Automated Detection of Tornado Debris Signature Paths

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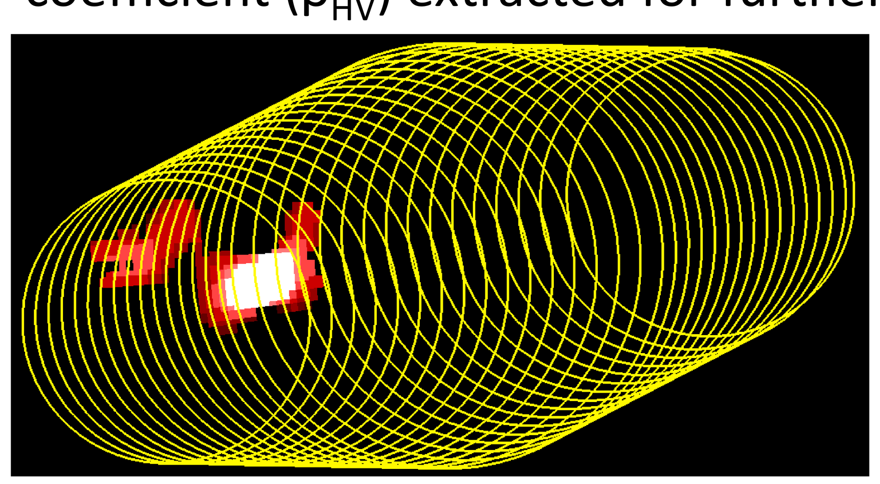
Introduction

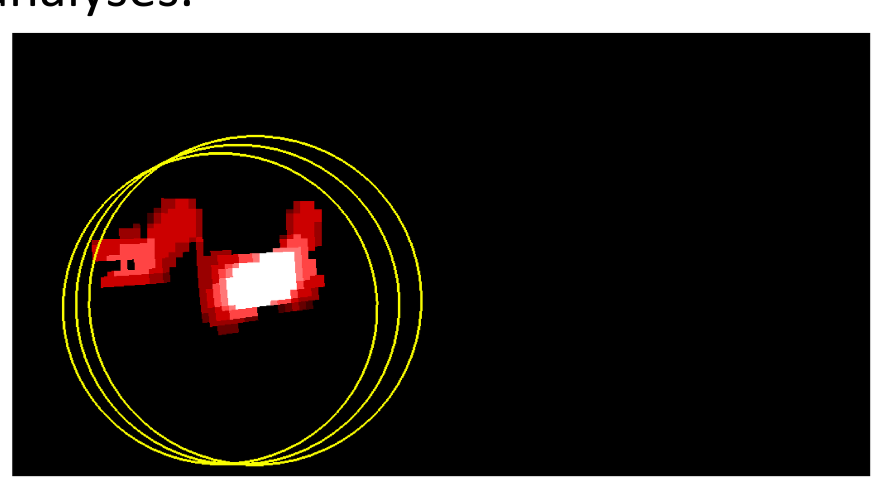
- The diversity of shapes, orientation, and composition of tornadic debris produces a distinct signature when scanned with polarimetric radar called the Tornadic Debris Signature (TDS).
- Observation of a TDS can provide a warning forecaster with confirmation of a damaging tornado even at nighttime or when the tornado is rain-wrapped.
- This presentation explores a pixel-based method to automate the detection of the TDS using common thresholds cited in the research literature.

Data & Methods

- 952 tornado paths within 120km from a polarized WSR-88D radar were recorded in Storm Data from 09 May 2010 – 31 July 2013.
- Level-II data +/- 30 minutes around each event were processed and quality controlled in the Warning Decision Support System – Integrated Information (WDSS-II) software environment.
- Azimuthal shear fields were calculated and matched against a 5km-7.5km buffer placed along the track in 1 min. intervals.
- This window attempts to account for non-linear tornado motion and spatiotemporal uncertainty in the original Storm Data record.
- Events with at least one volume scan exceeding an azimuthal shear of 0.005 s^{-1} at a beam height below 1500m had spatial windows of azimuthal shear, reflectivity (Z_{HH}), differential reflectivity (Z_{DR}), and co-polar cross correlation coefficient (ρ_{HV}) extracted for further analyses.



