Radar Detection of Tornadogenesis

Kristofer S. Tuftedal and James V. Aanstoos

Department of Geological and Atmospheric Sciences, Iowa State University, Ames, IA

Introduction

With the implementation of polarimetric products to the array of basic Doppler radar products, there are many different products for meteorologists to look at during severe weather events. Certain radar signatures have been found to be suggestive or indicative of tornadic activity in supercells, such as tornado vortex signatures (TVS) or the more recent polarimetric signature of a tornado debris signature (TDS). However, these signatures are limited to moments prior to tornadogenesis or while a tornado is ongoing. This study attempts to find a signature that is present exclusively in either non-tornadic supercells or tornadic supercells.

Methods

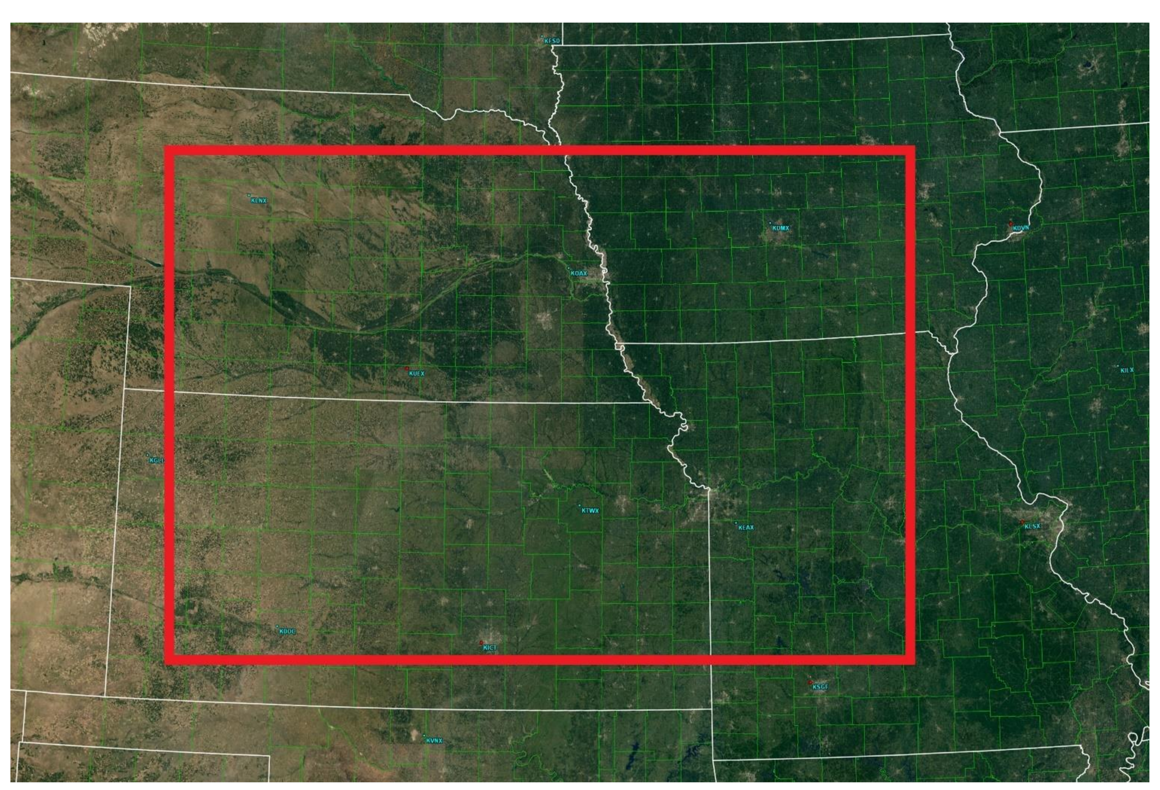

FIG 1. The domain (enclosed in the red box) for this study.

