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INVESTIGATING THUNDERSTORM WIND DAMAGE WITH A HIGH-RESOLUTION VERIFICATION DATASET

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ABSTRACT

The National Severe Storms Laboratory's Severe Hazards Analysis and Verification Experiment (SHAVE) began verifying wind damage on high temporal and spatial resolution scales in 2007. During the first three years of wind damage data collection, the details of the reports focused on tree/tree limb size and simple descriptions of structural damage (i.e., "small shed destroyed"). During the summer of 2010, the SHAVE wind call script was modified in order to increase the detail of the reports in the archive. The new script focused on concise questions which offered parallels to the Enhanced Fujita scale damage indicators and degrees of damage. This modification to the call script and the high resolution nature of the reports allows researchers to compare familiar wind damage signatures from high resolution radar data to a more encompassing and detailed damage swath than can be found in *Storm Data*. The primary purpose of this study was to investigate radar signatures associated with severe wind and/or wind damage. Wind damage swaths collected during SHAVE were used as the verification for these signatures. In total, 74 SHAVE report swaths collected between 2008 and 2010 were analyzed. This paper summarizes the relationships between differing storm types and radar signatures while discussing how SHAVE reports can be implemented when verifying severe wind damage events.

1. INTRODUCTION

Since 2007, the Severe Hazards Analysis and Verification Experiment (SHAVE; Ortega et al. 2009) has collected wind damage reports through phone calls to citizens affected by severe or marginally severe storms. Over the last two years, studies have incorporated SHAVE's hail (Meyer et al. 2010) and flash flooding (Erlingis et al. 2009) databases. However, no previous studies had utilized SHAVE's wind reports, which—like the hail and flash flooding reports—have a significantly higher resolution than those in *Storm Data*.

After initial evaluation of 2008 and 2009 wind cases, the SHAVE wind questionnaire was modified in June 2010 to increase the detail and applications of wind reports in the archive. Many of the new questions had parallels to damage indicators (DIs) and their respective degrees of damage (DODs) in the Enhanced Fujita Scale (EF-Scale; Wind Science and Engineering Center 2004). This allowed for more accurate wind speed assessment and increased the research applications of the SHAVE data. Further, callers were instructed to ask about wind direction for additional comparison to radar signatures. Preliminary statistics suggest that SHAVE wind calls that can be used to determine wind speed using the EF-Scale increased 7% from 2009 to 2010.

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2. DATASET

For the purposes of this project, 74 cases were investigated in an attempt to quantify the probability of detection (POD) for various common wind damage radar signatures. These cases are summarized in Table 1. Due to the modifications in the wind questionnaire during summer 2010, the majority of cases were from that year. The cases were divided into three storm types: supercells, non-supercells (including multicells and pulse storms), and lines or mesoscale convective systems (MCSs). Storms that transitioned between two or more storm types throughout the entirety of the event were categorized by their initial storm type. The dataset encompassed 24 states and over 4000 SHAVE calls, including over 1400 wind damage reports.

Table 1. Project Cases

Year	Cases
2008	3
2009	9
2010	62
Storm Type	
Supercell	7
Non-supercell	24
Lines	43

3. METHODOLOGY

In order to evaluate the POD of common wind damage signatures, Warning Decision Support System – Integrated Information (WDSSII; Lakshmanan et al. 2007) was used in association with SHAVE wind reports on Google Earth. Signatures were manually identified on WDSSII, and the radar scan time, height above radar level (ARL), and latitude/longitude for each was catalogued. The signatures were later divided by the storm types given in Table 1.

From the 74 cases, 387 common radar signatures were identified. A list of the signatures and the number of occurrences are shown in Table 2. The most common signatures throughout the investigated cases included low-level divergence (defined as divergence below 0.5 km ARL), mid-level convergence (defined as convergence between 1.5 km and 5.5 km ARL), rotation, and high velocity (typically above 25 m s^{-1}). Additional common signatures were descending reflectivity cores and three-body scatter spikes (TBSSs). Other less common signatures included hook echoes and gust front kinks. Examples of some of the common signatures are shown in Figure 1.