Full spatial uncertainty window for a single tornado track



Spatial uncertainty window at a single time step

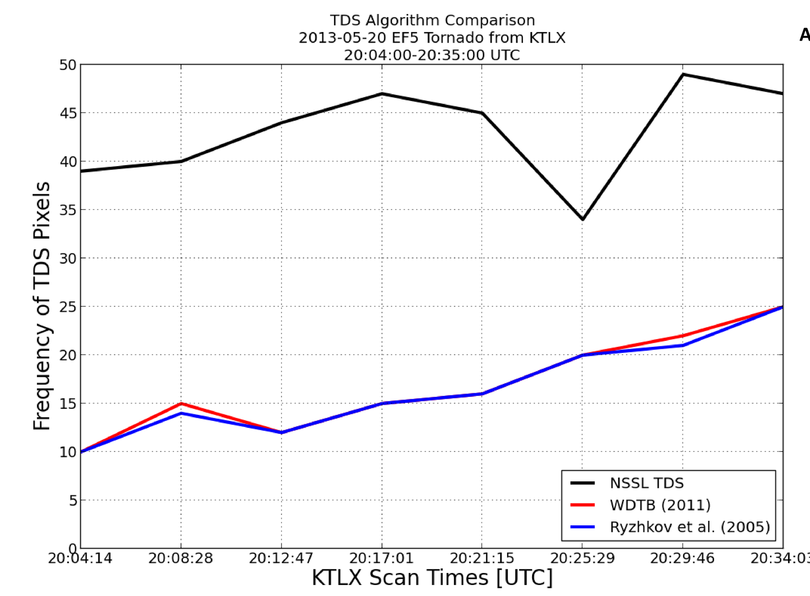
Tornado Events by EF-Rating

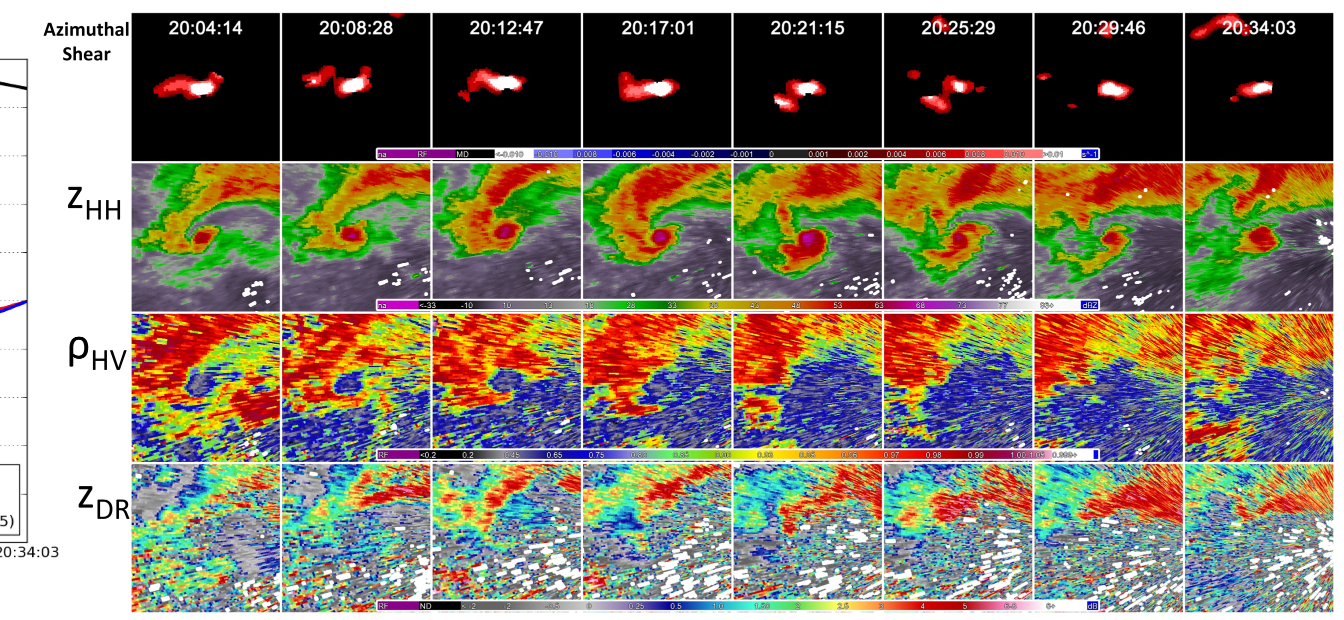
EF0	EF1	EF2	EF3	EF4	EF5
63	107	30	21	6	1

