Weather Warning Verification Using Geographic Information Systems

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Introduction

The National Weather Service issues approximately 30,000 short-term warnings for weather hazards in the United States each year. These include tornado warnings, severe thunderstorm warnings, flash flood warnings, and special marine warnings. Historically, these warnings have been issued by county, where the entire county is under a warning. As of late, however, the NWS has begun to emphasize the importance of "polygon warnings". These warnings are now issued for a polygon that outlines the major weather threat. This can dramatically reduce the area of coverage of the warning and thus reduce the tendencies for false alarms. Therefore this is seen as a major service improvement for the agency.

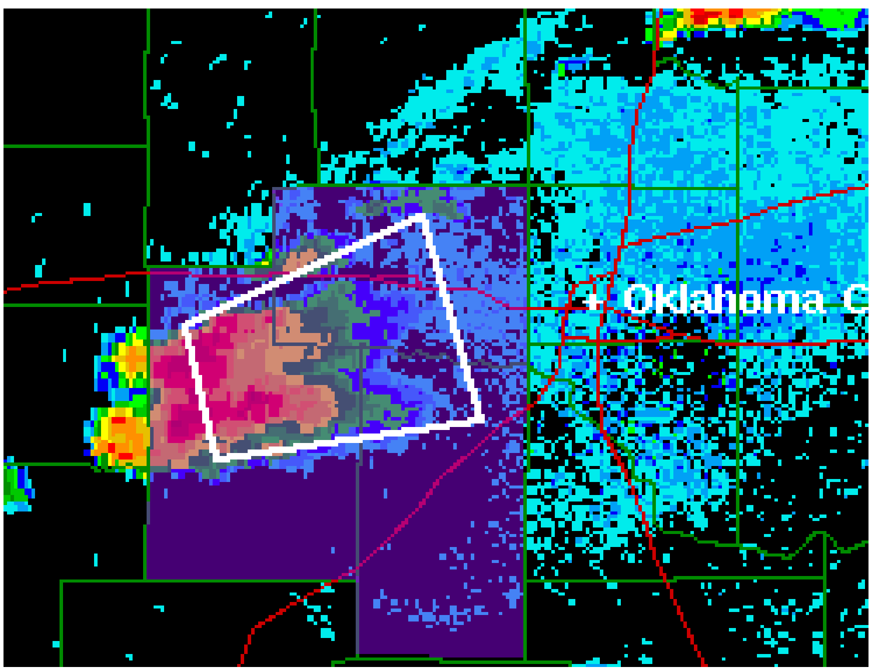

Figure 1: Comparison of polygon warning (white outline) with county-based warning (blue highlighted counties.

A major part of the NWS' warning program is to measure the quality of our service. In the past this meant matching warning events such as a tornado touchdown to the individual warnings. In other words, was there a warning out for that county during the time a tornado touched down? Also, how much lead time was provided between the warning issuance time and the event time? And lastly, the NWS tracks the false alarm ratio, measuring what percentage of warnings issued were "false alarms", in other words did not have an associated event measured during the time of the warning and in the county warned.

However, with polygon warnings the verification situation changes dramatically. Before a database could be used to keep track of which counties were warned under each warning and then do a one-for-one match between events and warnings. Suddenly, by moving to polygon warnings, there is a major need for performing geospatial analysis that can't be done with database software outside of a GIS. Some ground-breaking work has now been done in this arena using ESRI's ArcGIS. To start, a shapefile of all the polygon warnings for a year (2005) has been constructed. In addition, a point shapefile of all the events has been constructed from the event reports. ArcGIS does have some excellent geoprocessing tools to work with. However, the nature of this specific task requires some substantial amount of custom programming. Examples include having to parse out strings in some of the table attributes and applying special tests (temporal, for example) to determine if a proper match has been made between warnings and events. For these reasons, a choice was made to use Visual Basic for Applications (VBA) for the required tasks.

Results

Initial results have been very promising. ArcGIS has been used to compute the Probability of Detection (POD), or in other words, "was there a warning in place for the area that had a tornado touchdown". In addition, the Lead Time (LT) for each event that did indeed have a warning was computed. The resultant tables have been exported for statistical use in Microsoft Excel. Figure 2 below shows the 48-state view of polygon warnings and events. Figure 3 is a close-up look at the state of Mississippi, which seemed to be the most tornado-active region in the U.S. in 2005.

