

**P1.4 INTEGRATING A GEOGRAPHIC INFORMATION SYSTEM INTO STORM ASSESSMENT:
THE SOUTHEAST ALABAMA TORNADO OUTBREAK OF 1 MARCH 2007**

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1. INTRODUCTION

On 1-2 March 2007, an early spring tornado outbreak occurred in the Deep South. The outbreak included multiple tornadoes, including the Enterprise, Alabama event which resulted in nine fatalities. The National Weather Service (NWS) post-storm assessment included the input of multiple assessment teams that surveyed the damage over a period of three days. The result was an EF-4 rating on the Enhanced Fujita Scale (McDonald and Mehta, 2006). The extensive amount of photographic and Global Positioning System (GPS) data collected during the assessment opened up the possibility of utilizing Geographic Information Systems (GIS) technology to merge and analyze the data. The result was a detailed and spatially accurate data set of the damage swath produced by the tornado. Having a geo-referenced data set allowed for further analysis, by merging the damage analysis with radar data within a GIS framework, and also provided insight into the life cycle of the tornado as it related to the damage pattern and associated radar signature. The process of creating spatially-referenced damage data sets for severe weather events shows promise as a new tool in post-storm analysis.

2. EVENT OVERVIEW

The tornado outbreak occurred during a rare NWS Storm Prediction Center "High Risk" day in the Deep South, characterized by strong shear and sufficient instability. The initial mode of the outbreak was one of multiple, long-track high precipitation supercells. This mode produced two EF-4 (Miller's Ferry and Enterprise, Alabama) tornadoes during the afternoon of March 1st. During the subsequent evening and overnight hours, the event transitioned to a squall line with imbedded supercells, producing additional tornadoes, including an EF-2 tornado which killed 6 people near Newton, Georgia.

The Enterprise tornado touched down southwest of the city, at approximately 1:05 pm CST (1905 UTC), tracking northeast through the heart of the town. The tornado struck the Enterprise High School at 1:15 pm CST (1915 UTC), before exiting the town to the northeast and lifting at 1:20 pm CST (1920 UTC). Nine fatalities resulted from the storm, including eight deaths at Enterprise High School. Fifty others were injured, and the damage estimate was \$250 million (Storm Data,

National Climatic Data Center (NCDC)).

3. STORM SURVEY

Multiple NWS assessment teams surveyed the damage in Enterprise. The initial survey was completed on March 2 by staff from the Tallahassee National Weather Service Forecast Office. This initial survey resulted in a preliminary rating of EF-3. The initial survey generated a large number of on-ground photographs from the high school and the immediate neighborhood. An aerial survey was also conducted using a fixed wing aircraft, providing additional photographic evidence. No GPS data were available from this survey.

Due to the possibility of greater than EF-3 damage, the NWS dispatched a Quick Response Team to further investigate the damage in Enterprise. This survey was conducted on March 4 and produced additional ground photographs, as well as photographs from a helicopter overflight. A GPS track file was available from the helicopter overflight, documenting the flight path. Once completed, more than 250 damage photographs from the two survey teams were available for analysis.

4. METHODOLOGY

The utility of using a GIS approach is found in the ability to integrate multiple spatially-referenced data sets, and the ability to merge and analyze those data sets. The Enterprise storm assessment produced a large number of damage photographs, with most of the aerial surveys covering areas not visited on the ground. With such large amounts of photographic data, visualizing the distribution of the damage, without spatial reference, quickly became overwhelming.

The first step in the analysis process was to acquire the one-meter resolution ortho-imagery for Southeast Alabama from the U.S. Geological Survey. The data were ingested and displayed using ESRI's ArcMap software¹. The available GPS data from the helicopter aerial survey were then ingested and overlaid on the ortho-imagery (Fig. 1). Two different techniques were used to geo-locate the photographs: those with available GPS data; and those without GPS data.

For the photographs taken during the helicopter flight, the original time stamps from the photographs

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¹ Reference to any specific commercial product, process, or service by trade name, trademark, manufacture, or otherwise does not constitute an endorsement, a recommendation, or a favoring by the NWS or the United States government.

were manually matched to the time stamps along the GPS flight track. This allowed determination of where the photographs were taken. The ortho-imagery at this particular location was then compared to the photograph, to identify damaged ground features, such as homes, structures, and trees. Figure 2 shows a photo, from the helicopter survey, depicting destroyed chicken houses. These correspond to the chicken houses in the ortho-imagery from Fig. 1.

For the photographs taken from the fixed wing aircraft and from the ground (no GPS data), the location process was more difficult and tedious. When possible, the general location of the photographs was gathered through conversations with the photographers. The individual photographs were compared to the ortho-imagery to determine exact location. Once the location was identified, damage to ground features was noted.

For each instance of damage identified from a photograph, a point feature was created using ArcMap and added to a damage shapefile (Fig. 3). Information describing the damage was added to the attribute table, along with a subjective estimate of the degree of damage (minor vs. major).

This process was applied to all the available damage survey photographs from the Enterprise tornado. After all the photographs were processed, the resulting damage shapefile contained 583 damage points.

5. RESULTS

Using the shapefile generated from the damage photographs, detailed maps of the tornado's path were created. Figure 4 shows an overview of the damage from the Enterprise tornado. Figure 5 is centered on Enterprise High School and the surrounding neighborhood. This image clearly shows the distribution of individual damage points, with the most severe damage close to the centerline of the damage swath. Each point corresponds to damage geo-located from damage photographs.

