Mobile Doppler Radar Observations of a Tornadic Supercell Near Springfield, Illinois, on 15 March 2016

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1. Introduction

On 15 March 2016, a an isolated supercell thunderstorm developed west of Springfield, Illinois, and produced a tornado between 0044-0052 UTC 16 March (red star in Fig. 1a). A Doppler on Wheels radar was stationed at the University of Illinois Urbana-Champaign as a part of a National Science Foundation-sponsored educational mission and deployed southwest of Springfield to gather data on the supercell and tornado. The data collected during this deployment is presented below to add another case to a growing body of high-resolution, mobile Doppler radar intercepts of supercells and tornadoes.

2. Synoptic and Mesoscale Overview

At 0000 UTC 16 March 2016, a surface low was located over northwestern Illinois (Fig. 1a). A cold front extended southward from this low across west-central Illinois to near St. Louis, while a warm front extended east-southeastward to near Indianapolis. The warm sector was characterized by surface temperatures in the lower 70s (F) and dewpoints in the upper 50s.

At 300 mb, a negatively-tilted trough was over the Northern Rockies and Northern Plains (Fig. 1b). A 100+ knot jet streak was rounding the base of this trough, placing Central Illinois and the surface low in the divergent left-exit region of this jet streak.

A sounding launched at 0000 UTC from Lincoln, IL (Fig. 1c), depicts a conditionally-unstable atmosphere with 1404 J kg^{-1} of surface-based convective

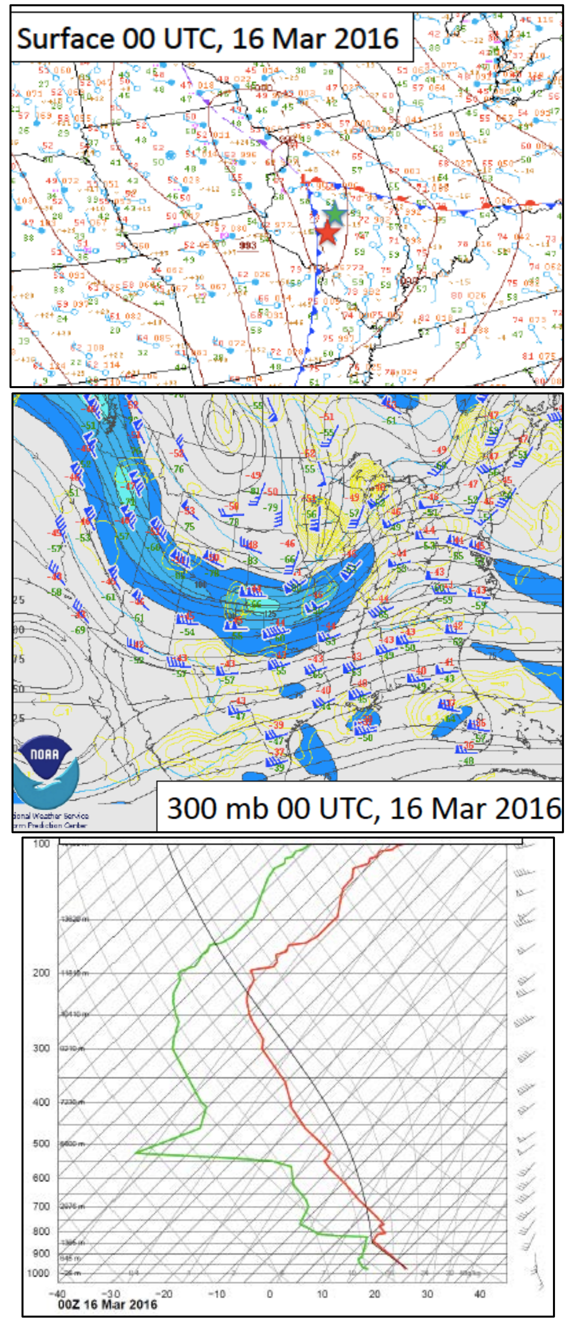

Figure 1: (a) Weather Prediction Center surface map valid at 0000 UTC 16 March. (b) 300 mb analysis with streamlines (blue), isotachs (shaded; kts), divergence (yellow), and rawinsonde observations valid at 0000 UTC 16 March. (c) Sounding launched at Lincoln, IL, 0000 UTC 16 March, at the green star in (a). The red star in (a) is the location of the tornado.

available potential energy (CAPE). A substantial cap remained, however, as the convective inhibition (CIN) was still 90 J kg^{-1}. A mesoanalysis from the Storm Prediction Center (SPC; not shown) revealed that the only uncapped CAPE was only immediately along and ahead of the surface cold front. The 0-6 km bulk shear was between 55-60 knots and the 0-1 km storm-relative helicity was around 200 $m^2 s^{-2}$, meaning that the pre-storm environment was more than adequate to support organized convection, including supercells.