- Non-tornadic dataset was determined by comparing maximum pseudovorticity values from each storm to pseudovorticity values from the definition of a TVS on supercells without a TDS or tornadic damage reports.

$$\zeta_{pv} = \Delta V / L$$

- Visual analysis was done using GR2Analyst to search for signatures in Reflectivity (Z_{HH}), spectrum width (σ_v), differential reflectivity (Z_{DR}), correlation coefficient (ρ_{hv}), and specific differential phase (K_{DP}).
- Signatures were compared to pre-tornado time schematics from Van Den Broeke et al. (2008).
- Statistically significant difference testing was done on any potential signatures using JMP Pro 12.

Results

- Z_{HH}, σ_v, ρ_{hv}, and K_{DP} (Fig. 2 through 5) were similar between all non- and pre-tornadic cases with no consistent, reoccurring differences.

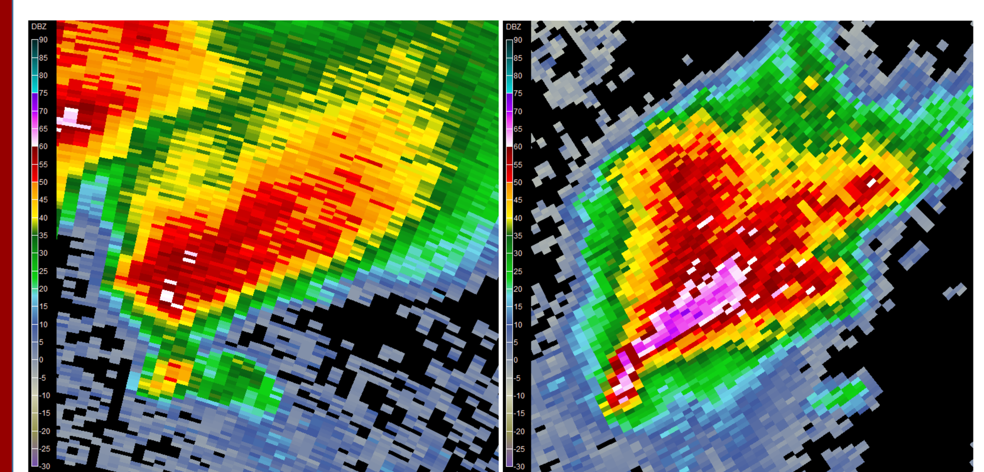

FIG 2. Z_{HH} for both non-tornadic (left) and pre-tornadic (right) cases 7 minutes prior to the maximum pseudovorticity value and tornadogenesis.

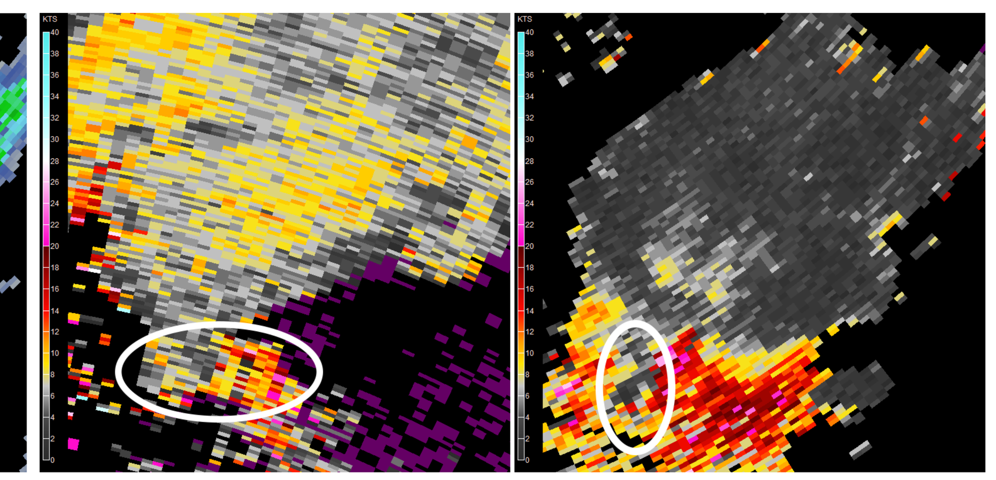

FIG 3. Same as Fig. 2, but for σ_v. Circled regions are the hook echoes.