Level III data from the Fort Rucker (KEOX) WSR-88D were obtained from the NCDC, to compare the radar signatures with the distribution of damage. Figure 6 shows a ten minute time series of base reflectivity data as the tornadic supercell moved through Enterprise, overlaid onto the ortho-imagery and the damage points. Figure 7 shows the same time series using velocity data relative to the storm motion (SRM). These two figures clearly illustrate the evolution of the storm, and the associated damage, as it moved through Enterprise. The reflectivity time series shows a distinct hook echo that became better defined at 1915 UTC, which was the approximate time that the tornado struck the high school and produced the most severe damage. By 1920 UTC, the reflectivity signature had degraded, corresponding to the tapering off of the damage, as the tornado lifted northeast of the town.

Examining the SRM time series reveals some interesting details. As with the reflectivity data, the velocity data indicates a strengthening circulation from 1910 to 1915 UTC, with the gate-to-gate shear increasing from 96 kt to 103 kt. Once again, this corresponds to the tornado intensity increase as it approached Enterprise High School, and matches well with the distribution of damage. By 1920 UTC, the gate-to-gate shear had decreased to 81 kt, with a corresponding decrease in damage as the tornado weakened and lifted.

One interesting detail from the SRM data is that the strongest gate-to-gate couplets at 1910 UTC and 1915 UTC were located noticeable south of the damage swath. There are several possible explanations for this apparent discrepancy. A portion could be due to errors in mapping the radar data. In addition, Enterprise is located approximately 20 nm from the Fort Rucker radar, where the 0.5 degree beam is approximately 1500 ft above the ground. It is possible that the tilt in the low level tornadic circulation was such that the ground level circulation was displaced from that at the top of the boundary layer. This illustrates the difficulty in determining the exact location of a tornado in real-time, using radar imagery alone.

6. ONGOING AND FUTURE WORK

While this initial investigation into the use of GIS technology in storm damage assessment showed promise, several substantial drawbacks were evident. The primary obstacle was the time needed to complete the data entry. Approximately two weeks were needed to complete this process for the Enterprise tornado. Some of the delay was attributable to manually matching photographs with their associated GPS location from the track file. However, the greatest difficulty was geo-locating photographs without a GPS reference. With the widespread availability of handheld GPS units, it is of vital importance that GPS data be obtained while conducting storm damage assessments. An additional drawback was the subjective nature of the damage categorization. Using only two categories (minor and major) limited the potential detail possible in the damage analysis.

In order to make use of the potential benefits and address the drawbacks of such a detailed storm analysis, the methodology was improved, and a series of tools were created, within the ArcGIS framework, to streamline and semi-automate the analysis process. With most GPS units, a log file, containing the path followed during the survey, is easily generated and downloaded to a computer. The use of digital photography, which generates time-stamped files, eliminates the need for any direct connection between the GPS unit and the camera. The only requirement is that the time setting on the camera be matched up to the time on the GPS unit. To geo-locate the photographs taken during a survey, a tool was created which automatically matches digital photographs with

the times (and thus, locations) in the associated GPS log file. The result is a point shapefile representing the location of each photograph taken during a storm survey. By clicking on a photo-point, the user is able to view the associated photograph, allowing for quick damage matching with the underlying ortho-imagery (Fig. 8). In addition, this ortho-imagery is now available online through ESRI, eliminating the need to individually download the space-intensive imagery files.

An additional tool was created to allow the user to “point-and-click” on the ortho-imagery, and add a damage locator to the damage shapefile. Input options associated with this tool allow the user to designate the type of damage (e.g. tornado vs. straight line winds), EF rating, general damage severity (Minor, Moderate, Major, Extreme), as well as a text description of the damage point (Fig. 9). All of this additional information is stored in the attribute table of the damage shapefile. The user is also able to quickly edit or delete previously entered damage points.

These tools significantly decrease the time needed to enter the data for a storm analysis. This revised process was used to enter damage data for the fatal Newton, Georgia tornado. Figure 10 shows the damage plotted from this event, with the severity of the damage color coded. The damage paths clearly indicate two tornadoes touching down successively. The newly developed tools reduced the data entry process from a couple of weeks down to 1-2 days. It is hoped that the more efficient process will allow a GIS novice to perform the analysis in a timely manner.

Further enhancements are also planned to make the process more efficient and effective. Storm survey

teams from the Tallahassee WFO are being encouraged to . Incorporating more elements of the EF scale assessment process, such as Damage Indicators and Degrees of Damage, would allow this process to be integrated into the rating of tornadoes. Providing the damage data in Keyhole Markup Language (KML) format would increase the portability and visibility of the data.

7. ACKNOWLEDGMENTS

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8. REFERENCES

McDonald, J.R. and K.C. Mehta, 2006: A recommendation for an Enhanced Fujita Scale (EF-Scale), Wind Science and Engineering Center, Texas Tech University, Lubbock, TX. 111 pp .

National Climatic Data Center: Storm Data Publications. Available [<http://www.ncdc.noaa.gov/oa/climate/sd>].



Figure 1. Screen Capture from ArcMap showing ortho-imagery overlaid with GPS track from helicopter survey. Labels are times associated with the GPS track. The yellow circle and red star refer to Figure 2.