Given this environment, SPC issued a categorical Enhanced Risk of severe weather for the region (Fig. 2a), including a 10% chance of a tornado within 25 miles of a point (Fig. 2b).

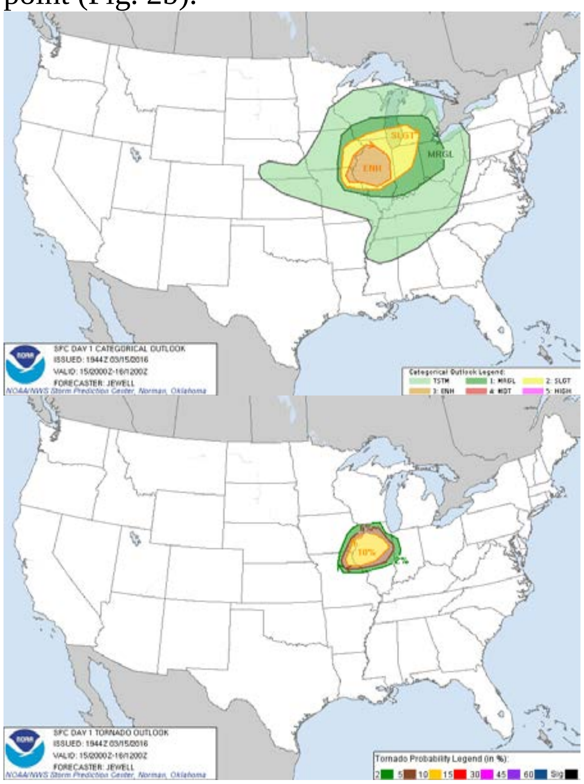

Figure 2: (a) Storm Prediction Center Categorical Convective Outlook issued at 2000 UTC 15 March 2016 (b) SPC Probabilistic Tornado Outlook issued at 2000 UTC 15 March 2016

During the early evening hours of 15 March, a cluster of thunderstorms developed within the Enhanced Risk area above (Figs. 2a and 3a). The storms within this cluster were of mixed modes, including supercells and line segments with embedded rotation. Several tornadoes were reported with this activity (not shown); these cells were not intercepted owing to more unfavorable terrain in this region of Illinois and likely attenuation of the X-band beam owing to passage through multiple convective cores.

An isolated supercell formed to the southeast of this earlier activity (circled in white in Fig. 3a) and tracked east-northeastward toward Springfield, Illinois, after 0000 UTC 16 March. A zoomed-in view of WSR-88D imagery reveals two thin hook echoes on the right-rear flank of this supercell at the time the tornado was first reported (Fig. 3b). A tornado warning was issued for this cell at 0005 UTC and in effect at the time of tornadogenesis.

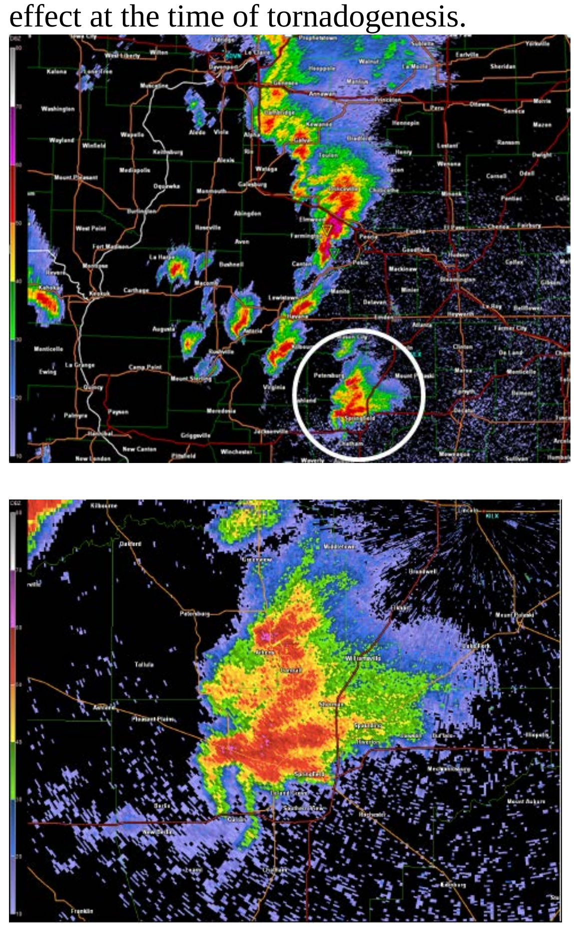

Figure 3: (a) Wide view and (b) zoomed-in view of KILX WSR-88D base reflectivity imagery at 0044 UTC 16 March.

