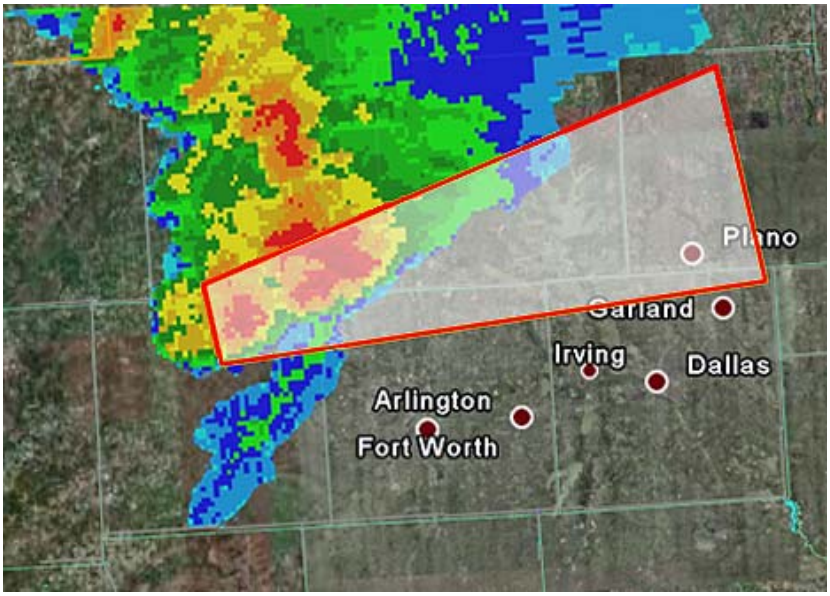
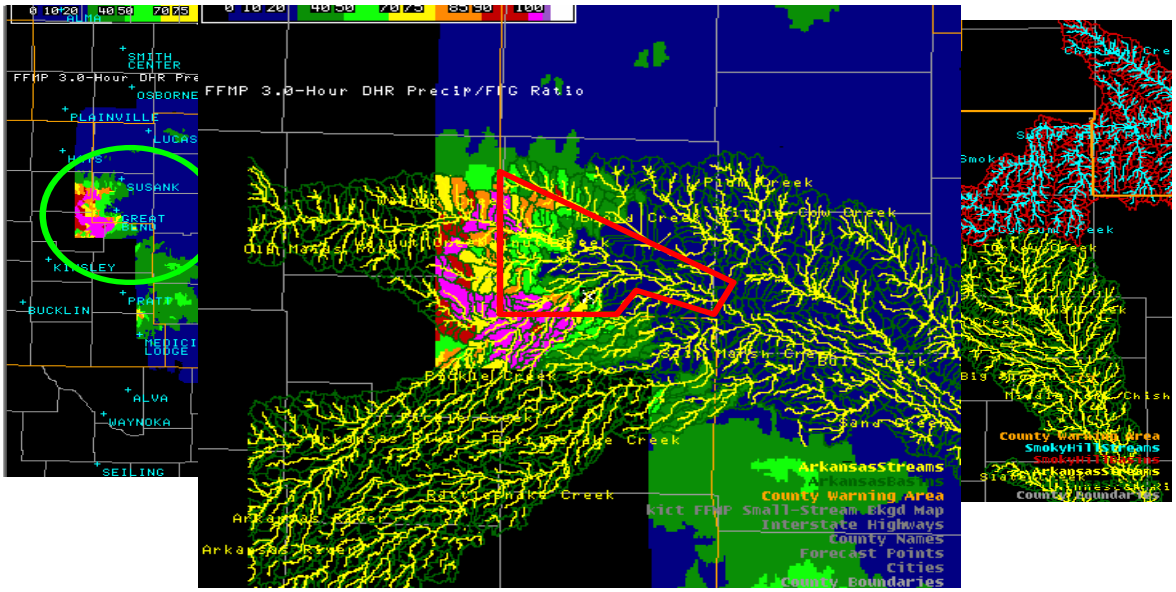
Storm-Based Warnings
Team Report





U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, Maryland

Cover Graphics:

Upper: Storm-Based Tornado Warning Polygon

Lower: Storm-Based Flash Flood Warning Polygon

Storm-Based Warnings Team Report

March 2007

U.S. DEPARTMENT OF COMMERCE
Carlos M. Gutierrez, Secretary

National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr., Administrator

National Weather Service
Mary M. Glackin, Assistant Administrator

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Appendices

Storm-Based Warnings Team Report

March 30, 2007

1. Executive Summary

The NWS mission is to provide weather forecasts and warnings for the protection of life and property and to provide weather information for the Nation's economic well-being. There is a continuing need to improve the specificity and accuracy of warnings for tornadoes, severe thunderstorms and flash floods over land and, where applicable, adjacent marine areas. NWS currently issues and disseminates warnings for these hazards using geopolitical (e.g., county or marine zone) boundaries. Verification and dissemination methods are currently tied to county- or zone- based warnings.

Threat-based polygon warnings, or storm-based (SB) warnings, are essential to effectively warn for severe weather and flash floods. SB warnings show the specific meteorological threat area and are not restricted to geopolitical boundaries. By focusing on the true threat area, polygons will help improve NWS warning accuracy and quality. SB warnings will promote improved graphical warning displays, and in partnership with the private sector, support a wider warning distribution through cell phone alerts, pagers, web-enabled Personal Data Assistants (PDA), etc. SB warnings also support the NOAA Strategic Plan goal to "employ scientific and emerging technological capabilities to advance decision-support services and educate stakeholders."