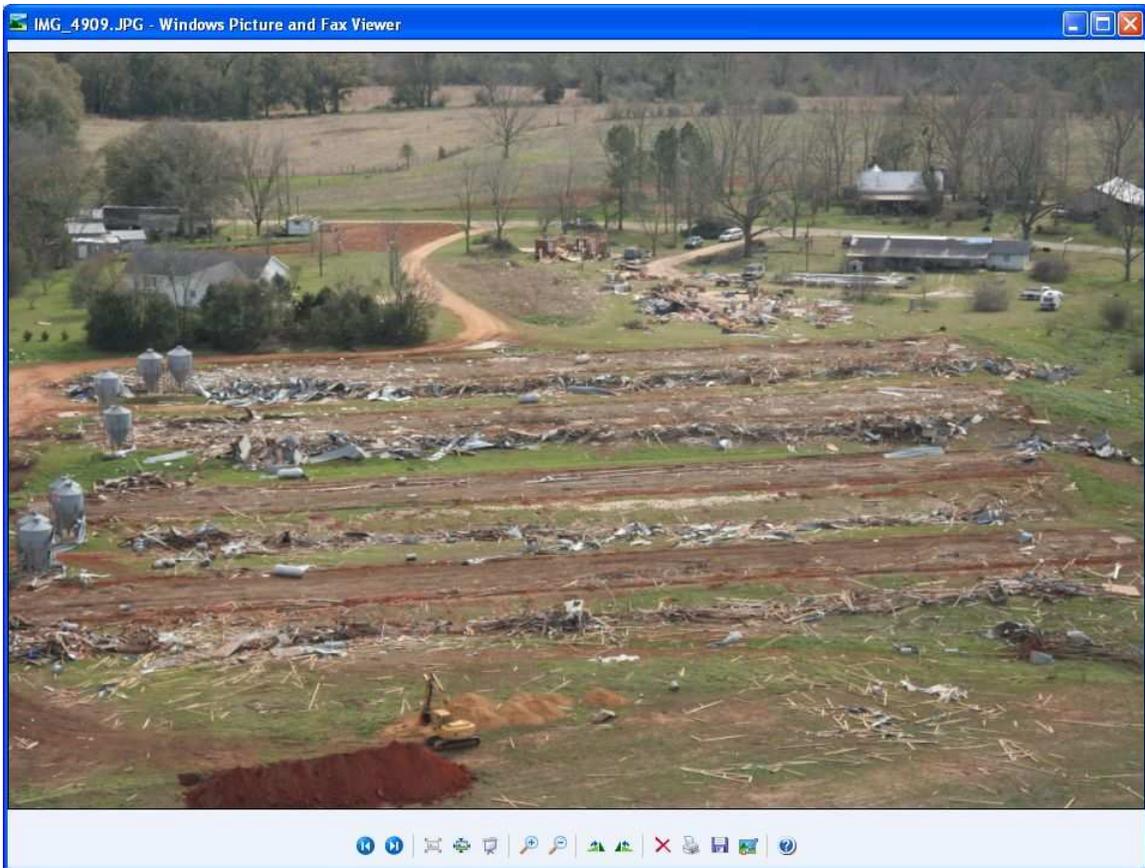


Figure 2. Photograph from helicopter showing destroyed chicken houses. These chicken houses correspond to those circled in the ortho-imagery in Figure 1 (yellow circle). The photograph was taken from the location designated by the red star in Figure 1.

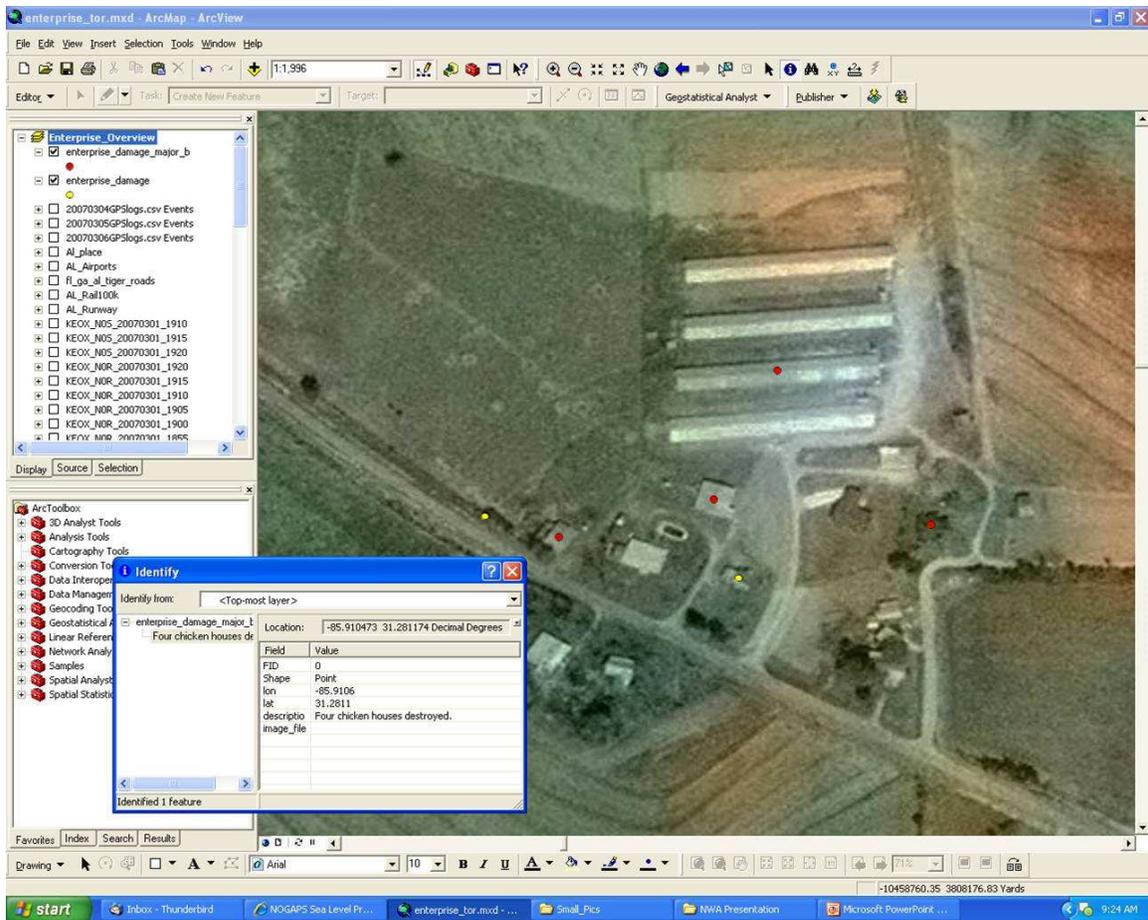


Figure 3. ArcMap screen capture depicting damage points and associated table data corresponding to the destroyed chicken houses in Figure 2.

