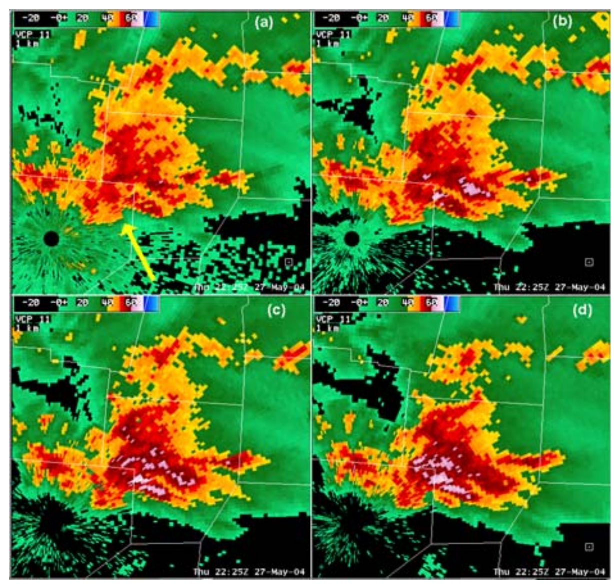

Fig. 6. Same as Fig. 5 except showing Base Reflectivity (72 km zoom). KILN radar location evident in lower left portion of each panel. Arrow points to developing low-level appendage.

By 2235 UTC, it became evident that the rear flank downdraft (RFD) had moved out ahead of the tornado cyclone, apparently choking off the

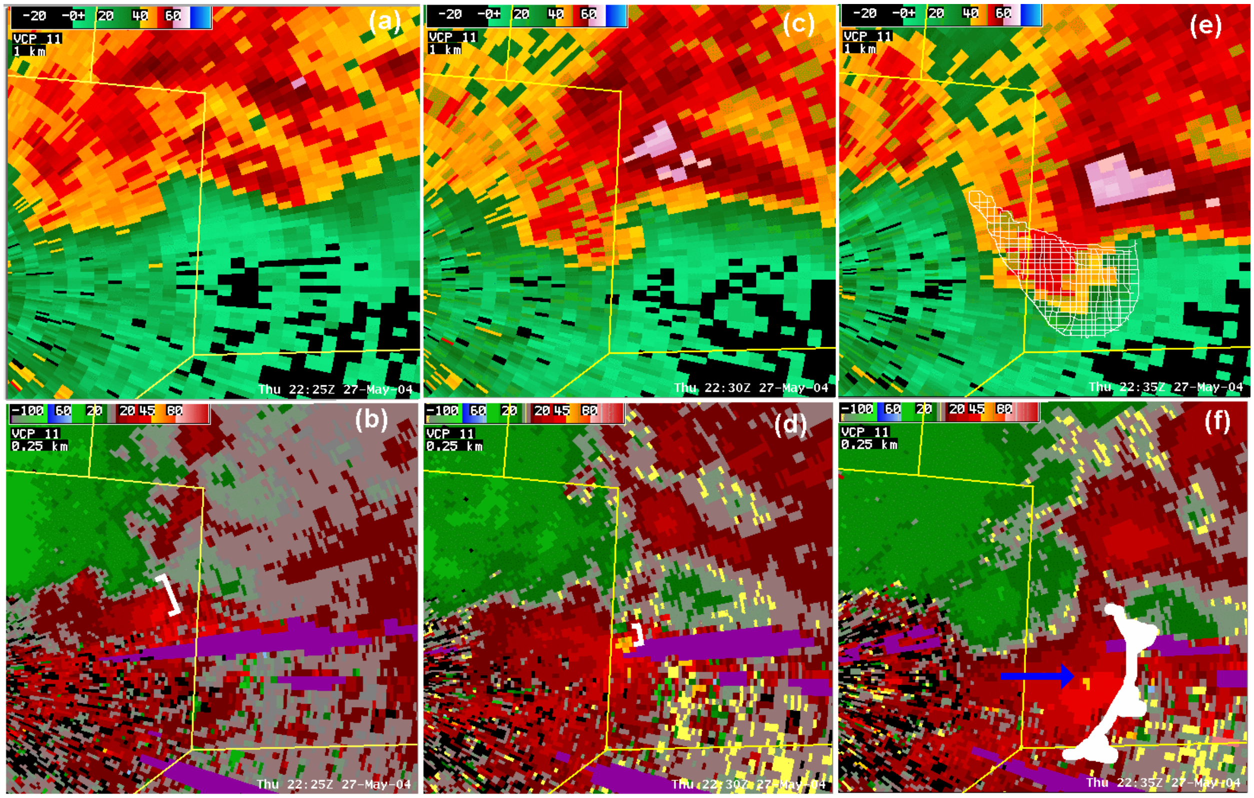

Fig. 7. KILN 8-bit 0.5° Base Reflectivity (a,c,e) and Velocity (b,d,f) imagery from 2225-2235 UTC on 27 May 2004. KILN radar located just to the left of each panel. Low level mesocyclone (b) and tornado cyclone (d) noted by white brackets. Forward edge of RFD outflow (frontal symbol) and remnants of low-level tornado cyclone (arrow) depicted in (f). Hatched area (e) correlates with mesocyclone and outflow/RFD related wind damage during this period.

inflow of any low-level storm-relative horizontal vorticity necessary for sustaining tornado genesis. The affect of this was rapid weakening of the tornado cyclone. High resolution WSR-88D base radial velocity imagery showed a broad area of 45-26 ms^{-1} flow at ~274 m (900 ft) AGL in association with the RFD (Fig. 7f). Non-tornadic damage, primarily in the form of downed trees, appeared to be correlated first with the low-level mesocyclone, and then with the RFD as it become the more dominant low-level feature (note hatched area in Fig. 7e). This outflow/RFD feature persisted through about 2300 UTC as the storm continued on its southeast track, and eventually weakened. Prior to weakening, however, between 2246 and 2251 UTC, another weak tornado (F1) developed. It apparently formed in association with the low-level mesocyclone, at the intersection of the RFD generated gust front and forward-flank downdraft outflow boundary.

4. SUMMARY

During the afternoon and early evening hours of 27 May 2004, thunderstorms developed across central IL and IN, and spread east into OH. A supercell developed on the leading edge of this convection, in rather close proximity to the Wilmington, OH WSR-88D (KILN) radar. While this supercell was responsible for producing large hail and two weak tornadoes, it was the preponderance of damaging winds that was the focus of this study, specifically that associated with the storm's mesocyclone and RFD.

Meteorological conditions for this event indicated that the Ohio Valley was under a broad south-southwesterly flow of very warm, moist air, ahead of a SW-NE oriented frontal zone that was positioned well to the northwest. The environment was categorized by moderate instability and shear, with boundary layer forcing being the primary initiator and sustainer for the convection. Thermodynamic indicators supported the potential for large hail, damaging wind and rotating storms. Enhanced 0-1 km SRH also signified the potential for rotation, especially at low-levels.

As the storm in question for this study passed within ~18.5 km (10 nm) of the KILN radar, evidence for the storm exhibiting HP supercell characteristics became clear. High resolution

KILN SRM and base velocity data indicated not only strengthening of the low-level mesocyclone at heights as low as ~183 m (600 ft) AGL, but also showed evidence for development of a brief tornado cyclone. The storm soon transitioned from an inflow-dominated HP supercell to outflow/RFD dominated. Non-tornadic damaging winds appeared to correlate well with both the low-level mesocyclone and then with the RFD feature.

5. ACKNOWLEDGMENTS

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