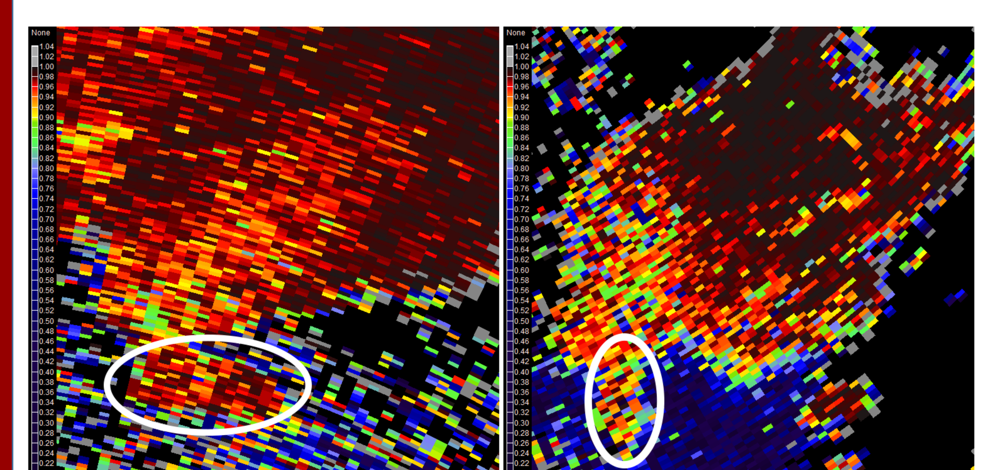

FIG 4. Same as Fig. 3, but for ρ_{hv}.

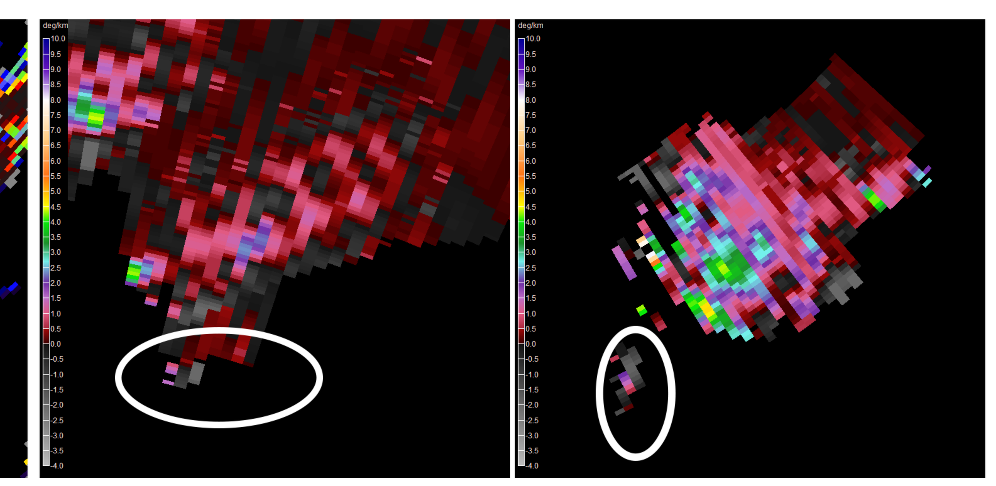

FIG 5. Same as Fig. 4, but for K_{DP}.

- Z_{DR} showed differences between non- and pre-tornadic cases (Fig. 6), with slight overlap in average values of individual cases.
- Non-tornadic cases had higher values than pre-tornadic cases in the hook echo region of the supercell, with the exception of one outlier pre-tornadic case.

