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ENHANCED, HIGH-DENSITY SEVERE STORM VERIFICATION

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1. Introduction

The National Weather Service (NWS) has traditionally issued country-scale warnings to alert the public about severe convective weather threats, and has recently begun disseminating storm-scale threat information in the form of polygons embedded in the warning text (Ferree et al. 2006). Given recent advancements in meteorological science and technology, it is possible to further reduce the spatial and temporal scale of hazardous weather warnings as well as provide a measurement of uncertainty in the warnings. To accomplish these goals, better verification of severe weather events is crucial. At present, warning validation data are collected by the same team of forecasters who issue the warnings either during or soon after warning operations. The validation data they collect is usually on the same temporal and spatial scale as the warnings they issue – roughly hourly and one county (very roughly 1000 km^2 to 3000 km^2). Because of the current mechanism in the way the verification data are collected, many temporal and spatial errors appear in the resulting publication, *Storm Data*, the official record of severe weather events for the United States (Trapp et. al 2006; Witt et. al 1998). However, the Severe Hail Verification Experiment (SHAVE), conducted during the Spring/Summer of 2006 (Smith et. al 2006; Ortega et. al 2006) showed that it is possible to collect very high-resolution validation data with a time and space scale on the order of 1-5 minutes and 10 km^2 by combining geographic information with real-time high-resolution radar data over the CONtinental United States (CONUS; see Figure 1) using unbiased resources that that are external to those entities actually issuing the warnings.

Improved validation data are not only required for ongoing and future research (to verify high-resolution digital warning grids), but also have the capability to validate county-based and storm-based warnings currently issued by NWS offices, thus reducing the perceived false alarm rate for storms that are, in fact, severe but unverifiable using present verification methods. This manuscript describes some preliminary results from SHAVE and proposes additions to SHAVE concepts for future experiments.

2. The Severe Hail Verification Experiment

SHAVE was conducted during May through August of 2006. Researchers in SHAVE combined radar and environmental information available from the National Severe Storms Laboratory's Warning Decision Support System – Integrated Information (WDSS-II; Lakshmanan et al. 2006; Lakshmanan et al. 2007) with geographic information available in Google Earth and other sources. This information was used to identify locations to make targeted telephone calls to the public in regions where storms occurred. These calls were conducted within minutes of an event in order to collect information about the occurrence, size, and duration of hail. During the experiment, hail swaths from severe thunderstorms were documented at a much higher spatial and temporal resolution than is available in the National Climate Data Center's *Storm Data* publication and in NWS local storm report products.

The goals, facilities, data collection strategies, and some broad initial results from SHAVE are described in Smith et al (2006). Over 14000 verification telephone calls were made during the experiment, resulting in over 5500 valid data points describing hail size, duration, and ground coverage. Although data collected during the experiment were provided to NWS forecasters in real-time via the internet, the data were collected independently of NWS warning and verification operations. SHAVE personnel collected additional information that are not usually included in *Storm Data*, such as information about non-severe events (small hail) or non-events adjacent to severe events in the same county, and additional descriptive information about the event. Such information is sometimes collected during NWS warning operations, usually during contacts with storm spotters, but is not made part of the permanent record at the National Climate Data Center.