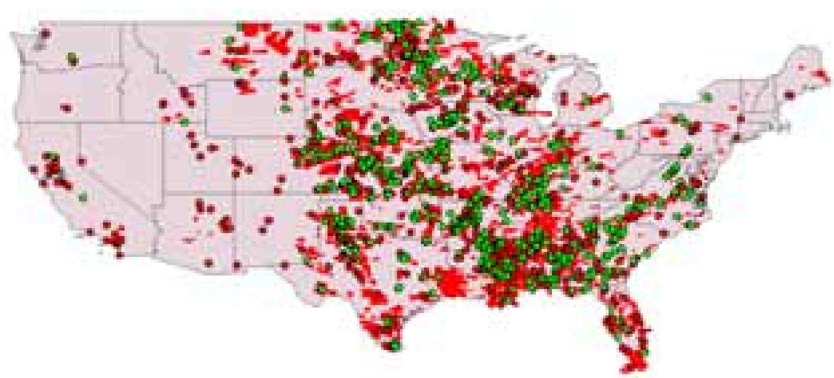

Figure 2. 2005 results, matching tornado warnings (red filled polygons) with tornado events (filled circles, green = event verified, red = event not verified).

What was discovered was that the Probability of Detection using polygons rather than counties was lower due to the fact that now the warning was much smaller in area, raising the risk that a warning might miss an event that would have been counted as verified using county-based methods. This is analogous to an archer shooting at a smaller target. It becomes more challenging to hit the target. This, however, is an indication of a higher quality of service, where a smaller population will be warned. This illustrates the importance of the agency developing completely new verification measures that better gauge the quality of warning support as the agency converts to polygon warnings.

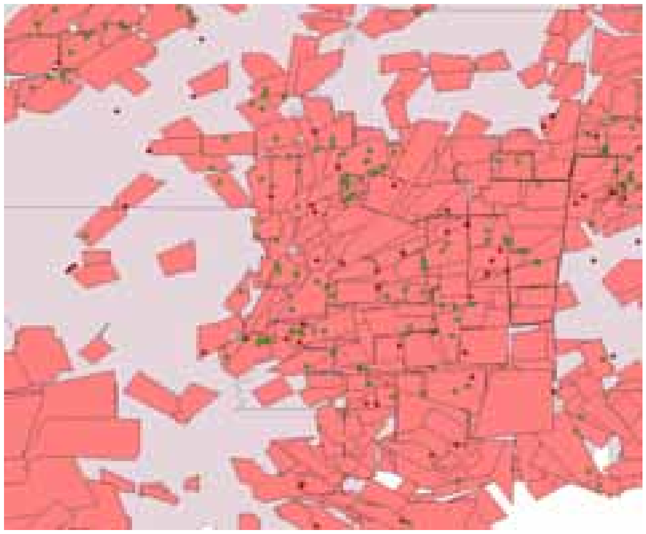

Figure 3. Close-in look over central Mississippi showing tornado warning polygons with overlays of events, both verified (green) and not verified (red).

Future work will look at other events such as hail reports and match them to other NWS warnings such as the Severe Thunderstorm Warnings as shown below in Figure 4.