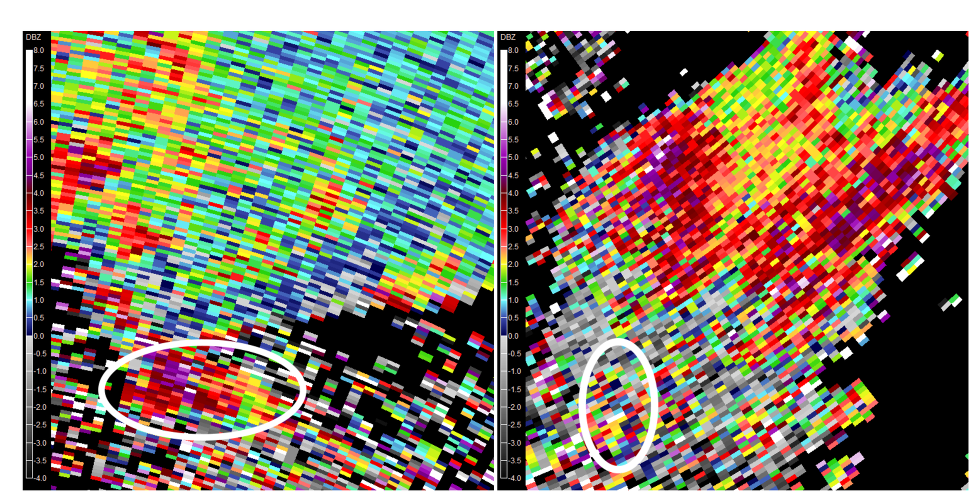

FIG 6. Same as Fig. 5, but for Z_{DR}.

TABLE 1. The means, lower and upper bounds of the 95% confidence interval, and the t-test probabilities (pre-tornadic mean > non-tornadic mean) for all values of hook echo Z_{DR}.

Results of the Pooled t-test				
Case Type	Avg Z_{DR}	Lower 95% CI	Upper 95% CI	t-test Probabilities
All Non-Tornadic	2.23	2.19	2.27	N/A
All Pre-Tornadic	1.79	1.74	1.84	< 0.0001
Pre-Tornadic w/o outlier	1.49	1.44	1.54	< 0.0001

Conclusion

For the 10 cases looked at in the study, there is a strong statistically significant difference between the mean values of Z_{DR} in the hook echoes of pre- and non-tornadic supercells. The signature is not always easy to pick up visually due to the high values associated with descending reflectivity cores (DRC), especially during interaction between DRCs and the parent supercell. This offers a tantalizing suggestion of the possibility for this signature to have a relationship in some way with tornadogenesis. However, due to the small sample of cases used, the evidence of a relationship between Z_{DR} value and tornadogenesis is very preliminary at this point. As for what could be causing this signature, without some form of ground observations or in-situ data, it is difficult to know for sure. One potential cause could be due to how size sorting of hydrometeors occurs in the non-tornadic verses the pre-tornadic cases and either that having an effect on tornadogenesis, or tornadogenesis having an effect on size sorting.

Future Work

Further study into this signature is required to determine its usefulness, reliability, and whether the signature is specific to certain types of supercells. The outlier mentioned in the results did not exhibit the appearance of a typical supercell, but went on to produce multiple strong tornadoes. This leads to the thought that the signature may only be present in certain types of supercells.

Acknowledgements

Bill Gallus for insight on thresholds for the non-tornadic cases. Sean Stelten for discussion on storm scale processes potentially causing the signature. James Aanstoos for insight on radar products, suggesting statistical analyses to perform on the signature, and being a great mentor.

References

Van Den Broeke, M. S., J. M. Straka, E. N. Rasmussen, 2008: Polarimetric radar observations at low levels during tornado life cycles in a small sample of classic Southern Plains supercells. *J. Appl. Meteor. Climatol.*, **47**, 1232-1247.