3. Data and Methods

The data analyzed in this paper were collected with a DOW mobile X-band dual-polarimetric radar. The DOW scanned at elevations of 0.5°, 1.0°, 1.5°, 2.0°, 3.0°, and 5.0°. During the time of the tornado, the supercell was 20-25 km from the radar.

The radar data were edited with SOLO3 software. First, the data were thresholded against the normalized coherent power (NCP), to remove noise. Data for which the NCP was below 0.25 were deleted; this was an indication of a low signal-to-noise ratio. Ground clutter, identified from areas of Doppler velocities near 0 m s^{-1} co-located with high reflectivity values owing to non-metrological objects was removed manually. Any other remaining noise was manually deleted at the conclusion of the editing process.

4. Radar Analysis

The analysis of the high-resolution mobile Doppler radar data begins at 0034 UTC. At this time, a tight Doppler velocity couplet was located within the hook echo of the storm (Fig. 4a). This circulation broadened with height (Fig. 4b). By 0039 UTC, however, this circulation broadened and weakened at all levels (Figs. 4c, d). The circulation began to reintensify by 0044 UTC, the time of tornadogenesis (Figs. 5a, b), but still appeared to be weaker than at 10 minutes earlier (compare to Figs 4a, b). The circulation also retightened by this time. The circulation became even tighter by 0049 UTC (Figs. 5c, d), as the tornado continued. Mobile Doppler radar data on the tornado were unfortunately lost after this time, however, as the tornado became blocked by trees and other ground clutter near the radar site.

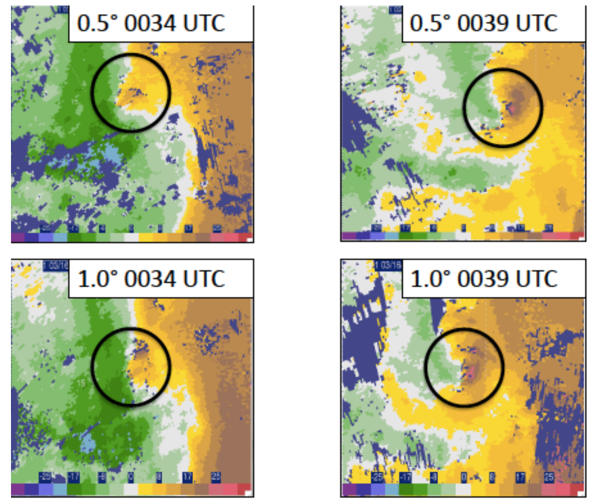

Figure 4: Mobile Doppler radar velocity observations at (a) 0.5° at 0034 UTC, (b) 1.0° at 0034 UTC, (c) 0.5° at 0039 UTC, and (d) 1.0° at 0039 UTC.

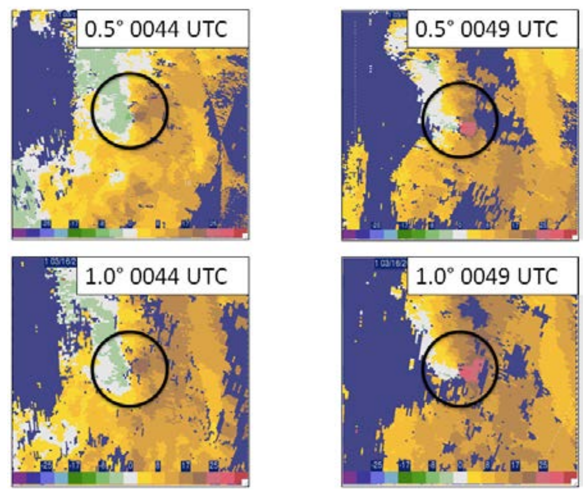

Figure 5: Mobile Doppler radar velocity observations at (a) 0.5° at 0044 UTC, (b) 1.0° at 0044 UTC, (c) 0.5° at 0049 UTC, and (d) 1.0° at 0049 UTC.