**Enterprise, Alabama
EF-4 Tornado
March 1, 2007**

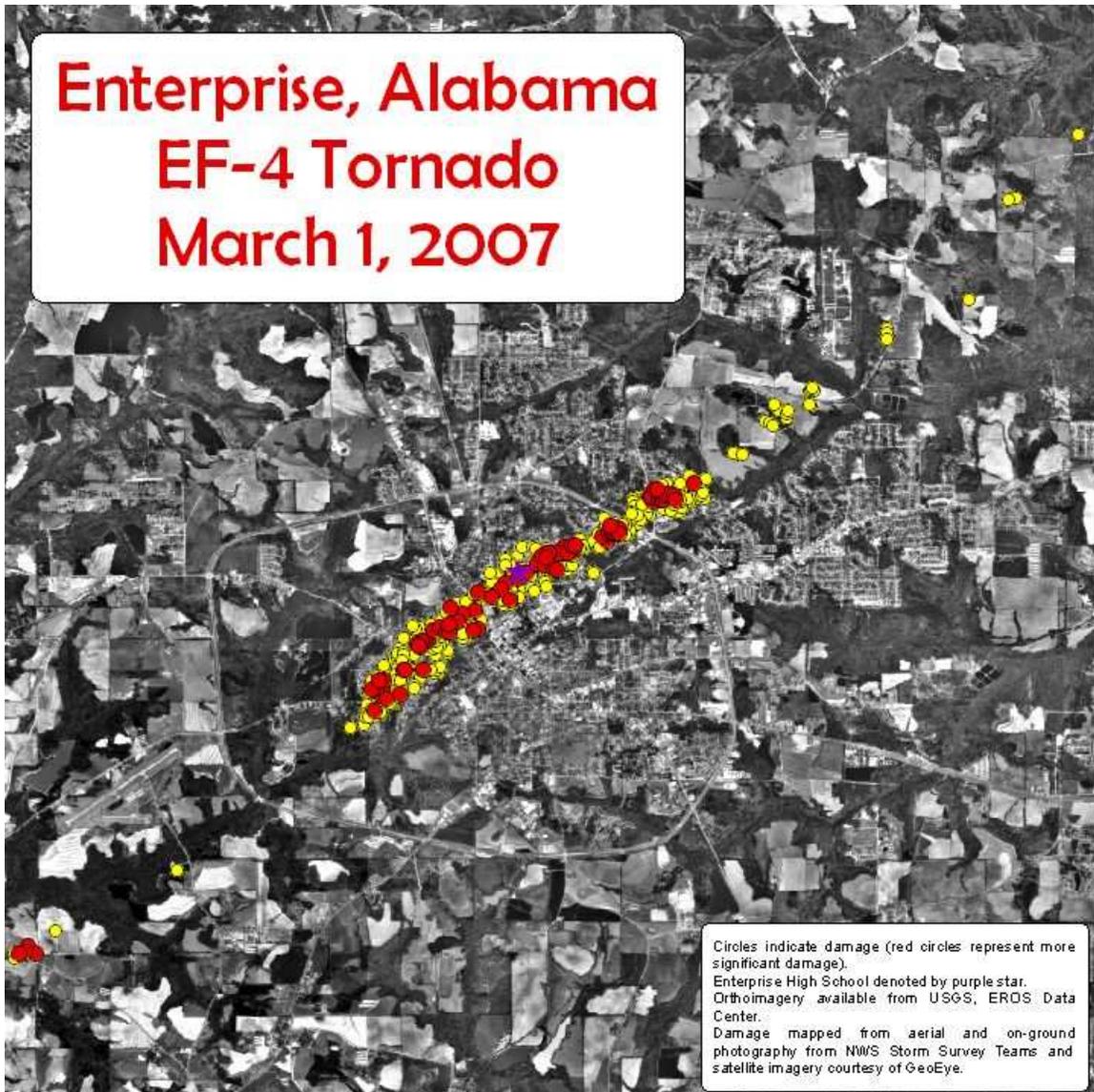


Figure 4. Damage points overlaid on ortho-imagery for Enterprise tornado. This wide-angle image encompasses entire damage path. Yellow circles denote minor damage. Red circles denote major damage. The purple star designates Enterprise High School.

