# JP1.1 THE ADVANTAGES OF USING POLYGONS FOR THE VERIFICATION OF NATIONAL WEATHER SERVICE WARNINGS

Peter A. Browning* and Mark Mitchell
NOAA/NWS Weather Forecast Office
Pleasant Hill MO

## 1. INTRODUCTION

The verification of National Weather Service (NWS) warnings first began in the late 1970s (Grenier et. al., 1990) and was formalized by the National Verification Plan in 1982 (NWS, 1982). Since then, little has changed. NWS warnings are issued for specified geopolitical boundaries (county or parish) and the verification of these warnings depends on whether severe weather occurs within this specified geopolitical boundary during the valid time of the warning. Events occurring outside of these boundaries (both time and space) are considered unwarned events. Warnings issued without reports of severe weather inside these boundaries are considered false alarms. For warnings which include more than one county, no attempt is made to combine the geopolitical boundaries into one area, but instead each county of the multi-county warning requires independent verification.

This system has served well in providing accountability for NWS warnings. Improvements in verification scores have resulted through the years through the use of: the WSR-88D Doppler radar (beginning in the middle 1990s), better trained warning forecasters and improvements in report gathering. Recently, the NWS has established goals for improving warning verification scores, including a reduction in the false alarm ratio (FAR) of tornado warnings (NWS, 1999). It has been suggested (Smith, 2000), Wood and Quoetone, 2000) that the FAR can be reduced through changes in the warning verification system. Smith (2000) noted that as many as 75 percent of tornado warnings issued by some offices in the southeast U.S. were multi-county warnings - mainly due to the size and often irregular shapes of counties. If a tornado was in fact observed with each of these warnings, then in order for the verification score to reflect the service provided, a tornado would have had to touch down in each of the counties in the warnings.

To further examine the effect of multi-county warnings on the FAR, all of the April 2001 through July 2001 multi-county tornado and severe thunderstorm warnings from the NWS Weather Forecast Office (NWFO) Pleasant Hill MO (EAX) county warning area were analyzed. If the area defined by the multiple counties were considered as one warning area, then the FAR improved by 60 percent (FAR reduced from 0.38 to 0.15). So for multi-county warnings, there is a percentage of the warned area that is reflected in the FAR.

Recently the NWS upgraded the computer workstations at NWS offices with the Advanced Weather Information Processing System (AWIPS; Friday, 1994). These workstations provide new tools and formatters that speed up the generation and delivery of warnings. The warning generation tool (WARNGEN) provides a means for the forecaster to delineate the warning area by determining the location and motion of the severe weather threat, and by drawing a polygon that outlines the warning area. This polygon is then manipulated by the forecaster to reflect the warning area to be used by the formatter. The formatter determines which counties and portions of counties should be included in the warning based on how the polygon area compares with geopolitical boundaries. The coordinates of the points that make up the polygon is included in the text of the warning message and is now being used by some NWS partners and customers as the warned area.

Since these polygons represent where the forecaster believes the severe weather threat lies, and automated dissemination systems are beginning to use these areas, then we need to look at how well they verify and how they compare to county-based verification statistics. This idea is not new. Smith (2000) described an effort underway in the Southern Region of the NWS. Three offices are beginning to accumulate data for comparing county-based verification with polygon-based verification. Although no data was presented, expected results were for improvements in FAR while little improvement (or perhaps some degradation) was expected in the probability of detection (POD). Wood and Quoetone (2000) compared verification scores from warnings issued by students in training using a few severe weather cases. They found that the POD did fall while the FAR was improved. This study provides additional data for use in comparing the county-based verification system to a polygon-based system.

## 2. DATA

Warnings and severe weather reports from April through July 2001 from the NWFO EAX county warning

* *Corresponding author address*: Peter A. Browning, NWS NWFO, 1803 N. 7 Highway, Pleasant Hill, MO 64080; e-mail: peter.browning@noaa.gov

area were collected, decoded and saved into a database. All warnings during this period were issued using the AWIPS WARNGEN application, which produces a polygon warning area. The polygon coordinates were matched up with all severe reports to produce verification scores for comparison with the county-based verification system. All reports of severe weather were used in the calculations. Warning verification statistics were computed for POD, FAR and critical success index (CSI). See Grenier et. al. (1990) for a description of these statistics.

In addition to county and polygon warning area data, automated warning areas similar to the default WARNGEN polygons were generated. These default polygons were derived from the location, speed and direction of movement of the severe weather from each of the warning text messages. For warnings based on an individual cell, a four sided polygon was constructed that began 2 miles upstream of the location and 6 miles to either side (12 mile width), then widened out by a factor of 0.12 for each mile along the path. The length of the polygon was determined from the extrapolated distance determined from the motion vector and the expiration time of the warning. For lines, a polygon was drawn using the indicated points along the line, the motion vector and expiration time. For both cells and lines, a small buffer was added to the length of the warning box.

