Operational Application of Environment and Radar Predictors for Tornado Intensity

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1. Introduction & Goal

An important goal of NWS warnings is to elicit a proper safety response from the public, one that ideally aligns with the forecasted threat. Toward achieving this goal for tornado warnings:

- Numerous studies resulting in published research articles linking environmental factors or radar observations to tornado intensity.
- Doppler Radar advancements, including dual-polarization upgrade, improved spatial resolution, and enhanced low-level scanning strategies increasing temporal resolution.
- Impact-Based Warning (IBW) tags have been included in some NWS tornado warnings to convey the potential for more significant damage from an expected strong to violent tornado.

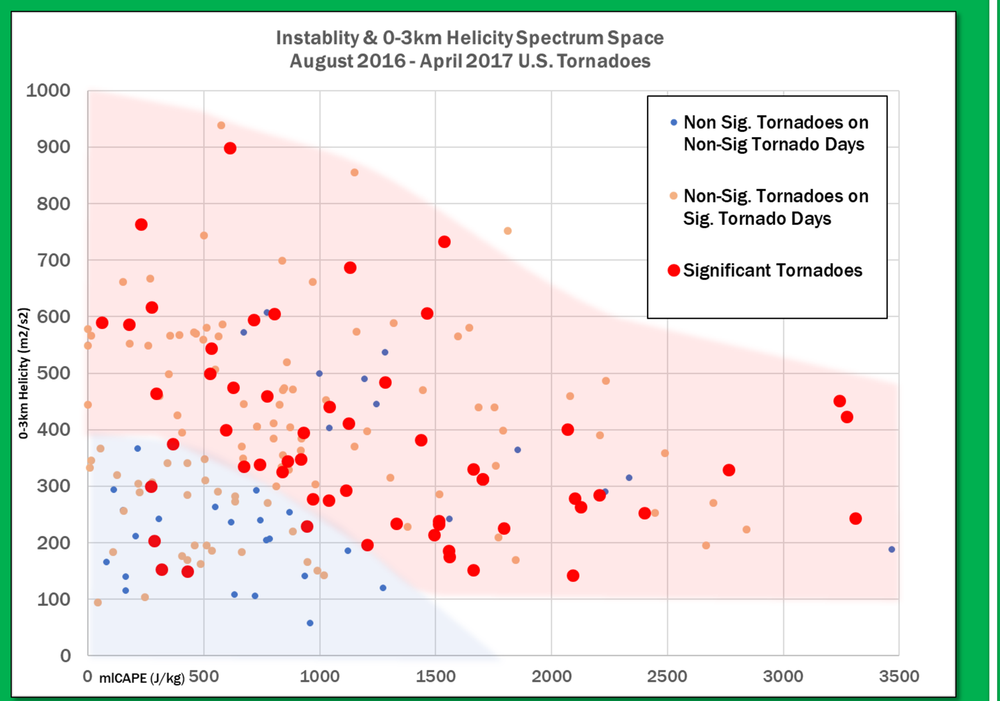
One goal of this IBW approach is to stress the greater impact of the EF-2 to EF-5 tornadoes that are 30 times more likely to result in a fatality than EF-0 and EF-1 tornadoes. Studies need to be incorporated into operational decision making for IBW to be most effective.

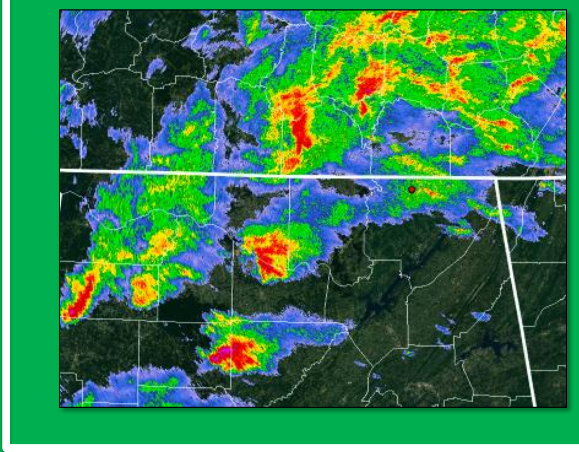
Integrating both environmental factors and radar was the approach of this study, with a goal of giving NWS warning operators an idea of what to expect for radar behavior and trends given the environment, and in the future a possible predictor toward tornado intensity.

2. Operational Challenges & Motivation

Significant tornado environments for a region can often be recognized in the hours and even days in advance. However, even in significant tornado environments, there is variability in storm structure and persistence, and if tornadoes do result they are rarely all EF-2 and stronger.

Right: The spectrum space of instability (mlCAPE) and kinematics (0-3 km helicity) of the tornadic near-storm environments in this study. While non-significant tornado event days often did have operationally-useful spread from most significant days, there were also many EF-0 and EF-1 tornadoes during the stronger event days