Enterprise, Alabama
EF-4 Tornado
March 1, 2007

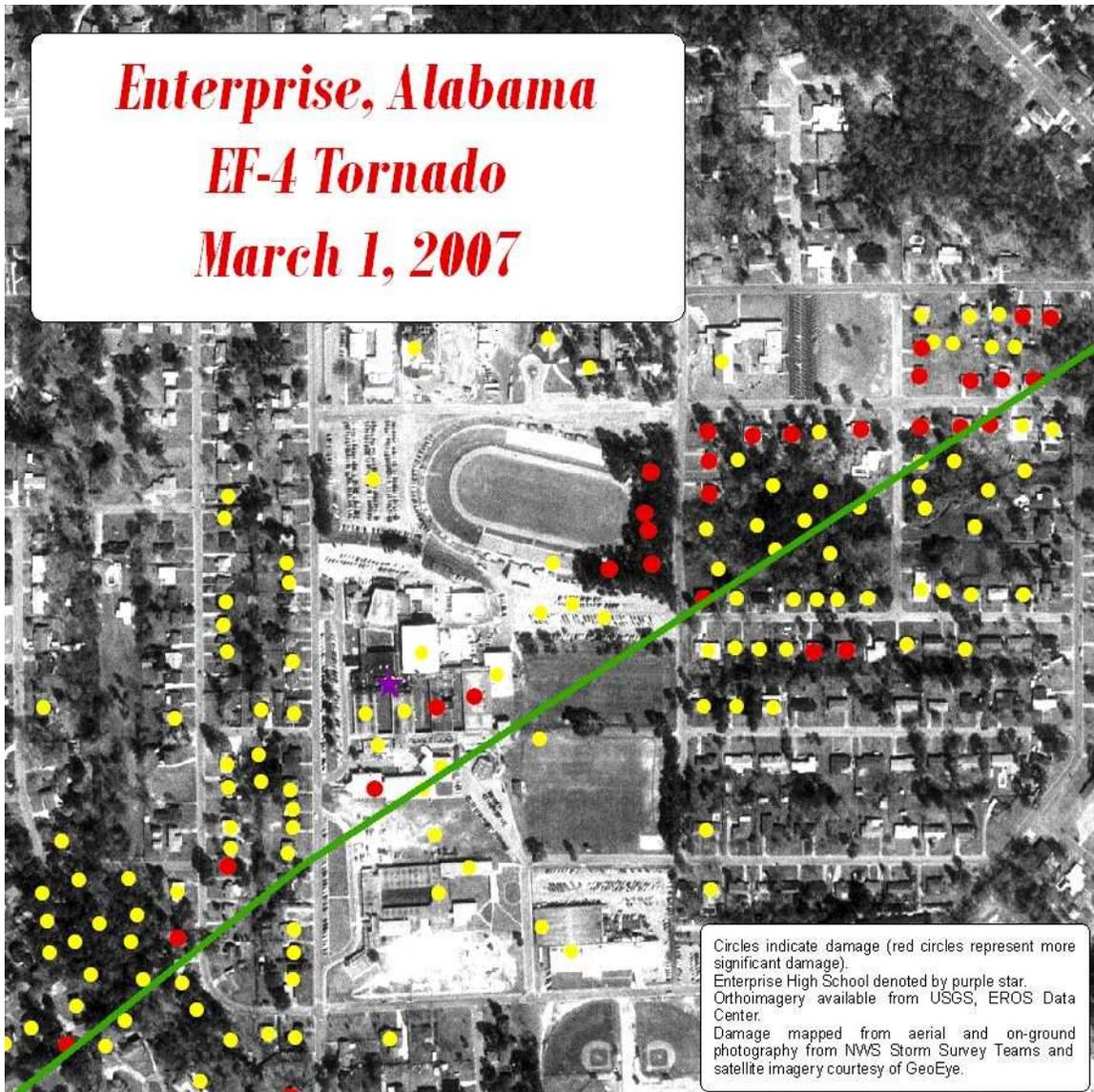


Figure 5. Damage points overlaid on ortho-imagery for Enterprise tornado. This image focuses on Enterprise High School (denoted by purple star). Yellow circles denote minor damage. Red circles denote major damage. Green line is rough centerline of damage.

