A STUDY OF THE GIS TOOLS AVAILABLE DURING TORNADO EVENTS AND THEIR EFFECTIVENESS FOR METEROLOGISTS, FIRST RESPONDERS AND EMERGENCY MANAGERS

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1. Introduction

The largest number of confirmed tornadoes in a single day in Wisconsin occurred on August 18th, 2005. The majority of the tornadoes were weak and caused very little damage. However, two communities were impacted with stronger tornadoes; the Town of Pleasant Springs and the Village of Viola. These communities had the greatest extent (area) and dollar figure losses than any other area that day. This paper examines the tornado which occurred in the Town of Pleasant Springs because it was the most severe, caused a loss of a life, and the area which it affected was rich with GIS (Geographic Information Systems) data.

Emergency management officials across the country have just begun to incorporate GIS into their emergency operations as a means to more effectively respond, plan, and prepare for a disaster. This was similar for emergency management officials in Wisconsin on August 18th, 2005. Many of the GIS tools discussed in this paper were not known or not readily available to them at the time of the disaster. Therefore, this paper discusses and examines the many datasets available to meteorologists and emergency managers for use before, during and after a tornado event.

When meteorological information is combined with GIS it can become extremely powerful. For instance, during Hurricane Katrina radar data and GIS tools were combined to view the areas that were being impacted as the storm moved inland. Meteorological data can be combined with many local datasets (parcel, school, hospital layers) to assess the impacts an approaching storm may have on an area. Specifically, this paper examines the ability of GIS users to create damage estimates, in real time, as a tornado is impacting a community.

2. Methodology

The ability to track a tornado as it moves through a community can be an important tool for many first responders, emergency managers, and decision makers as well as the public. Three damage path datasets were used in this study. The first path (buffer method) was created by importing NEXRAD base reflectivity and base velocity information into GIS from the National Climatic Data Center (NCDC). Using the base velocity information we plotted a time series of points indicating the location of the center of rotation as seen in the velocity image. The base reflectivity was used as verification a storm capable of producing a tornado existed in the location we termed the center of rotation. Once the time series of points was created a path was generated by connecting each point.

Initial reports estimated the tornado to be of F3 intensity and nearly ½ of a mile wide. We used these parameters to generate a damage path. A series of 4 buffers were added around the path, 2640 feet (1/2 mile), 1320 feet (1/4 mile), 660 feet (1/8 mile), and 330 feet (1/16 mile). Each buffer represented a different Fujita Scale rating, F3, F2, F1, and F0 respectively.

A second tornado path (NWS method) was generated by the National Weather Service Office in Sullivan, WI. This path was created from an examination of the damage by field crews. Contours of F-ratings were created. The path was imported into GIS and analyzed.

A third path was created by the Environmental Remote Sensing Center (ERSC) at the University of Wisconsin, Madison. This path was created by combining ASTER and Landsat datasets to come up with a satellite based analysis which was used as a means of verification for the other datasets created in the study (Lillesand, et. al., 2002).

Damage estimates were created by taking the first two damage paths (Buffer and NWS methods) and overlaying land parcel information on top of the paths. Each land parcel was labeled with the corresponding F-rating it corresponded to. Damage estimates were then created by applying a percentage of damage related to each F-rating and the corresponding value of the parcel.

The process used follows the same methodology as a study created for the May 3rd, 1999 tornado outbreak in Oklahoma (North Central Texas Council of Governments, 2000). In this process percentages of damages were assigned to each parcel according it its F-rated damage. If a parcel was damaged by F0 winds, it was considered not damaged; parcels assigned F1 winds were multiplied by 10%, F2 winds by 50%, and F3 winds by 80%.

A layer was created days after the event by multiple sources where field crews assigned one of three ratings