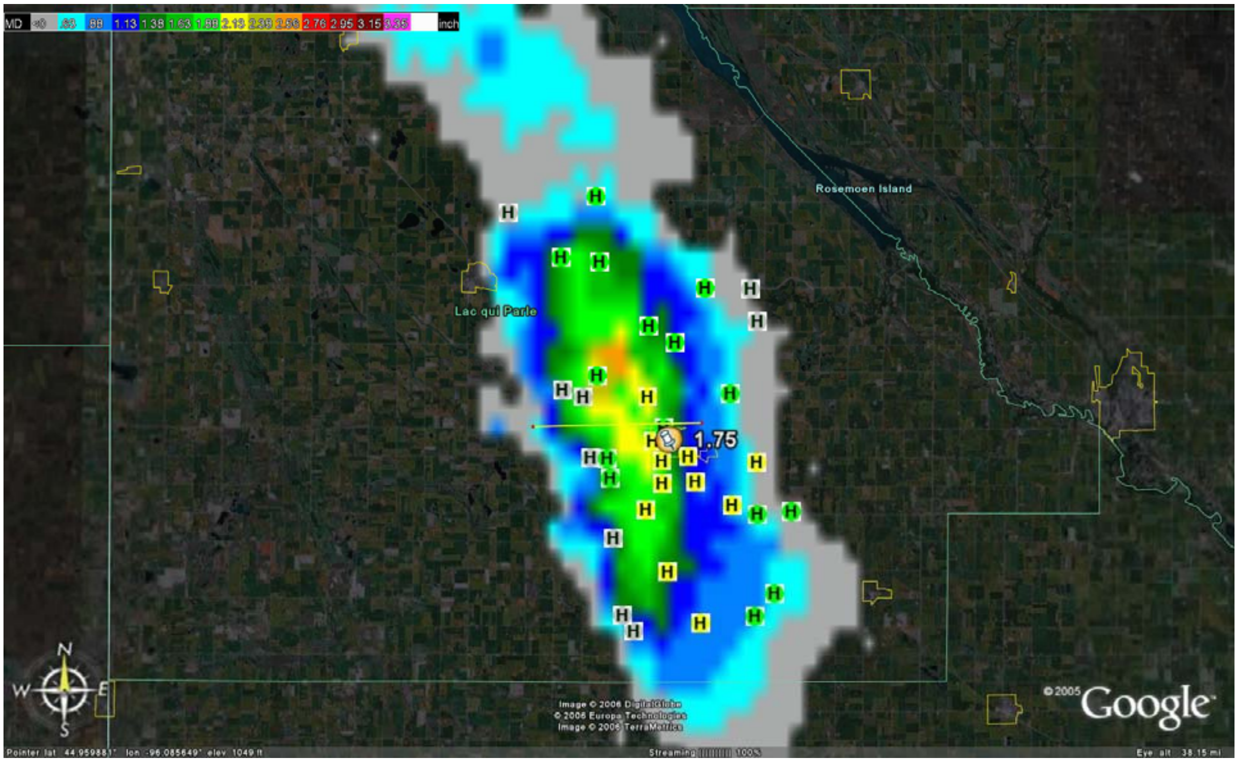

Figure 1: The NSSL Hail Swath algorithm showing radar-estimated maximum hail size during a 180 minute period for a storm that occurred in Lac qui Parie County, MN on July 27, 2006. The grey icons (no hail), green icons (hail up to 1" – 2.54 cm) and yellow icons (hail >1" to 2" – 2.54 cm to 5.08 cm) represent data points collected during the Severe Hail Verification Experiment. The single "push pin" icon represents two collocated data points collected in the county by the National Weather Service as part of warning verifications efforts and published on the Storm Prediction Center web site at http://www.spc.noaa.gov/climo. The purple line is 10 km long in the scale of the map.

Table 1 is a listing of a few of the storms tracked and examined by researchers during the first few weeks of SHAVE. The listed storms were sampled with at least ten verification data points over some portion of their path. An approximate hail swath area was calculated for each storm based on the track and area of the core aloft, which usually gives a reasonable estimate of the region where hail fell. Storms occurred over both rural and urban areas with highly varying population densities. For some storms, the data points are fairly evenly spaced, while for others there are clusters of verification data points around major roads or towns. The mean area per data point for this selection of storms was one point per 59 km^2, compared to an estimated average of one point per several hundred to several thousand km^2 for most traditional storm verification data. The mean temporal frequency of the data in this sample was one report every 3.1 minutes. Data collected later in the project had not yet been fully analyzed at the time this manuscript was submitted, but may have even better temporal and spatial resolution as sampling strategies improved over the course of the project.

3. Extending SHAVE

Since the warning verification agency is the same one that issues the warnings, it is natural that the official historical record of severe storm events is biased toward the temporal and spatial scale of severe convective weather warnings. To develop scientifically sound warning methodologies at finer temporal and spatial scales than roughly one hour and one county, a higher resolution database (on the order of 5 min and 10 km^2) of storm damage information is required. Unfortunately, this database as a whole does not yet exist and must be built from scratch. However, there are many tools and existing, though disperse, data sets that may be leveraged to begin this work.