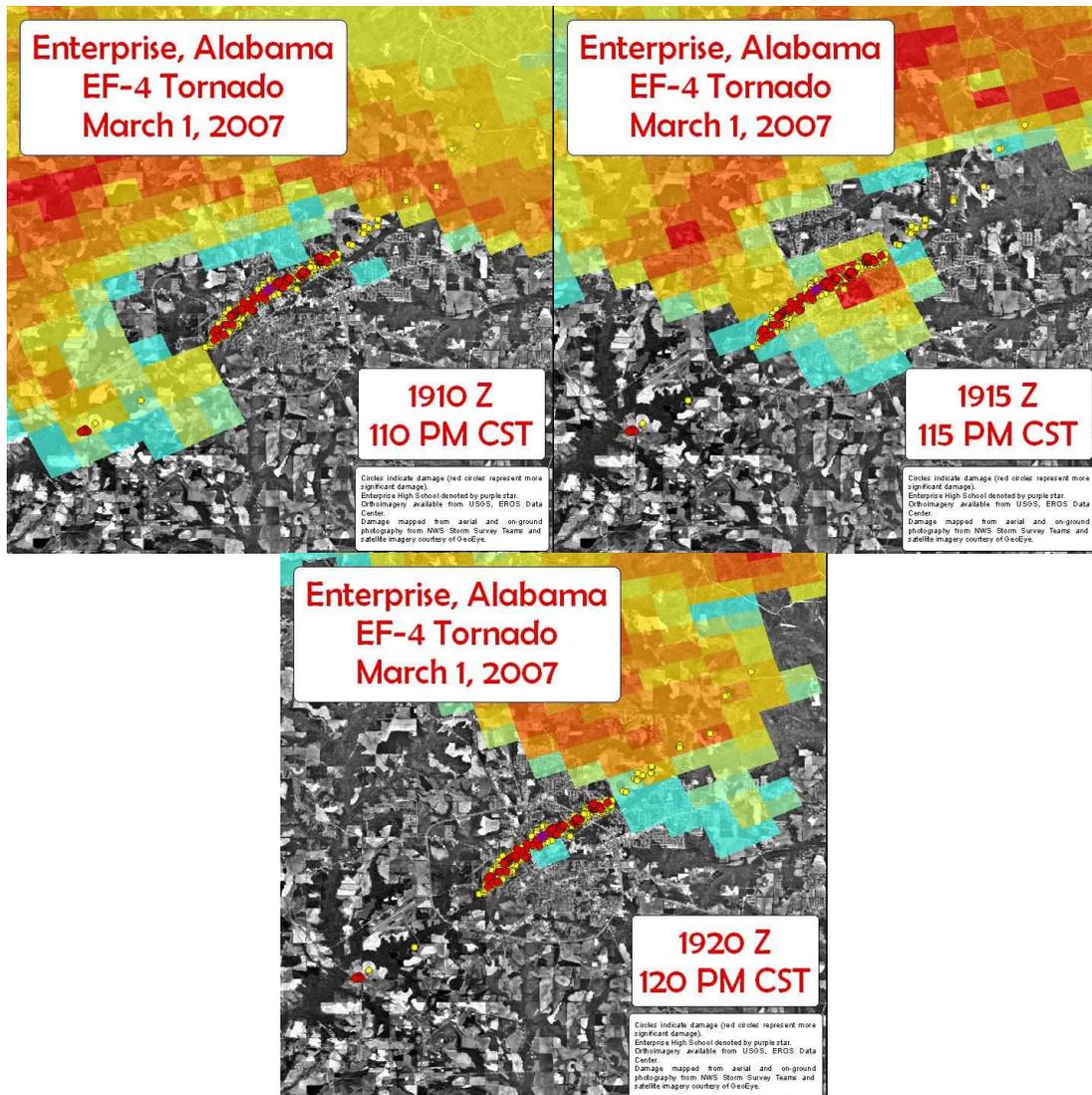


Figure 6. Time series of 0.5 degree Fort Rucker WSR-88D base reflectivity overlaid on ortho-imagery and damage points.

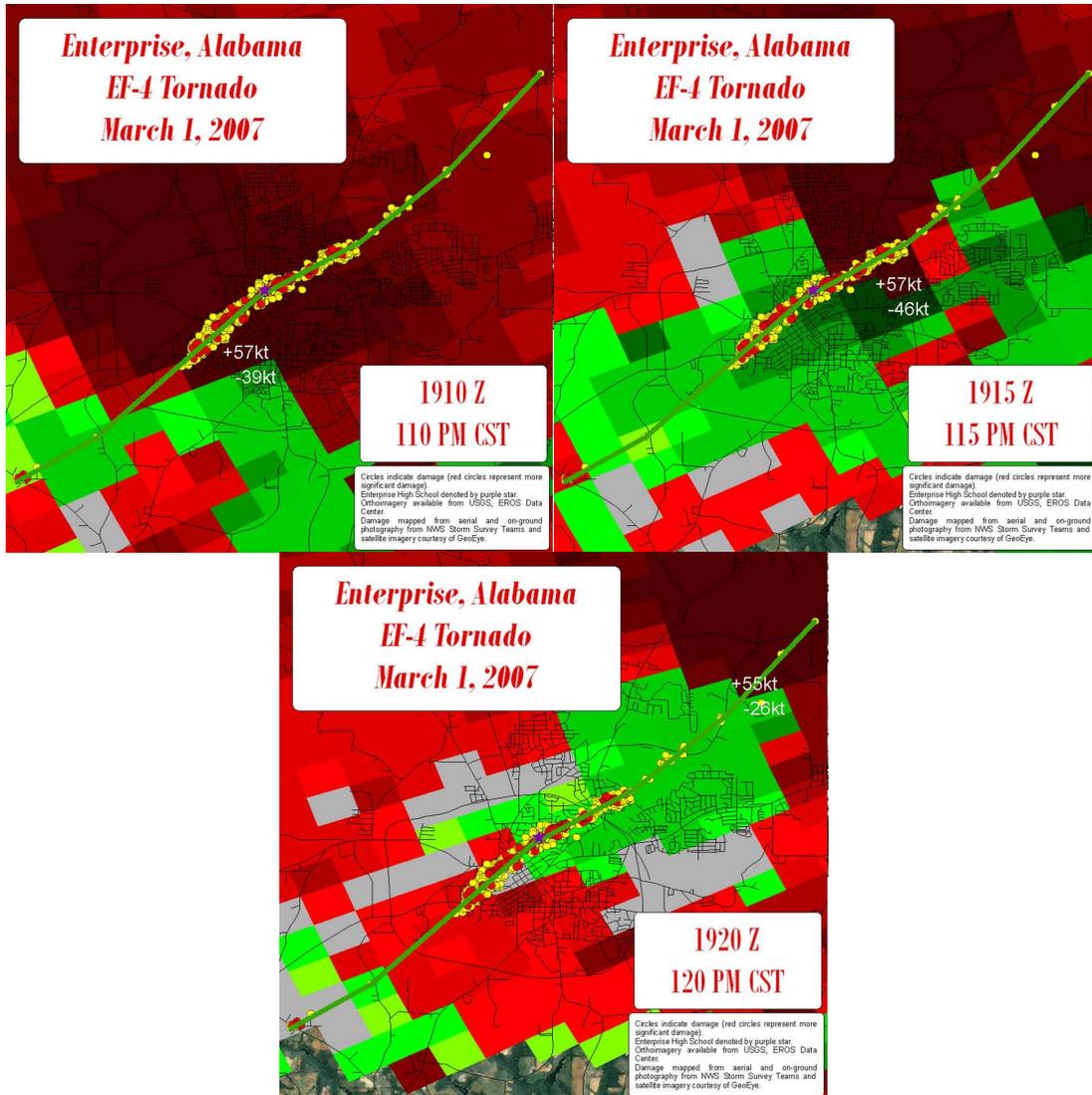


Figure 7. Time series of 0.5 degree Storm Relative Velocity from KEOX WSR-88D overlaid on ortho-imagery and damage points. Maximum gate-to-gate inbound and outbound velocities (knots) are annotated.