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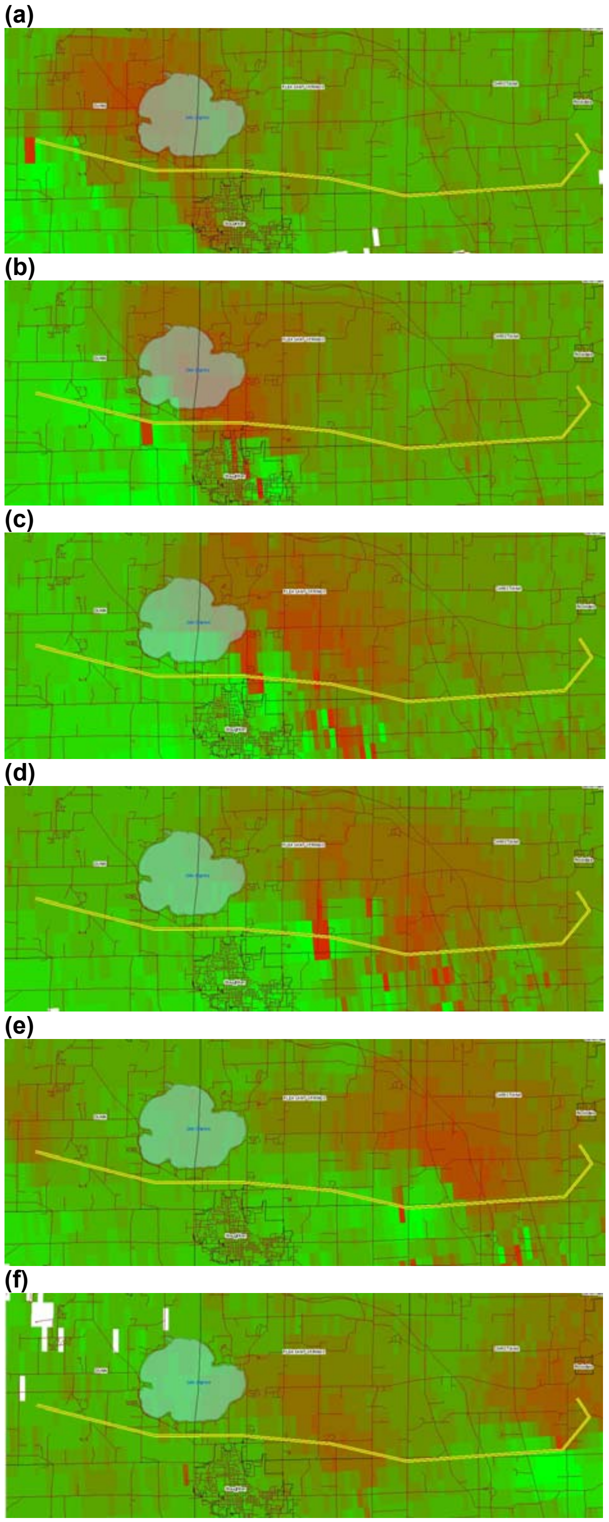

Figure 1. NEXRAD base velocity from Dane County, WI. Each image shows the path constructed using the velocity information. (a) 2326 Z (b) 2332 Z (c) 2337 Z (d) 2342 Z (e) 2348 Z (f) 0004 Z. *Source: National Climatic Data Center*

to damaged parcels of land; minor, major, or destroyed. Since the maximum damage from this tornado was considered F3 damage, destroyed was rated an F3, major an F2, and minor F1. The same damage estimate mechanism was used assigning percentages of damage to each of the field report parcels.

We used the ERSC satellite derived damage path as a verification mechanism to ensure the validity of the two damage paths; the Buffer path and the NWS path. Both paths show remarkable agreement with this image. In addition, both paths show agreement with the field report data collected by field crews in the days after the event.

3. Results

Table 1 shows a summary of each damage assessment method. The damage estimate created by using NEXRAD radar data is named Buffer. NWS path represents the estimate created using the path constructed by the National Weather Service Office in Sullivan, WI. The field crew estimate was created from the field reports layer. The Dane County Final row represents the final damage totals in terms of building damage numbers and dollar amounts by the private sector.

The buffer method produced the lowest error out of all of the methods used in this study in terms of the estimated damage costs. However, all three methods produced high error when it came to the actual number of parcels damaged vs. the final totals.

Figure 2. Contours of Fujita Scale damage created by field reports from the National Weather Service and then geocoded into GIS. *Source: National Weather Service, Sullivan, WI*

Conversely, the NWS damage estimate generated the best results when it came to the actual number of parcels damaged whereas; the worst results came from the Buffer method.

The Buffer method over-estimated the damages in terms of dollar figures as well as the number of parcels for each of the F-rated paths. The NWS method underestimated the total damages as well as the number of damaged parcels except for the F2 damaged parcels which were overestimated. The Dane County field data underestimated all of the damaged parcels as well as the total dollar amount.

