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RADAR SIGNATURES COMPARED WITH HIGH-RESOLUTION HAIL REPORTS

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1. Introduction

According to the National Weather Service Verification website (2009), the average lead time for verified severe warnings is about 17 minutes since 2006. These forecasters have several automated tools and manual techniques available for guidance in the issuance of severe weather warnings. Some of the tools the National Weather Service (NWS) uses include the subjective analysis of radar data to identify reflectivity structures such as three-body scatter spikes (TBSS), weak-echo regions (WER), and bounded weak-echo regions (BWER), all of which have been associated with severe hail. The TBSS is the result of non-Rayleigh scattering from large hydrometeors to the ground, followed by backscattering from the ground back to the hydrometeors aloft and then backscattering from the hydrometeors to the radar, hence the term "three-body" (Zrnic, 1987).

WER and BWER are defined as the presence of high reflectivities aloft and low reflectivities directly below. WER and BWER both suggest an intense updraft that prevents precipitation from forming at lower levels and falling to the surface.

Previous studies have associated these structures with severe hail, using NWS *Storm Data* for verification. *Storm Data*, however, lacks the spatial resolution, which may have an effect on evaluating the reliability and capability of these structures. Additionally, these studies used very simple searching methods to achieve their results. The Severe Hazards Analysis and verification Experiment (SHAVE) at the National Severe Storms Laboratory (NSSL) has been conducted during the summers since 2006 to collect high-resolution hail reports throughout the contiguous United States (CONUS). This experiment uses Google Earth and digital telephone databases to poll the public about the size of hail received at a point. The high-resolution nature of SHAVE reports (roughly 2 km x 2 km) allows for increased confidence in identifying where severe, non-severe, and 'no hail' fell along a storm's path (Ortega et al., 2009). An example of a SHAVE hail report swath is shown in Figure 1. This

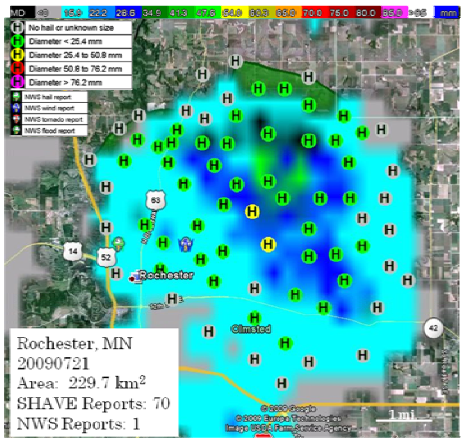

Figure 1: SHAVE data for a thunderstorm in Rochester, MN. There are 70 SHAVE reports for the storm (shown in H circles) where there is only one NWS hail report.

study will compare SHAVE data with TBSS, WER, and BWER to determine the relationship between the radar signatures and the SHAVE reports, especially in the context of improving lead time for severe thunderstorm warnings.

2. Data

For this study, ten cases of varying geographic location and storm type (supercell, multi-cell, squall line, etc.) were selected from the summers of 2007 through 2009. These cases (shown in Figure 2)

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Date	Place	Type of Storm	Max Hail Size (mm)	Volume Scans
20070716	Iowa	Supercell	76	30
20080602	Colorado	Supercell	70	16
20080606	SW Michigan	Supercell	25	22
20080612	Northern Missouri	Line Segment	44	25
20080619	South Dakota	Single Cell	22	20
20080620	Iowa	Supercell	22	17
20080723	New Jersey	Multicell	44	25
20090630	Arkansas	Supercell	70	13
20090701	Virginia	Single Cell	22	13
20090721	Minnesota	Supercell	32	17

Figure 2: Table of ten cases used for this study. The case that will be presented in this paper is highlighted in yellow.

included 3 cases with hail greater than 19.05 mm (0.75 in), 4 cases with hail greater than 25.4 mm (1.0 in), and 3 cases with hail greater than 50.8 mm (2.0 in).

These cases were selected from the storms in the SHAVE database based on their varying location and storm type. More importantly, however, was the presence of a 'no-hail' boundary at the beginning of the storm. With a 'no-hail' boundary near the beginning of the storm's life cycle, the onset of hail could be examined. The density of SHAVE reports and the storm's distance from the radar were also taken into account when selecting storms for this study, since some storms were too close to the radar to determine the presence of reflectivity structures. Radar data from the WSR-88D network was used in the analysis of these cases, using the Warning Decision Support System-Integrated Information (WDSSII) software at NSSL. WDSSII allows for vertical cross sections of the storm to be taken.

3. Methods

After choosing ten cases based on the criteria described in the previous section, each volume scan for the storms' life cycle was manually analyzed using the WDSSII software. For each volume scan, the latitude, longitude and storm relative motion were recorded. Then, spectrum width, reflectivity, and velocity data were examined to determine if a TBSS was present. TBSS are characterized by low reflectivity values down-radial from the storm, low velocities, and high spectrum widths. A TBSS is shown in Figure 3. If a TBSS was present, it was noted at the time of the 0.5 degree scan.