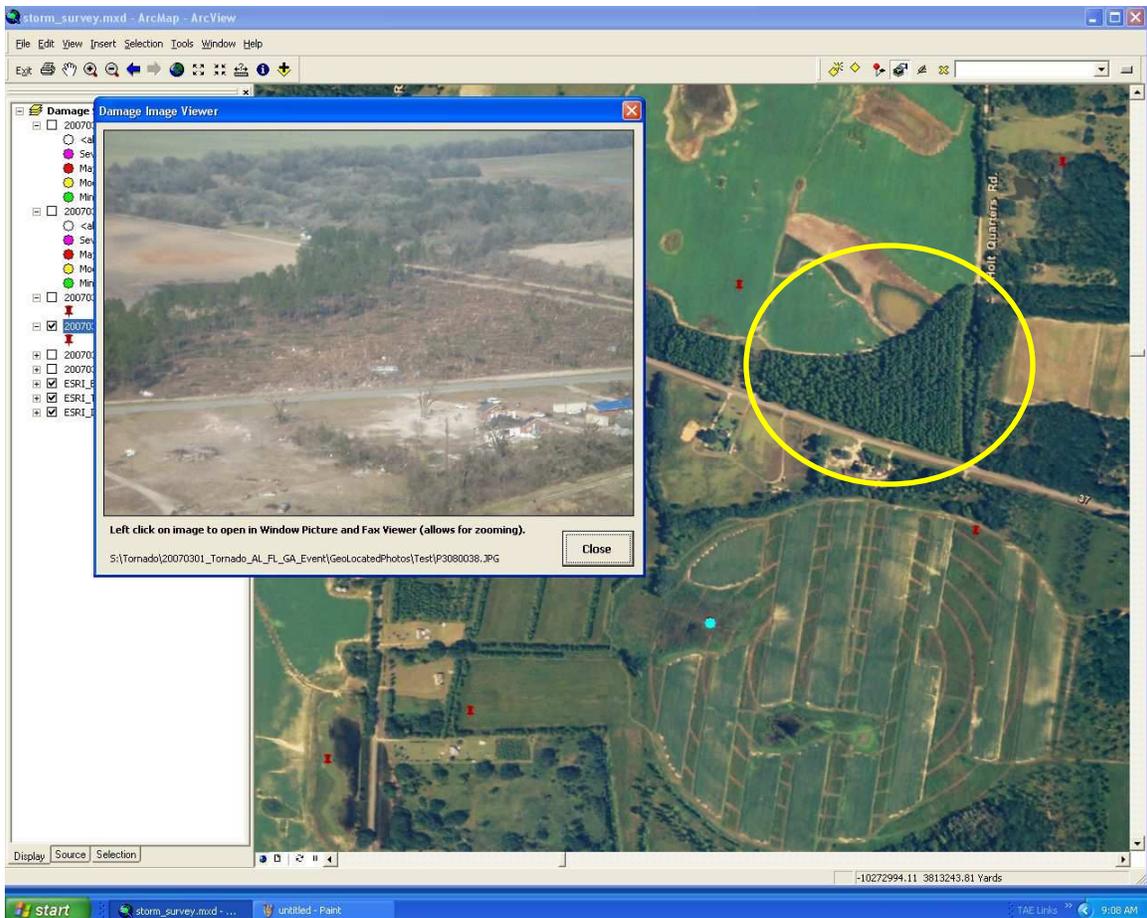


Figure 8. Screen capture of damage photograph point shapefile with associated damage photograph displayed. The blue point corresponds to the location the photograph was taken. The extensive tree damage is easily recognized in the associated ortho-imagery (yellow circle).