- Distributions of radar variables with tornadic debris involved determining which volume scan had the highest possible chance of lofted debris.
- Following observations from the research literature, the volume scans with the highest Z_{HH} and lowest ρ_{HV} observed within a 7x7 pixel window around the peak azimuthal shear were extracted.
- Using observations from the literature, three preliminary TDS algorithms were developed using the criteria below and pixels exceeding all thresholds were counted for each algorithm.

Ryzhkov et. al (2005) TDS Paper	Warning Decision Training Branch Dual-Pol Training (2011)	NSSL TDS Algorithm First Guess
ρ_{HV} < 0.80	ρ_{HV} < 0.80	ρ_{HV} < 0.80
Z_{HH} >= 20 dBZ	Z_{HH} >= 45 dBZ	Z_{HH} >= 20 dBZ
-0.5 dB <= Z_{DR} <= 0.5 dB	-0.5 dB <= Z_{DR} <= 0.5 dB	Az. Shear > 0.008 s^{-1}

Time Series Case Study – 2013 May 20 – EF5 Tornado from KTLX

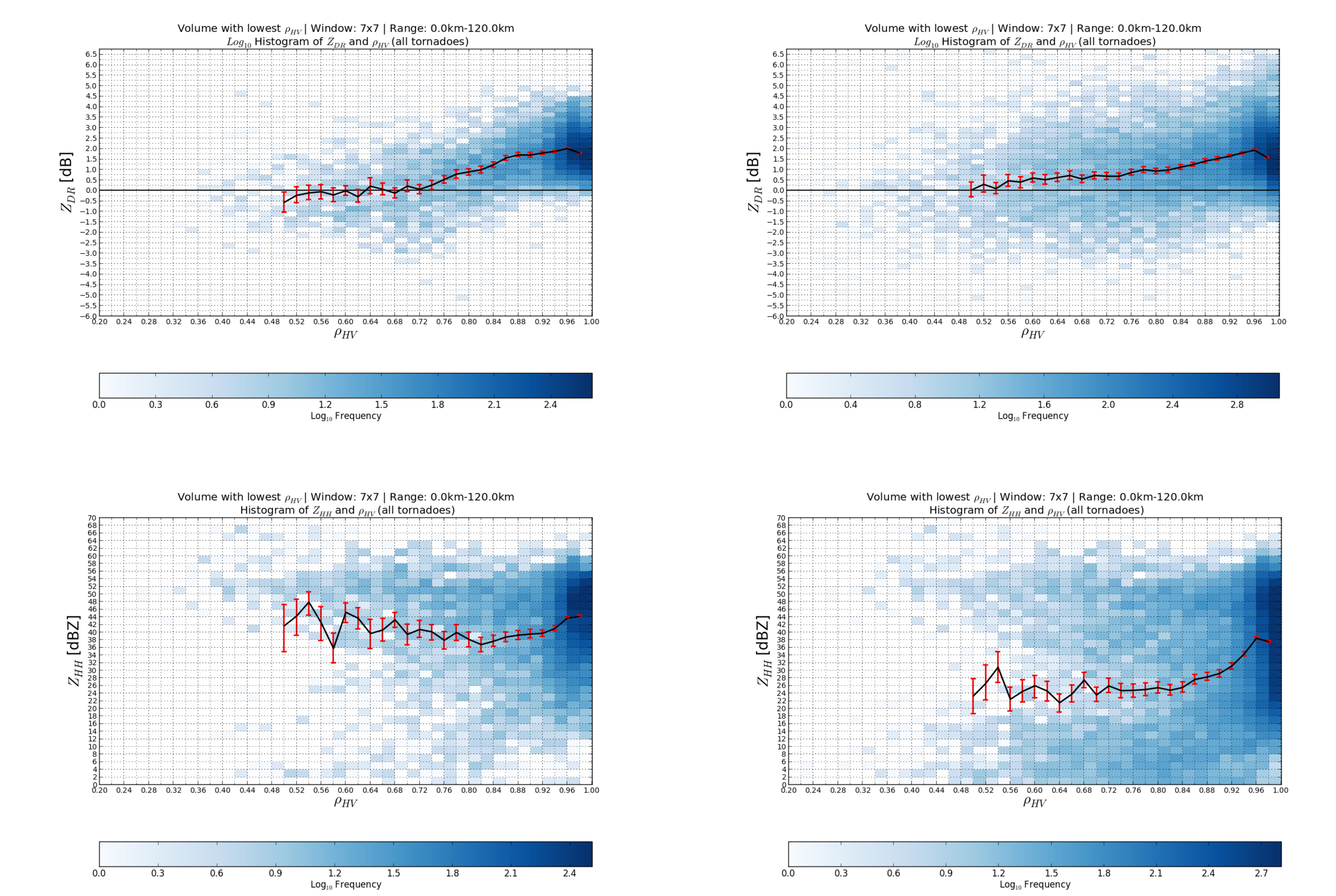




- Azimuthal Shear and Z_{HH} remain well-defined and collocated in the hook region throughout the event.
- Diminishing ρ_{HV} hole into background makes automated debris identification difficult as tornado moves closer to the radar.
- Low Z_{DR} (< -0.5 dB) is seen in most of the hook region, keeping TDS pixel classification counts low for both the WDTB and Ryzhkov criteria.