Table 2. Signature occurrences

Signature	Occurrences
Low-level divergence	89
Mid-level convergence	82
Rotation	58
High velocity	45
Descending reflectivity	34
TBSS	18
Other divergence	46
Other convergence	17
Other	12

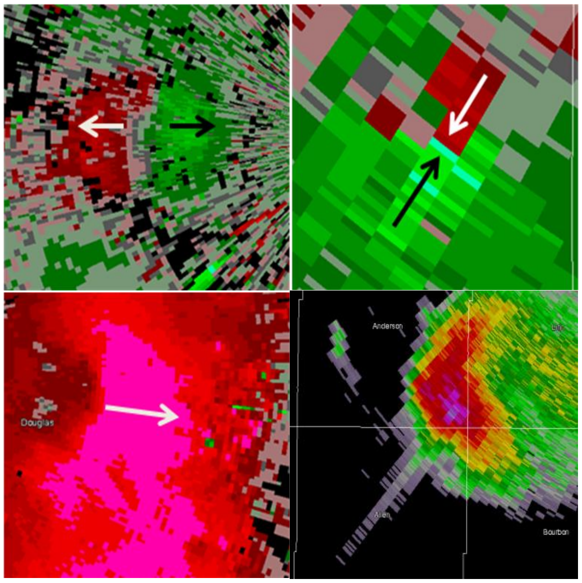
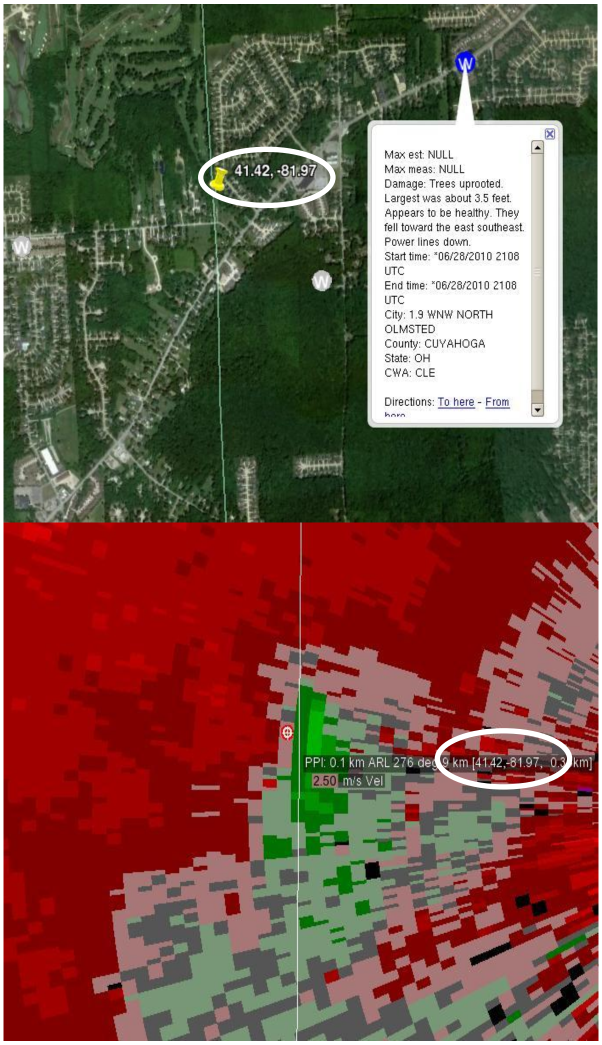


FIG. 1. Examples of radar signatures investigated throughout the project: divergence (top left), convergence (top right), high velocity (bottom left), TBSS (bottom right). White arrows indicate winds blowing away from the radar, while black arrows indicate winds heading towards the radar.

Once the signatures were identified, they were compared to SHAVE wind reports using Google Earth. If at least one wind damage report was close to the location of a radar signature, this was considered a hit. If there were no reports nearby, this was a miss. In general, the report was *close* or *nearby* if it was within 0.02 of a degree with both latitude and longitude. However, this was extended in the case of some signatures, particularly mid-level convergence, as the effects at the surface would naturally be delayed. Figure 2 shows how Google Earth and WDSSII can be utilized to easily determine the distance between a radar signature and associated SHAVE wind reports.



Max est: NULL
Max meas: NULL
Damage: Trees uprooted. Largest was about 3.5 feet. Appears to be healthy. They fell toward the east southeast. Power lines down.
Start time: *06/28/2010 2108 UTC
End time: *06/28/2010 2108 UTC
City: 1.9 WNW NORTH OLMSTED
County: CUYAHOGA
State: OH
CWA: CLE

Directions: To here - From

FIG. 2. Google Earth (top) and WDSSII (bottom) representation of SHAVE reports and a divergence signature, respectively. Comparing the latitude/longitude of each allowed for quick evaluation of radar signatures.