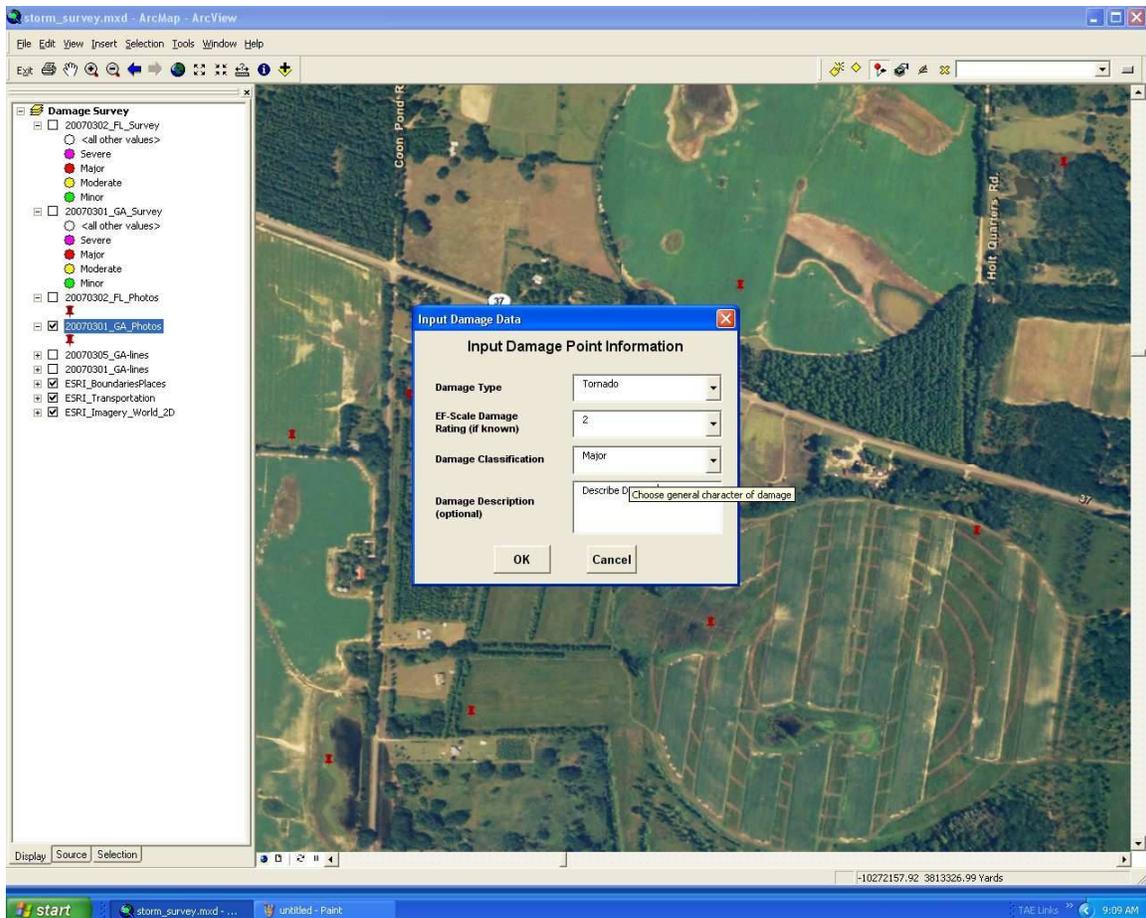


Figure 9. Screen capture showing the damage input window displayed when the user clicks a point on the background map.

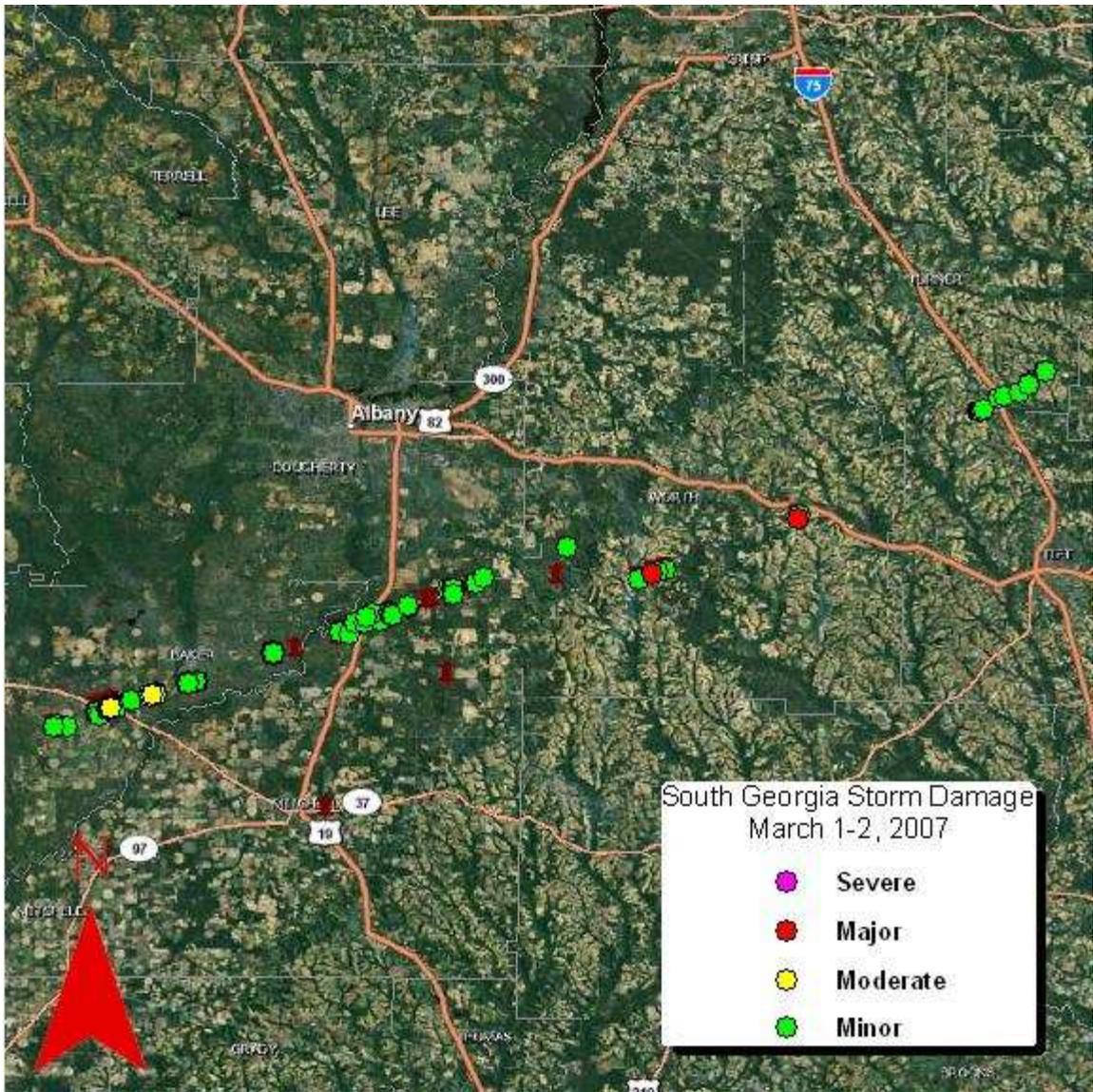


Figure 10. Damage plotted for South Georgia for the March 1-2, 2007 event. The damage points are color coded. The red push pin symbols indicate the locations of geo-located photographs.