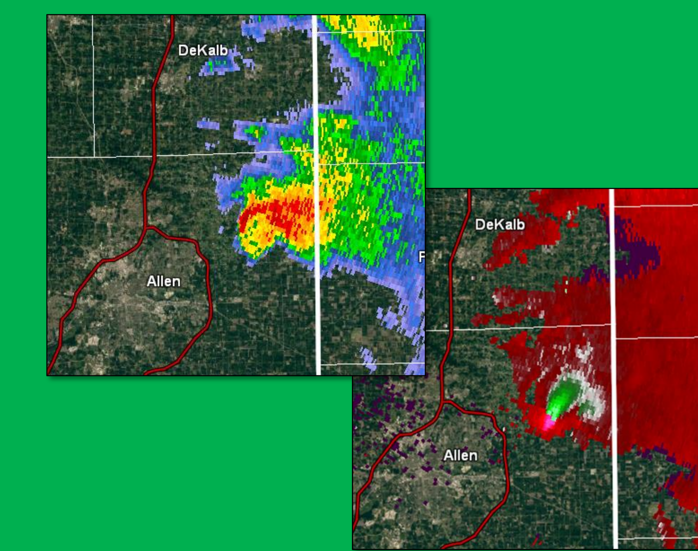


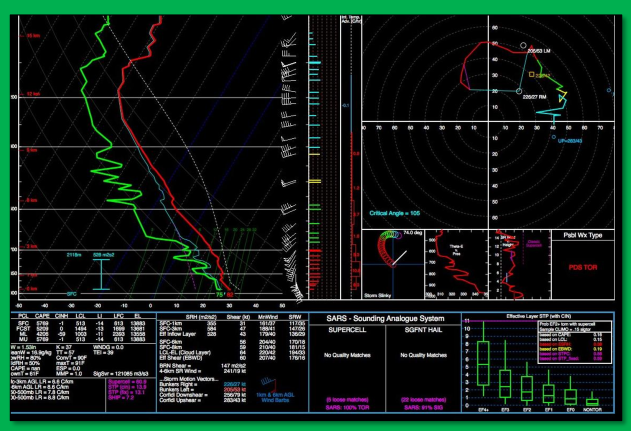


Left: Snapshot of the 2016 Nov 30 multiple tornado event which saw supercells produce tornadoes from EF-0 to EF-3.

3. Methodology

Used in this study were one-hour Rapid Refresh (RAP) Bufkit data interrogated in SHARPpy to analyze near-storm environments as close to tornado occurrence time and location as possible. Archived radar data were analyzed in the GR2Analyst software. Approximately 200 tornadoes from August 2016 – April 2017 were analyzed. Environment characteristics like instability and kinematics that had stronger correlations[1] to tornado intensity were found, and then the data was divided into nine bins. Radar data, including rotational velocity (Vr) and tornado debris signatures (TDS), along with storm modes and longevity were tabulated for each bin.





4. Data Analysis & Results

Significant Tornado Days

Helicity (444 m²/s², 299 m²/s²) / Instability (535 J/kg, 1,117 J/kg)

25 Tornadoes, 7 Significant 19% Supercell 81% QLCS Avg. Vr: 41 kt Sig: 41 kt Vr Std. Dev.: 16 kt TDS Frequency: 22% Avg. TDS Height: 1.4 km Avg. Path Length: 10.7 km	19 Tornadoes, 6 Significant 63% Supercell 37% QLCS Avg. Vr: 44 kt Sig: 72 kt Vr Std. Dev.: 17 kt TDS Frequency: 37% Avg. TDS Height: 2.4 km Avg. Path Length: 16.5 km	14 Tornadoes, 5 Significant 50% Supercell 50% QLCS Avg. Vr: 52 kt Sig: 60 kt Vr Std. Dev.: 19 kt TDS Frequency: 21% Avg. TDS Height: 4.1 km Avg. Path Length: 24.0 km
14 Tornadoes, 2 Significant 36% Supercell 64% QLCS Avg. Vr: 45 kt Sig: 52 kt Vr Std. Dev.: 12 kt TDS Frequency: 14% Avg. Path Length: 9.6 km	21 Tornadoes, 7 Significant 62% Supercell 38% QLCS Avg. Vr: 49 kt Sig: 56 kt Vr Std. Dev.: 9 kt TDS Frequency: 24% Avg. TDS Height: 2.5 km Avg. Path Length: 13.6 km	17 Tornadoes, 8 Significant 71% Supercell 29% QLCS Avg. Vr: 45 kt Sig: 50 kt Vr Std. Dev.: 15 kt TDS Frequency: 41% Avg. TDS Height: 3.3 km Avg. Path Length: 8.1 km
14 Tornadoes, 3 Significant 50% Supercell 50% QLCS Avg. Vr: 39 kt Sig: 52 kt Vr Std. Dev.: 11 kt TDS Frequency: 14% Avg. Path Length: 6.5 km	14 Tornadoes, 4 Significant 50% Supercell 50% QLCS Avg. Vr: 40 kt Sig: 43 kt Vr Std. Dev.: 13 kt TDS Frequency: 6% Avg. Path Length: 6.4 km	24 Tornadoes, 15 Significant 67% Supercell 33% QLCS Avg. Vr: 46 kt Sig: 51 kt Vr Std. Dev.: 18 kt TDS Frequency: 38% Avg. TDS Height: 2.9 km Avg. Path Length: 13.7 km

- More persistent radar signatures and longer-lived tornadoes occurred in the presence of both higher instability and helicity
- A higher percentage of the tornadoes being from a QLCS storm mode were found in moderate to high helicity and low instability
- There was spread in Vr across the board, but it was noted that EF-2 tornadoes on average had 8 kt higher Vr than non-significant
- Tornadoes in this study with lower instability had very limited TDS occurrence, and the greater the helicity in those cases then the Vr difference between significant and non-significant tornadoes approached zero.

5. Future Work and References

The data used in this analysis will be further expanded to include multiple full years and divided for warm and cool season. A predictor that could be computed and spatially plotted to assist warning forecasters in tandem with other data remains the goal.

[1]Clayton, A., E. Lenning, M. Friedlein, A. W. Lyza, and K. R. Knupp, 2017; Utilizing Environmental and Radar Predictors to Anticipate Tornado Intensity; AMS 38th Conference on Radar Meteorology Preprint (2017); Chicago, IL; 165.

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