Date	Storm Path Length (km)	Sampled Path Length (km)	Storm Type	Urban v. Rural	Approx. Hail area (km^2)	# of data points	% path sampled	Mean area per data point (km^2)	Mean temporal sampling (min)
17-May-06	263	263	isolated	rural	4305	45	100%	96	4.5
	32	21	isolated	urban	183	13	63%	9	2.8
	42	25	isolated	urban	398	21	60%	11	2.0
22-May-06	49	13	line	urban	383	23	27%	5	3.3
	141	136	cluster	rural	1905	12	96%	153	17.9
23-May-06	48	15	line	rural	509	10	31%	16	6.5
	22	10	line	rural	2615	10	47%	124	3.9
	52	48	supercell	rural	3453	15	92%	212	6.3
24-May-06	123	10	line	rural	1870	12	8%	12	18.3
	88	21	cluster	urban	1853	23	24%	19	7.2
	132	41	supercell	rural	1709	13	31%	41	10.4
	145	86	supercell	urban	3699	21	59%	104	6.9
	179	95	supercell	rural	2806	21	53%	71	6.0
	120	86	supercell	rural	1728	21	72%	59	3.6
25-May-06	236	135	supercell	urban	9457	11	57%	491	10.9
	197	72	supercell	rural	6300	29	36%	79	3.0
	226	89	supercell	rural	6107	28	39%	86	0.8
	114	27		rural	1789	11	23%	38	0.6
	222	20	supercell	urban	4028	10	9%	36	1.1
	95	52	supercell	rural	1250	13	54%	52	3.8
26-May-06	240	48	supercell	rural	14392	22	20%	131	2.7
	230	40	supercell	rural	6001	10	17%	105	3.1
	122	35	isolated	rural	1219	15	29%	23	4.4
	136	22	cluster	urban	2126	13	16%	26	1.7
	162	124	supercell	urban	3519	42	77%	64	5.3
30-May-06	75	58	supercell	rural	1124	16	78%	55	8.3
	17	9	line	rural	215	10	56%	12	6.7
	211	19	line	urban	2997	16	9%	17	1.8
31-May-06	242	56	supercell	rural	9758	44	23%	51	1.8
	13	5	supercell	rural	301	11	39%	11	4.7
	58	16	cluster	rural	686	13	27%	14	2.2
	123	17	cluster	rural	2484	11	14%	31	3.3
1-Jun-06	31	7	isolated	rural	198	10	23%	4	3.2
3-Jun-06	65	24	isolated	urban	442	20	36%	8	3.6
5-Jun-06	227	96	line	rural	8545	17	42%	212	5.7
	163	104	supercell	rural	3065	39	64%	50	3.4
6-Jun-06	54	13		urban	552	14	24%	10	0.5
	64	18		rural	1024	12	28%	24	1.4
13-Jun-06	238	65	supercell	urban	6760	40	27%	46	1.6
	20	6	isolated	urban	93	11	29%	2	0.4
	72	31	isolated	urban	688	29	43%	10	1.2
	100	36	line	rural	554	23	36%	9	2.8
	125	57	line	rural	2103	33	45%	29	1.7
	77	20	supercell	urban	616	35	25%	4	0.6
Totals	**5388**	**2189**			**125808**	**868**	**41%**	**59**	**3.1**

Table 1: A selection of storms tracked and sampled during the Severe Hail Verification Experiment.

SHAVE was very successful at collecting a wealth of data describing the spatial extent and intensity of hail by surveying the public in real-time immediately following storm passage. For a few event days, wind damage data were also collected. In general, the persons who were contacted in real-time did not have as much information to share about the extent of wind-related damage as they did about hail. However, when telephone surveys were conducted the day following an intense event (the 19 July 2006 St. Louis severe wind event) rather than in real-time, people typically had much more information to share, as they had more time to assess the extent of the damage to their property or talk to neighbors who had incurred damage.

An additional remote damage survey technique that was tested during and following the SHAVE experiment combined the use of media reports, Google Earth satellite imagery and maps to reconstruct tornado damage paths. Photographs, video, and address information available from news-related web sites may be used to assist those conducting damage assessments on the ground or to remotely verify

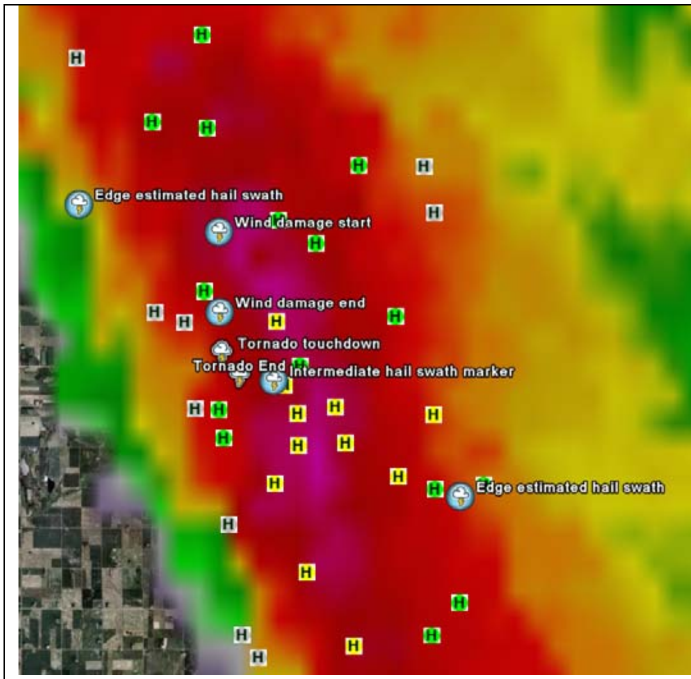

Figure 2: (top) The maximum low-altitude reflectivity over a 2-hour period overlaid with the hail reports from figure 1 and additional information listed in a NWS summary of the event (right).