An interesting finding was the similarities between the NWS path damage estimates and the Dane County damage estimates. The total damage estimates were only $409,960 apart. In addition, the total numbers of buildings were only 26 apart.

	F0	F1	F2	F3	Total (F1 - F3)	% Difference	Per building
Buffer							
Total Value	$163,436,700	$48,432,300	$27,780,700	$21,499,700	$261,149,400		
Damage Assessment	$0	$4,843,230	$13,890,350	$17,199,760	$35,933,340	13.22%	
Total Parcels	966	306	175	149	630	46.17%	$57,037
NWS Path							
Total Value	$51,137,100	$13,731,600	$18,167,500	$18,998,400	$102,034,600		
Damage Assessment	$0	$1,373,160	$9,083,750	$15,198,720	$25,655,630	19.17%	
Total Parcels	324	74	103	97	274	36.43%	$93,634
Field Reports							
Total Value	$0	$25,863,000	$16,471,700	$18,029,400	$60,364,100		
Damage Assessment	$0	$2,586,300	$8,235,850	$14,423,520	$25,245,670	20.46%	
Total Parcels	0	102	67	79	248	42.46%	$101,797
Dane County Final							
Total Damage					$31,738,284		
Total Buildings		231	90	110	431		

Table 1. Results from the three damage estimate methods are included. The total value of all parcels, the damage assessments, and final totals determined by the local officials are listed.

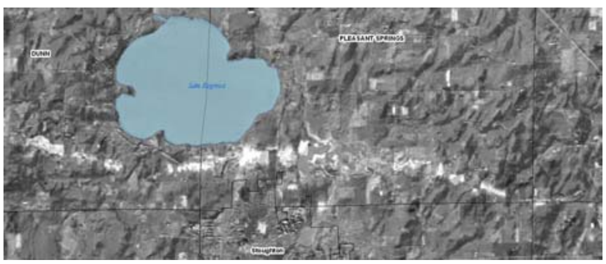

Figure 3. Satellite image representing the damage path from the tornado that affected the Pleasant Springs area on August 18th, 2005. *Source: ERSC*

The price per damaged parcel gradually rose between the parcel estimate and the field report estimate. This most likely was due to the doubled number of overall buildings considered damaged in the Buffer method versus the other two methods with less than a doubling of the overall estimated damages in dollars.

4. Discussion

A reliable and seamless means of obtaining a quick damage estimate would help considerably in the ability to request resources from outside sources at the local level. Furthermore, a reliable and seamless way to create a quick and accurate damage path or extent will help local officials move and coordinate their resources in a timelier manner in order to help in response and recover operations for its citizens. With this being said, it would require a method similar to the Buffer method to achieve the quickest result.

The Buffer method does appear to be accurate and reliable in many different ways. The path did resemble the paths generated by field crews as well as the satellite derived product. The buffer method was also able to capture the dollar figure amounts within a small margin of the actual totals.

There are a few areas where the Buffer method could lose its accuracy; notably, if a tornado event occurs within a hole in the NEXRAD radar network, or if a tornado occurs a substantial distance away from the nearest radar instrument. A rotation signature seen in radar does not automatically mean a tornado is present, but more likely insists a mesocyclone is present. This fact is probably more accurate the further the storm is away from radar given the elevation at which the data will be measured. Furthermore, a tornado is not always exactly coupled with a mesocyclone and therefore there can be discrepancies with the exact location of the tornado on the ground from what is seen in radar. That is why radar data coupled with storm reports would be essential when using this application during a real-time event.

The National Weather Service dataset proved to be the best damage path when compared to the satellite data, radar data, and field reports; however, it did not produce the best results in the analysis. This more than likely related to the lower number of parcels which intersected its path. This path was more irregular than the buffer path which created more problems when assigning an F-rating to each parcel and flagging damaged parcels.

It is worth noting that the field data from Dane County and given to Wisconsin Emergency Management was collected within the first few days of the event. The total dollar figures (Dane County Final) in table 1 were from the second week of October. Updated field data layers (if available) were not obtained at the time of the Dane County final damage estimate. Also worth noting was the time of the creation of the satellite image. This image was created from data several days after the event when cleanup had already began. This could have slightly altered the damage path especially in the areas where extensive cleanup had already occurred.

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