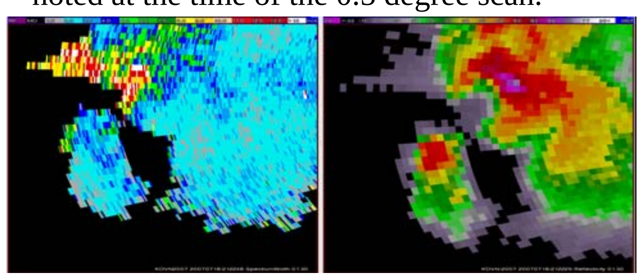

Figure 3: A TBSS from KDVN. Very high spectrum widths are shown on the left, and a "spike" of low reflectivity is shown on the right.

The cross section feature in the WDSSII software was used to determine the presence of a WER or a BWER. Again, if these features were present, they were noted at the time of the 0.5 degree scan. A BWER is shown in Figure 4. Because the time residents reported hail as falling was most often questionable, an automated way of determining when hail fell at a particular point was needed. This study used verification software that will be referred to as the "hail truth cell algorithm." This software used the position and storm motion data to generate a 5, 10, 15, 20, 25, and 30 minute cone of where the storm would move in that time period and recorded the maximum size hail observation within that cone. A diagram is shown in Figure 5. This allows for a spatial component in the analysis, since only hail presumed to have fallen in the storm's path is taken into account when statistics are calculated.

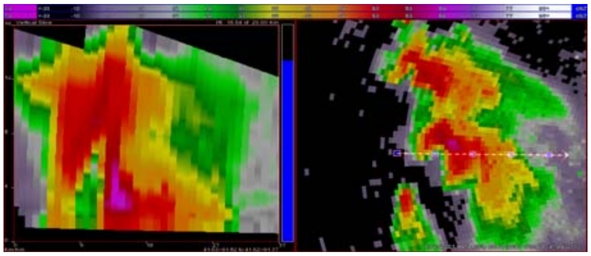

Figure 4: A BWER shown using the cross section feature in WDSSII. Base reflectivity is shown on the right.

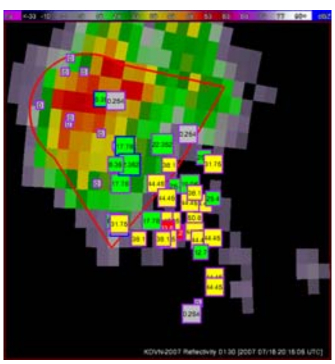

Figure 5: A 30 minute cone generated by the hail truth cell algorithm, based on storm position and motion. Hail reports with maximum sizes (in mm) are shown in the colored boxes.

WER and BWER were combined for this study, since there were not enough cases with BWERs to have statistical significance. The presence of a WER/BWER or TBSS was considered a forecast "yes" for hail. For each lead time, 5 through 30 minutes in 5 minute increments, an observed "yes" was the presence of a hail report. This was repeated for WER/BWER, TBSS, and TBSS and WER/BWER for hail sizes of 19.05 mm and 25.4 mm. The results were used to populate a contingency table for each signature and hail size, and statistics such as probability of detection (POD), false alarm ratio (FAR), critical success index (CSI), and probability of false detection (POFD) were computed.

4. Case Study

The case of July 23, 2008 in Mercer County, NJ will be explained in detail. The selection of the case was made because there was severe hail up to 44 mm and a no-hail boundary at the beginning of the storm. Each scan of the storms life time was looked at and recorded the latitude, longitude, and storm motion from the area of the highest reflectivity. Figure 6 shows the reflectivity and velocity of the storm.

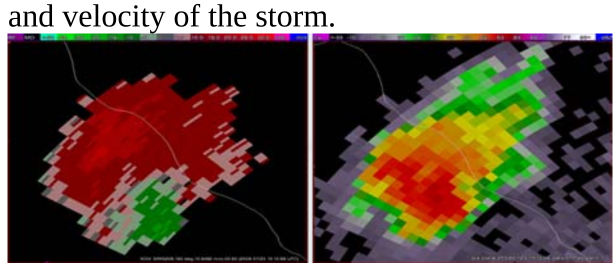

Figure 6: Velocity (left) and Reflectivity (right) of the Mercer Country storm from KDIX radar.

Each reflectivity and spectrum width scan was looked at to identify TBSS. In this case there were seven scans with a TBSS present and 22 scans with a WER present. A TBSS is shown in Figure 7.