DAMAGE TO A GROVE OF TREES...PHOTOS...AND EYEWITNESS ACCOUNTS HAVE ALL LED TO THE CONCLUSION THAT A TORNADO DID TOUCH DOWN JUST WEST OF DAWSON THURSDAY EVENING JULY 27. THE TIME WAS APPROXIMATELY 726 PM.

THE TORNADO TOUCHED DOWN TWO MILES WEST-NORTHWEST OF DAWSON... CROSSED HIGHWAY 212...AND DISSIPATED ONE AND ONE HALF MILES WEST OF DAWSON. THE PATH LENGTH WAS ONE HALF MILE...AND ITS MAXIMUM WIDTH WAS 100 FEET. THE TORNADO WILL BE RATED F0.

IN ADDITION TO THE TREE DAMAGE...A FEW SHINGLES AND PLANKS WERE TORN OFF A BARN...ALONG WITH A LITTLE BIT OF SIDING OFF A HOUSE.

THE STORM WAS ACCOMPANIED BY LARGE HAIL...VERY HEAVY RAIN...AND DAMAGING DOWNBURST WIND. THE DOWNBURST WIND WAS IN AN AREA FROM ONE TO THREE MILES NORTH OF THE TORNADO TRACK...AND SOME FARMS HAD SCATTERED TREES DOWN...ALONG WITH SHED AND MINOR HOUSE DAMAGE.

FOR SOME AROUND DAWSON...THE HAIL WAS DEVASTATING. SOME FARMERS DESCRIBED THAT THEY WERE HIT WITH LARGE HAIL FOR 35 MINUTES... DECIMATING CROPS. AT TIMES THE HAIL WAS AS BIG AS GOLF BALLS. THE HAIL SWATH WAS ABOUT TWO MILES WIDE...FROM JUST SOUTHEAST OF MADISON...TO THE WEST SIDE OF DAWSON...THEN TO ABOUT FIVE MILES SOUTHEAST OF DAWSON.

storm damage if a ground survey team is not available.

In addition to data collected via telephone, many highly detailed post-event damage surveys have been conducted over the years by NWS staff as well as by researchers in various organizations. These surveys have usually been for tornado damage, but some surveys also exist for hail and damaging winds. These surveys may be collected, catalogued, and added to a database as additional high-resolution data points. Figure 2 shows an example of additional information contained in a narrative from the NWS that has been combined with the hail report information collected by SHAVE from figure 1. In this case, combining the remotely-collected hail information with the NWS survey as well as radar-derived information provides a more complete picture of the storm's behavior. Other surveys may contain detailed damage paths for significant historical severe weather events that could be included in a high-resolution storm database.

4. High-resolution storm observation database

With the wealth of information that may be collected about storm damage (or lack thereof), it is possible to create a very detailed set of information about storms that are observed by many sources. Each piece of storm observation information may be georeferenced and time stamped. We propose to create a storm database that could include, but is not limited to, the following data sources:

- Detailed in-person damage surveys conducted by the NWS or others;
- Complete logs of storm spotter communications about a storm (not just reports of severe weather associated with the storm);
- Reports from the public collected via real-time telephone surveys for hail;
- Video of the storm;

- Still photographs of the storm or damage, (which may be highly accurate in time / space if taken with a GPS-enabled camera phone, for example)
- Reports/photos from storm chasers;
- Post event telephone surveys for severe wind and tornado events;
- Data collected by the media (online newspaper, photos, video, location / address information);
- Radar and environmental data.

This is very similar to the multimedia database of storm visual characteristics and storm environment proposed by Magsig et al. (2006) for use in training. However, our goal is to create a validation data set for use in the development of future high-resolution warning tools and techniques.

For high-impact severe weather events, in-person damage surveys by severe storm and engineering experts are highly desirable. Trained weather spotters are invaluable during severe weather operations and the information they provide should be thoroughly logged and included in the permanent record. Additionally, technological and scientific advancements in geographic information systems should be fully utilized to enable the maximum amount of storm verification information to be collected and stored in a database that may be used as a basis to create more effective warnings at finer temporal and spatial scales.

Acknowledgements

This extended abstract was prepared with funding provided by NOAA/Office of Oceanic and Atmospheric Research under NOAA-University of Oklahoma Cooperative Agreement #NA17RJ1227, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce. Thanks to Greg Stumpf and Kevin Manross for reviewing the manuscript.

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