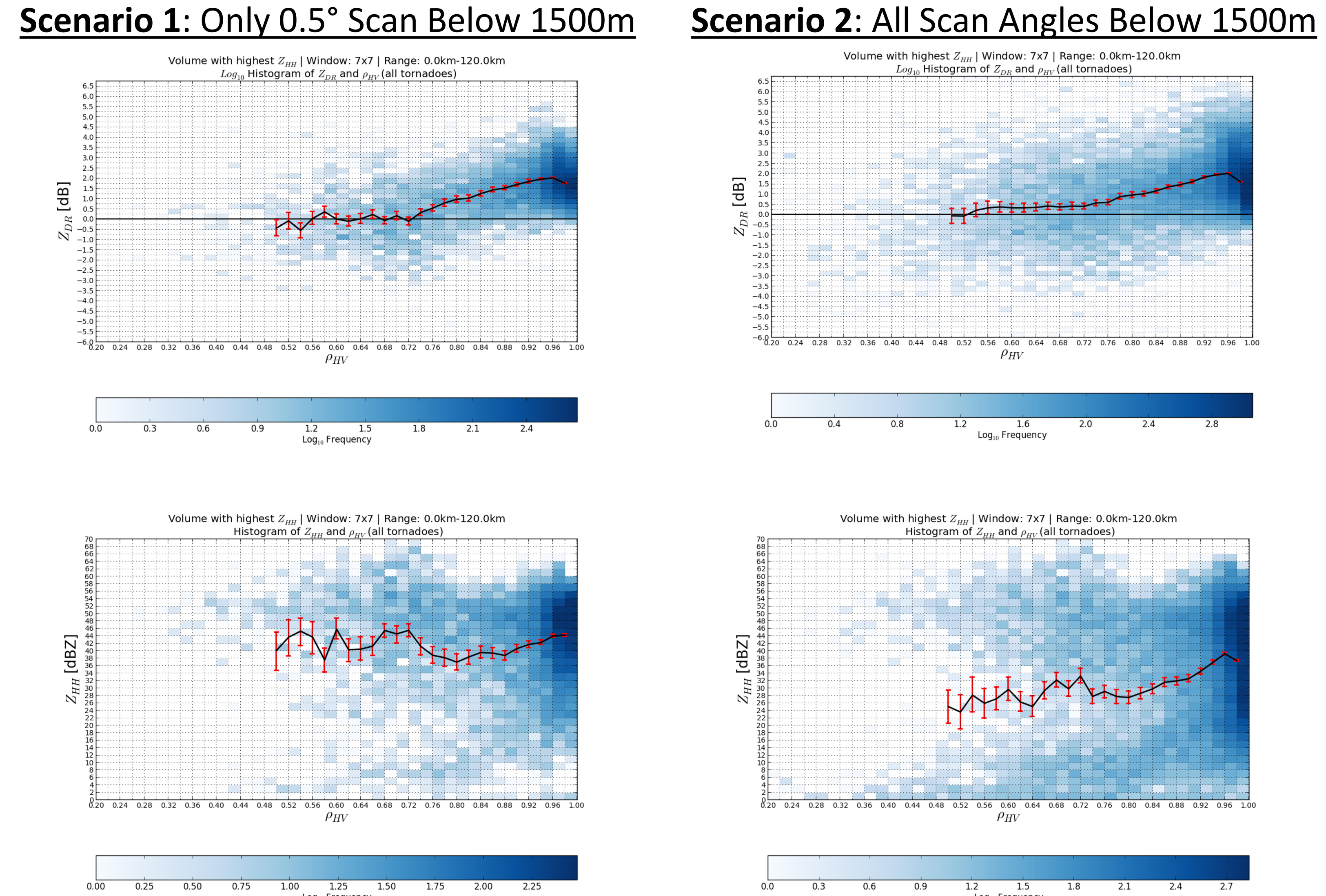
Volume Scan with the Lowest ρ_{HV}

Scenario 1: Only 0.5° Scan Below 1500m   **Scenario 2**: All Scan Angles Below 1500m



Volume Scan with the Highest Z_{HH}

Scenario 1: Only 0.5° Scan Below 1500m   **Scenario 2**: All Scan Angles Below 1500m



Discussion

- There is agreement with the research literature that as ρ_{HV} decreases, Z_{DR} decreases and Z_{HH} increases.
- Incorporating only the 0.5° angle information into the window (scenario 1) provides less spread in the distributions when compared to the inclusion of all scans below 1500m (scenario 2). This is particularly seen in the Z_{HH} field as debris may not be lofted high enough to produce a TDS-like signature at higher elevations above 0.5° and below 1500m.
- For scenario 2, the distributions of Z_{HH} vs. ρ_{HV} are bimodal with Z_{HH} values approaching ~10 dBZ and ~55 dBZ as ρ_{HV} decreases. This is seen to a lesser extent on the lower bound of Z_{HH} in scenario 1. The size of the data window could be a factor as a 7x7 window may be including non-TDS pixels. Smaller windows (3x3 and 5x5) were also investigated and while they mitigated this binomial distribution to a certain degree, they also underestimated the spatial extent of some signatures. This could be due to either: (1) The width of the TDS itself and/or (2) the temporal offset between the surveillance and Doppler scans.
- Negative Z_{DR} values are prevalent with values below -1.0 dB occurring more frequently when ρ_{HV} drops below 0.80.
- Similar trends in the bootstrapped means are seen regardless of whether the scan with the lowest ρ_{HV} or the scan with the highest Z_{HH} is utilized.

Summary & Future Work

- Thresholding by azimuthal shear provides promising results in identifying and tracking tornadic circulations.
- A pixel-based "one size fits all" approach to automating TDS detections is difficult due to many factors affecting signal quality (range from radar, width of the TDS, height and/or amount of lofted debris, etc.).
- Additional analyses applying thresholding by range from the radar or dynamic window sizing need to be evaluated, however, this may limit usability and relevance in an operational setting.

Acknowledgements

This poster was prepared by Darrel M. Kingfield with funding provided by NOAA/Office of Oceanic and Atmospheric Research under NOAA-University of Oklahoma Cooperative Agreement #NA11OAR4320072, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.