4. RESULTS

Many of the signatures investigated had over a 50% POD. A summary of the signatures and their PODs for supercell cases (Sup), non-supercell (Non-Sup) cases, and line/MCS cases is shown in Table 3. The signatures shown in the table are low-level divergence, mid-level convergence, high velocity, rotation, descending reflectivity cores, TBSSs, other divergence, other convergence, and other (including hook echoes, high reflectivity cores aloft, and gust front kinks).

In the case of supercells, high velocity, descending reflectivity cores, and TBSSs all had very high PODs. Of those, descending reflectivity cores had the highest sample, indentified 19 times with associated reports in 15 of those cases. High velocity and TBSSs were each sampled 5 times with associated reports 4 times. The most sampled signature in supercells was mid-level convergence, which had 36 occurrences and 19 occurrences with a report.

For non-supercells, other convergence signatures and other signatures had the highest POD, each at 100%. However, these signatures only had three combined occurrences. More common signatures with a high POD were again TBSSs, high velocity, and descending reflectivity cores. TBSSs had the highest POD of these signatures, with 11 or 13 occurrences being associated with a report. Low-level divergence signatures were the most sampled in non-supercells, with 31 occurrences, but only 16 occurred with a report nearby.

Table 3. POD for radar signatures

Signature	**Probability of Detection**			
	Sup	*Non-Sup*	*Lines*	*All*
LL Div	67%	52%	67%	62%
ML Conv	53%	71%	55%	57%
High Vel	80%	80%	63%	67%
Rotation	50%	60%	62%	59%
Desc. Ref.	79%	78%	67%	76%
TBSS	80%	85%	n/a	83%
Other Div	56%	60%	33%	48%
Other Conv	67%	100%	33%	59%
Other	0%	100%	25%	25%

As a whole, lines showed the most uncertainty in signature POD. The signatures with the highest POD were low-level divergence and descending reflectivity cores. Low-level divergence signatures were identified 55 times, with 37 of those occurring near a SHAVE damage report. Descending reflectivity cores only occurred six times. High velocity signatures were common in lines, with 35 occurrences and 22 with a report nearby.

Throughout all of the cases, TBSSs and descending reflectivity cores clearly had the highest PODs. TBSSs occurred 18 times with 15 of those associated with a report. The TBSS is typically known as a hail signature, and its relationship to wind damage is largely unknown (Lemon 1998). Unfortunately, no additional TBSS cases were sampled during 2010.

5. FUTURE WORK

The next step in this project will be to compare Near-Storm Environment (NSE) data to the SHAVE reports and radar signatures. NSE data are Rapid Update Cycle (RUC) analysis fields at a 1 km spatial resolution updated every hour. An example of these data is shown with overlaid radar imagery in Figure 3. Data for environmental variables including most unstable parcel's convective available potential energy (MUCAPE), various downdraft CAPEs (DCAPEs), dew point depression, mixing ratio, heights of wet bulb zero, lifted condensation level, and minimum Theta-E, 0-6 km shear magnitude, and 0-2 km storm relative flow have already been documented for each of the 74 cases.

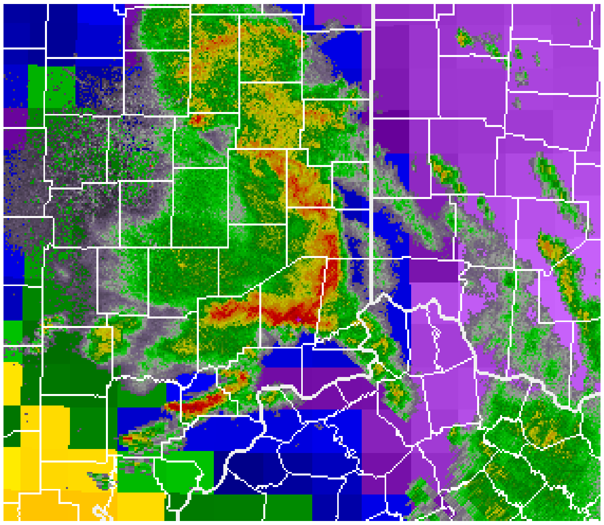


FIG. 3. NSE analysis fields of MUCAPE overlaid with radar imagery.

In order to compare the three datasets, it will first be necessary to determine the type of wind event (i.e., microburst or downburst) associated with each radar signature. This will be accomplished by measuring the square mileage covered by a cluster of SHAVE reports. Once the wind events are identified, an atmospheric conditions database will be constructed in an attempt to determine what atmospheric variables are most important in differentiating between high-impact or widespread events and low-impact or isolated wind damage events.

6. ACKNOWLEDGMENTS

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