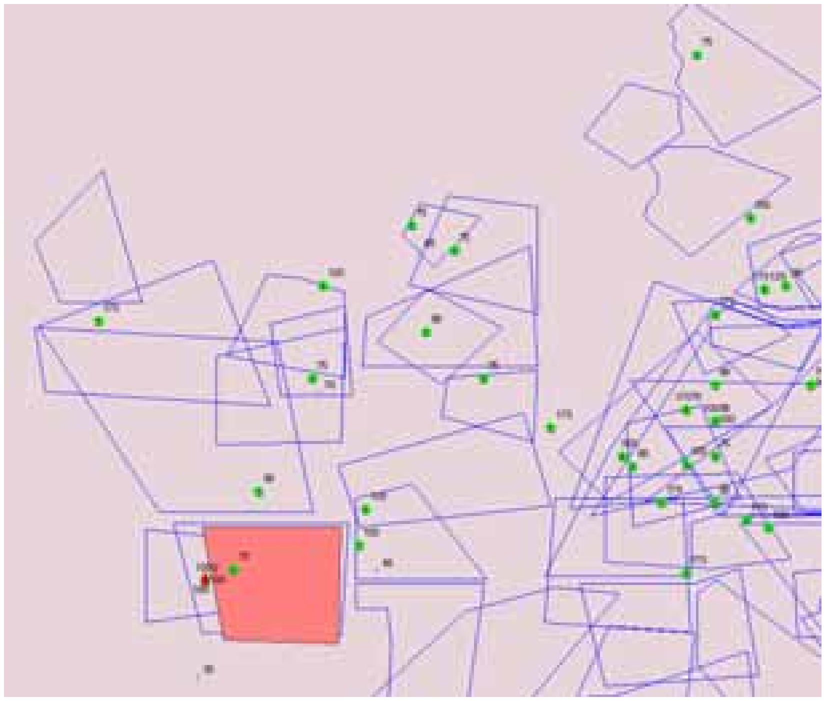

Figure 4. Hail reports (in green) overlayed with Severe Thunderstorm Warnings in New Mexico (blue unfilled polygons). The label for the hail reports is in hundredths of an inch, e.g., “75” signifies 0.75, or ¾” hailstones. The single red filled polygon is for a tornado warning with the red diamond-shaped marker showing a tornado touchdown.

County Area Ratio

In order to better illustrate the service improvement that polygon warnings provides it became necessary to design a new measure. This measure is a comparison of the area of each polygon warning to the sum of the counties that the warning was issued for. ArcGIS was used to compute the areas of the polygons and then customized VBA code was used to parse out the counties from each warning. These data are composed of a string list of all the counties in one field of the data attribute table. The VBA was required to break the string into individual Universal Geographic Codes (UGC) which are unique to each county in the country. Then the code matches a county table of area in square mileage and computes the ratio of the two areas for each warning. This new measure, County Area Ratio (CAR), has much promise for use by the agency to demonstrate service improvement with polygon warnings. An example of the CAR is shown in Figure 5.

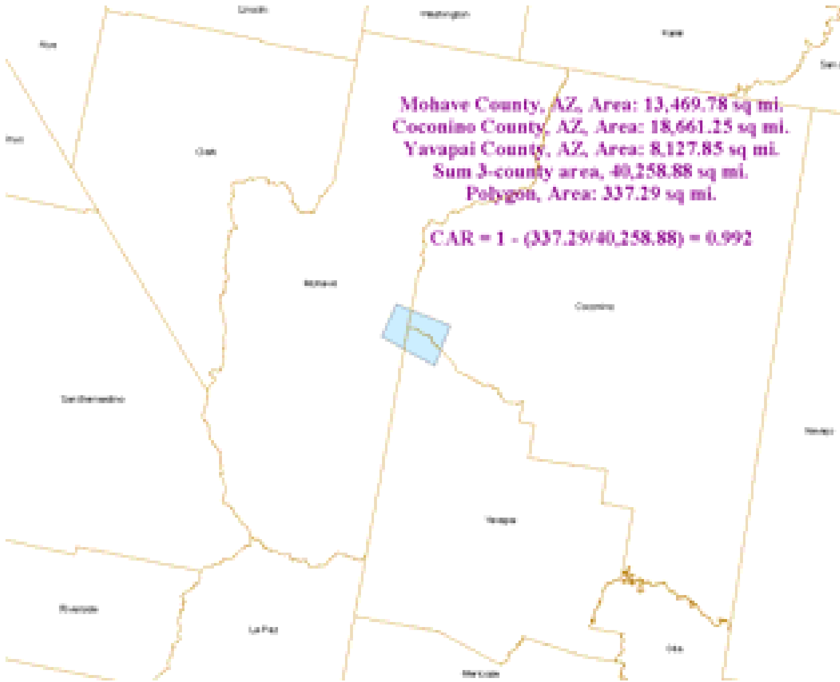

Figure 5 – Example of the CAR measure using an actual Severe Thunderstorm Warning issued in Arizona that overlapped three counties. Using the legacy county-based method this warning was huge, over 40,000 square miles, covering much of the state of Arizona. However, using polygons, the warning was much smaller, less than 400 square miles. Thus this results in a dramatically reduced area of the country that is under this warning.

Future Work

The agency has plans to integrate the warning database with other databases such as census records to enable population analyses such as number of persons in a warning area. In addition, the agency is examining options for building some of its warning support aids on a GIS platform that will be able to take advantage of the geoprocessing power of GIS and the great abundance of GIS-compatible data sets.

Conclusion

There remains much promise with the use of ArcGIS and VBA to revolutionize the way the National Weather Service verifies its warnings. This is only the start of many more applications of the GIS that the agency can take advantage of.