Investigating the Environment of the Indiana and Ohio Tornado Outbreak of 24 August 2016 Using a WRF Model Simulation

**Kevin Gray and Jeffrey Frame**

Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign

**INTRODUCTION**

On 24 August 2016, a tornado outbreak impacted Indiana and Ohio with 23 confirmed tornadoes (Fig 1a).

- **CIN** was removed by 1800 UTC across most of central Indiana (Fig. 2i), with 2000-3000 KJ/kg mixed-layer CAPE and 0-1 km storm-relative helicity (SRH) was well above 100 m2 s⁻¹, more than sufficient for rotating storms (Fig. 2g).

**RADAR ANALYSIS**

Mesoscale Overview

- Between 1500-1700 UTC, elevated storms developed over eastern Illinois (Fig. 3a).

- **SRH** was removed by 1800 UTC across most of central Indiana (Fig. 2i), with 2000-3000 KJ/kg mixed-layer CAPE and 0-1 km storm-relative helicity (SRH) was well above 100 m2 s⁻¹, more than sufficient for rotating storms (Fig. 2g).

**WRF MODEL SIMULATION**

Model Configuration

- **Initialization** was from 0600 UTC 24 August 2016 NAM analysis.

- **Vertical levels**: 60 levels.

**Simulated Environment – 1700 UTC**

- **Simulation** captures the MCV at 500 mb over northern Illinois with winds on the order of 40 kts on its southern flank (Fig. 6a).

- **Model soundings** (red star in Fig. 6c) reveal that the environment near the storms becomes uncapped between 1630-1725 UTC (Figs. 6d and 6e).

**MESOSCALE ENVIRONMENT**

- At 500 mb, a mesoscale convective vortex (MCV) over northern Illinois enhanced the flow over central Illinois and Indiana (Fig. 2a).

- At 700 mb, there was a weak cap in place over Indiana, evidenced by temperatures of 8-10°C (Fig. 2b).

- At 925 mb, winds on the order of 30 knots over central Illinois and Indiana yielded strong low-level shear (Fig. 2c).

- A surface wind shift from southerly to southwesterly flow (purple line in Fig. 2d) moved northeastward amidst a moist air mass (Fig. 2d).

- The 1200 UTC sounding from Lincoln, IL (star in Fig. 2a), depicts significant low-level shear available to surface-based storms and only weak shear available to elevated storms (Fig. 2e).

- **CIN** was removed by 1800 UTC across most of central Indiana (Fig. 2i), with 2000-3000 KJ/kg mixed-layer CAPE and 0-1 km storm-relative helicity (SRH) was well above 100 m2 s⁻¹, more than sufficient for rotating storms (Fig. 2g).

**Development of Initial Supercell**

- The southernmost storm was initially disorganized, with new cell formation to its south and cell decay to its north (Fig. 4a).

- Weak rotation developed within this cell around 1300 m above ground level (AGL); see white circle in Fig. 4b.

- This storm began to exhibit supercellular structure by 1821 UTC (Fig. 4c). At this time, the area of rotation weakened and shifted rearward, while low-level convergence strengthened ahead of the storm in the inflow region (Fig. 4d).

- As a small cell south of the developing supercell approached it (Fig. 4e), the convergence and rotation associated with the storm increased significantly, possibly owing to the development of a rear-flank downdraft (Fig. 4f). As convergence continued to increase, the vertical vorticity was likely amplified via stretching.

**MESOSCALE EVOLUTION OF SIMULATED CONVECTION (1 KM RESOLUTION)**

- **Quarter-linear convection crosses from Illinois into Indiana at 1630 UTC (Fig. 7a). This is slightly earlier than was observed (Fig. 3a).**

- A dominant supercell develops and persists on the southwestern end of the line (Figs. 7b and 7c).

- Although slight embedded rotation develops farther northeast (Figs. 7d and 7e), the model fails to develop additional supercells from this initial convection in northeastern Indiana.

- Too much stratiform precipitation developed ahead of the linear convection (Figs. 7a and 7b), or too much or too cold outflow may have limited instability farther northwest, preventing the development of additional supercells in northeastern Indiana.

**STORM-SCALE ANALYSIS (1 KM RESOLUTION)**

- **Convection is quasi-linear with only weak outflow at 1700 UTC.** Any vertical relative vorticity (ζ) is generated by horizontal shear across the gust front at this time (Fig. 8a).

- **Small cells form south of and merge with the southwestern end of the stronger convection.** A localized area of convergence develops at the far southwestern end of the strong convection, focusing ζ in this region (Fig. 8b).

- **An inflow notch forms and ζ becomes concentrated near the inflow notch (Fig. 8c).**

- By 1745 UTC, the storm is a mature supercell with strong ζ, a hook echo, and forward-flank and rear-flank gust fronts as indicated by the temperature and wind fields (Fig. 8d).

**CONCLUSIONS**

- On 24 August 2016, a surprise tornado outbreak impacted parts of Indiana and Ohio.

- Convection transitioned from disorganized elevated convection to discrete tornadic supercells as it became surface based and gained access to strong near-surface vertical wind shear.

- A WRF simulation of this event captures the thermodynamic and kinematic environment, including the MCV, which regionally augmented the vertical wind shear.

- As in the observations, robust supercellular convection did not develop in the simulation until the storms became surface based. The lack of strong outflow in both the observed and simulated storms likely aided in this transition to a supercellular mode.

**FUTURE WORK**

- Explore additional cloud microphysics options in the WRF simulation.

- Perform additional analysis of the transition from elevated to surface-based convection.

- Examine why many operational models failed to develop supercellular convection in this regime.

**ACKNOWLEDGEMENTS**

We are grateful to Zachary Hargrove (NWS Bismarck) for sharing scripts to plot WRF model output.