Analyses of the velocity difference across the circulation (ΔV) and circulation diameter were also conducted. The velocity difference is defined as the difference between the maximum and minimum radial velocity values; the physical distance between the points corresponding to these velocities was defined as circulation diameter.

The pretornadic circulation on the lowest scans at 0034 UTC was curiously as strong or stronger (as measured by ΔV) than the circulation immediately at the time of tornadogenesis (Fig. 6). The circulation weakened with time at all levels between 0037-0042 UTC, but strengthened just after this time, culminating in tornadogenesis at 0044 UTC (dotted line in Fig. 6). Throughout this period, the circulation generally weakened with height. The circulation dissipated rapidly by 0052 UTC.

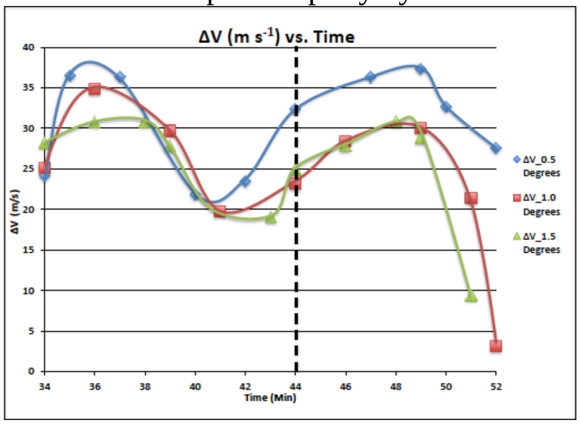

Figure 6: Time series of circulation intensity (ΔV) at 0.5° (blue), 1.0° (red), and 1.5° (green).

The circulation broadened as the pretornadic circulation weakened around 0037 UTC (Fig. 7). The circulation tightened at all levels, but most notably aloft, in the minutes before tornadogenesis, consistent with the conservation of angular momentum (Fig. 7). The diameter of the circulation remained less than 200 m during the time of the tornado and broadened as the tornado dissipated at 0052 UTC.

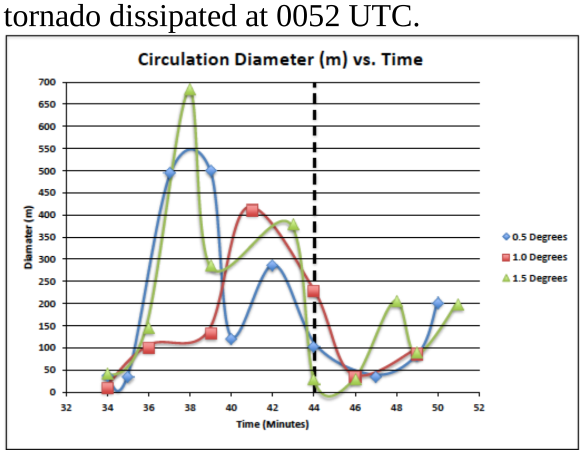

Figure 7: Time series of circulation diameter at 0.5° (blue), 1.0° (red), and 1.5° (green).

A National Weather Service damage survey rated the tornado as EF-1 on the Enhanced Fujita Scale, with damage documented to homes and trees (not shown). The tornado track and damage indicators determined from this survey agree remarkably well with the track of the circulation from the 0.5° mobile Doppler radar data (Fig. 8).

5. Summary and Conclusions

On 15 March 2016, a Doppler on Wheels radar gathered over 50 minutes of data on a tornadic supercell thunderstorm. During this period of observation, this storm produced an EF-1 tornado near Springfield, IL.

An analysis of the high-resolution radar data collected reveals that a pretornadic circulation, with nearly the same strength and width as the tornado, existed 10 minutes prior to tornadogenesis. The circulation weakened before reintensifying just before tornadogenesis. This analysis also illustrates that the circulation was generally the strongest on the lowest (0.5°) scan and weakened with height. The circulation was also stronger when it was smaller in size.

Future work includes additional analyses during the pre-tornadic phase of the storm and examination of dual-polarimetric data.

Figure 8: Map of the tornado track determined from the National Weather Service damage survey (green line), NWS damage indicators (yellow pins), and tornado location determined from the high-resolution radar data (red pins). The time (in UTC) of the radar scan is listed next to the corresponding red pin.