Since forecasters issued warnings with the county-based verification in mind, the polygons may be biased toward the county-based system. This default data set is an attempt to provide an additional (unbiased) data set for comparison purposes. Table 1 shows a comparison of warning verification statistics for the three types of warning areas. The poorest scores were achieved from the default warning polygons - what you could expect if you simply identified the location and motion of the severe weather without further manipulation of the polygon.

| | County | Polygon | Default |
|---|---|---|---|
| FAR | 0.321 | 0.336 | 0.362 |
| POD | 0.855 | 0.731 | 0.699 |
| CSI | 0.675 | 0.610 | 0.576 |
| No. of Warnings | 374 | 265 | 265 |
| Warnings Verified | 254 | 176 | 169 |
| Reports in Warnings | 384 | 328 | 314 |
| Total Reports | 449 | 449 | 449 |
| Avg. Area (sq. miles) | 579.3 | 506.9 | 640.5 |

Table 1. Comparison of verification scores for warnings issued by NWFO EAX during period 1 April through 31 July 2001. Three different methods for defining the warning area are compared.

## 3. DISCUSSION

A comparison of the county versus the polygon verification scores did show the expected decrease in POD, but not the expected decrease in FAR. There are a few points to consider when looking at these numbers. In many cases the polygon areas were focused on the area of the severe threat of a particular cluster of storms, with the warning area oriented along and ahead of the greatest threat. During the lifetime of the warning, reports were received outside of the polygon, but inside the county boundaries. This could easily happen if the forecaster doesn't properly anticipate the spreading or propagation of the severe weather (such as wind damage from the rear-flank downdraft of a supercell - the cell moves off to the east, but the strong winds could spread southward). Another common situation is the verification of warnings from other storms than those initially warned for. New development in the warned county could produce reports outside of the initial polygon.

On other occasions, the polygon was manipulated by the forecasters to closely match the county outlines. In these cases, little differences in verification statistics occurred, except for the case of multi-county warnings that did not have reports in all of the counties.

Forecasters expend a considerable amount of effort in determining whether a county should be included in or left out of the warning. Often WARNGEN polygons will include small portions of counties. In these cases, the severe threat gets measured in what the likelihood of receiving a report is instead of following the science of severe weather forecasting. Since the forecasters were operating using the county-based verification mind set, they would often alter the polygons to stop at county boundaries, eliminate the small portions of counties where severe weather reports were not likely to be received and eliminate the additional portions of counties downstream. (Note - better scores can be achieved if you limit the lead time for the next county and then warn when you are confident that it will still be severe when it crosses the county line).

The default warning polygon data set was an attempt to remove the county-based mind set biases seen in the polygon data set. The default warning polygons did not stop at county lines but also did not make use of forecaster interpretation of where the warned area is needed. As a result, the verification scores were even worse than the polygon data set. Adjustments could be made to the way that the default polygons were generated in an effort to improve the scores, but this was not done for this study. Average area for each warning method is also listed in table 1. The larger area

indicated by the default polygons were the result of fast moving lines or cells that resulted in large warning areas that occasionally extended outside of the NWFO EAX county warning area. Most default areas were similar in size to the forecaster polygons.

One other item needs to be mentioned. Storm reports used in this study were gathered with the aim of verifying warnings based on the county-based verification system. If a report is received that verifies a warning, little additional effort is spent on receiving additional reports from that county. Therefore, the verification statistics are weighed toward the county-based system. Since FAR and POD were not dramatically different for the polygon versus the county system, then it would not be too hard to maintain or improve upon skill scores using the polygon method.

## 4. CONCLUSIONS

Based on the data presented in this paper, it is of the opinion of the authors that the internal verification of NWS warnings be changed to better reflect the service provided; especially when partners and customers make use of the polygon coordinates included in every warning. There are advantages and disadvantages for switching.

### 4.1 *Advantages*

Advantages for verifying warnings using polygon warning areas are:

- Forecasters can focus on severe weather signatures and utilize conceptual models for determining the warning area without concern for county boundaries.

- Although false alarms will still occur, the FAR will properly measure over-warning. A multi-county tornado warning that verifies with a tornado in one of the counties should be considered good service; the threat may have been justified for the neighboring county that did not have a touchdown. A good example of this is a strongly rotating supercell. Recent research has shown that it could take 30 to 45 minutes before these storms produce a tornado unless it interacts with a boundary. If the storm is moving through a populated area at 20 $ms^{-1}$ or so, it could move through 2 or 3 counties before the tornado touches down. In this scenario the FAR would increase, but the public sees this as great service. What if this storm is similar to those that produce tornadoes quite rapidly (as seen in the Oklahoma outbreak)?

- The verification scores will match the published warning coordinates currently included within the warning text message.

- No changes are needed to the AWIPS software or to the format of the public warning product. Internal software for capturing the coordinates of the warnings along with warning valid times will be necessary.

### 4.2 *Disadvantages*

Disadvantages for verifying warnings using polygon warning areas are:

- It is easier to verify warnings by county outline; occasionally verifying for the wrong reason (from other storms) if a long enough valid time is provided.

- The warnings will include more portions of counties instead of fewer whole counties. This is not a problem for people who get their warnings on television or graphically on the internet. However, for those listening to radio, it could make it harder to determine the area affected.

The disadvantages listed are minor. First we should consider warnings to be correct when they are placed in locations where severe weather is expected. As for the difficulty in determining where the warning is valid, that is a problem we have today and will probably continue. Since the majority of the population is familiar with the towns around them, the use of pathcasts in warnings has helped to alert those who may be affected.

## 5. ACKNOWLEDGMENTS

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