The verification software was used after all of the data were recorded. For each scan, a 30 minute forecast cone was projected starting at the recorded latitude and longitude based on the recorded storm motion. The cone is split up into 5 minute

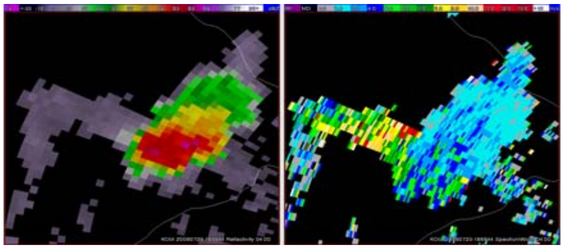

Figure 7: TBSS of the Mercer County storm. Low reflectivity spike (left) and high spectrum width values (right).

bins where the largest hail in each bin is recorded. The lead time for each of the reports are then calculated by the software based on the distance of the storm location and the report location. Due to the questioned hail-report times, the storm motion was used. Figure 8 shows the 30 minute forecasted cone with 5 minute bins.

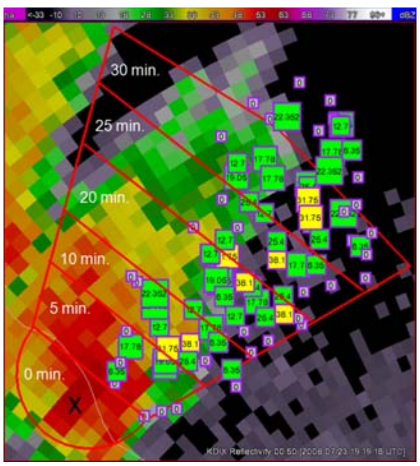

Figure 8: A 30 minute forecast cone generated by the hail truth cell algorithm, based on storm position and motion. 5 minute bins are shown with SHAVE hail reports (in mm).

5. Discussion/Results

Statistics were computed for a variety of scenarios with the presence of a TBSS and/or WER/BWER. The TBSS with a minimum hail size of 19.05 mm showed an increasing FAR with increasing lead time, but showed a low POFD for all lead times. This graph is shown in Figure 9.

Using a WER or BWER to forecast hail showed very similar POD and POFD curves, leaving a 50/50 chance that hail of 19.05 mm or greater would fall. The graph is shown in Figure 10.

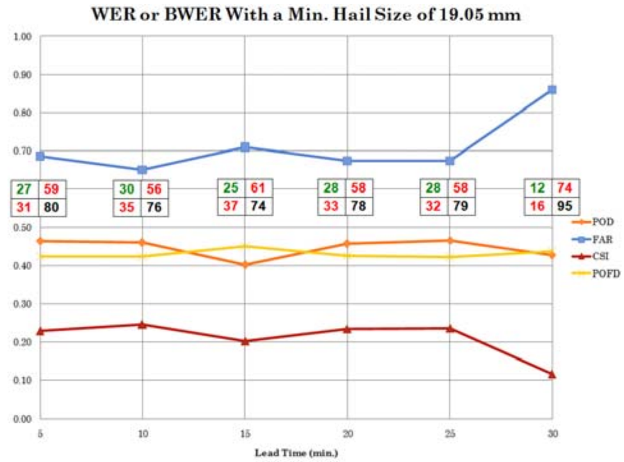

Figure 9: Contingency tables and statistics for TBSS with a minimum hail size of 19.05 mm for various lead times.

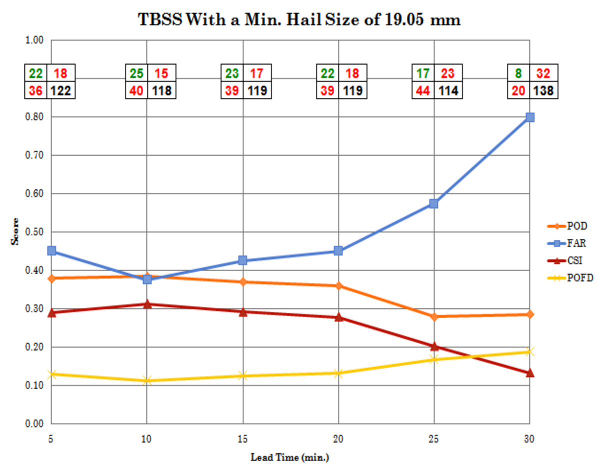

Figure 10: Contingency tables and statistics for WER/BWER with a minimum hail size of 19.05 mm for various lead times.

With both TBSS and WER/BWER, warning with the 25.4 mm hail showed a higher POD than the 19.05 mm hail. Somewhat surprisingly, the combination of both TBSS and WER/BWER showed no skill.

For all hail sizes and signatures a minimum of hits was present at the 30 minute mark. This may suggest a limit on the amount of lead time a warning using these signatures can provide.

6. Future Work

More cases will be added to the sample, including non-severe, significant severe (greater that 50.8 mm), and no-hail cases. Reflectivity heights with respect to the melting level will be recorded using the Constant Altitude Plan Position Indicator (CAPPI) feature in the WDSSII software. Environmental variables such as Convective Available Potential Energy (CAPE) and shear will also be investigated for their relationship to various hail sizes. More BWER cases will be compiled to investigate if BWERs hold any special context for large hail. Distance from the radar will also be examined, since some of the reflectivity structures may be range-dependent.

7. Acknowledgements

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8. References

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