2. Introduction/Background

In January 2003, the NWS Meteorological Services Division (MSD) Chiefs discussed the requirement to provide geographically concise, timely, and storm-specific warning information in a digital format. The Chiefs approved the concept and assembled a cross-NWS review team. The team first met in January 2004 creating a draft charter. The charter was briefed to the Operations Subcommittee of the Corporate Board in June, 2004. The Operations Subcommittee approved the team charter through December 31, 2005.

Team Members:
J. Michael Looney, Central Region Headquarters (CRH) - Facilitator
Brenton MacAloney, Office of Climate, Water and Weather Services (OCWWS), Performance Branch
Steven Naglic, Warning Coordination Meteorologist (WCM), WFO Columbia, SC
Peter Wolf, Science and Operations Officer, WFO Wichita, KS/WFO Jacksonville, FL
Jeffrey Lorens, Western Region Headquarters
Michael Coyne, Southern Region Headquarters/WFO Huntsville, AL
Richard Okulski, OCWWS Public Service Branch/WCM Memphis
Noreen Schwein, CRH representing OCWWS/Hydrologic Services Division)

Joseph Schaefer, Storm Prediction Center
Ken Waters, Pacific Region Headquarters

The Storm-Based Warning Team charter mandated the creation of a field evaluation of specific short-duration "Warnings by Polygon" for the 2005 severe weather season from March 1 through September 30, 2005. The warnings under evaluation included tornado, severe thunderstorm, special marine and flash flood warnings.

In preparation for the field evaluation, a series of interactive training sessions was developed by Pete Wolf, Science and Operations Officer, WFO Wichita, Kansas. Each of the 23 NWS Forecast Offices in the field evaluation was afforded three opportunities to participate in a training session. As a result, virtually every forecaster received training in the basic concept of SB warnings.

An aggressive outreach campaign was employed to fully acquaint customers with the planned evaluation. Outreach targets included local and national media, emergency managers, members of the scientific community, and private sector vendors of NWS warning information. Response was positive across this wide spectrum of partners and customers.

Additionally, in preparation for the field evaluation, a simple survey form was developed for the purpose of evaluating impact within the forecast office and upon segments of the customer and partner communities. The results were most interesting. Sixty-four percent of the forecasters reported "no increase" in workload, specifically 57% stated "no change" and 7% stated workload actually "decreased". Customer response was similarly interesting. Eighty-five percent of external customers responding to the survey indicated that the SB warning approach had no negative impact on their operations.

Legacy technologies dictated warning by county. Over the decades of NWS warning history, the warning by county concept was refined; the warning by county culture became entrenched within and outside the NWS. The advent of digital technology has, almost overnight, revolutionized communication. Warning by polygon, unlike textual warnings by county, meshes well with digital communication technologies such as Graphical Information Systems (GIS). A warning consisting of a set of latitude/longitude (lat/lon) vertices is easily transmitted via cell phone or PDA. Warning polygons are also easily displayed in various graphical formats.

Ease of digital communication, however, is a secondary benefit. The primary goal of warning by polygon is improved warning service to the citizens of this country. A storm-based warning methodology allows the forecaster the opportunity to be spatially specific, eliminating large areas needlessly warned when compared to warning by county. The field evaluation provided dramatic results. Using GIS software to calculate the size of warned areas, it was shown that warning by polygon decreased the area warned by almost 75 percent compared to warning by county. What does this mean for the American public? According to Dr. Daniel S. Sutter, Associate Professor of Economics, University of Texas, Pan American, this decrease in warning size (area) represents a savings of at

least $100 million per year to the citizens of the United States. This equates, according to Dr. Sutter, to lowering the False Alarm Rate to zero.

The results of the field evaluation strongly suggest a mandate to implement "Warnings by Polygon". The evaluation results were reported to the Operations Subcommittee in December, 2005. The subcommittee accepted all team recommendations and commissioned the existing team to begin the warning by polygon (storm-based warnings) implementation phase.

The field test recognized several areas to be addressed before the NWS is ready for implementation. Issues, stated in general terms, include several WarnGen software modification issues; unification of LSR/StormDat locations databases; development of WFO training incorporating the Weather Event Simulator (WES); development of customer training strategies; establishing a nexus with the SB Warning Team and the NOAA Weather Radio Improvement Plan Team; development of appropriate verification measures; and a review of GPRA metrics.

The submission of "Storm-based Warnings" into the requirements process (i.e., Operations and Services Improvement Process (OSIP)) began early in 2006. The present goal for initial operating capacity for "Storm-based Warnings" is the fall of 2007.

3. Mission/Vision Statement

Mission: Define issues associated with the polygon approach to the warning process and recommend solutions.

Vision: Provide geographically concise, timely, and meteorologically accurate warning information to all.

4. Test Description

The SB Team conducted a test and evaluation of storm-based short duration warnings at select WFOs from March 1st, 2005 through September 30th, 2005. The team evaluated:

- Level of service
- Impact to WFO operations and workload
- Impact to customer operations
- Software limitations
- Polygon methodology training
- Impact to existing verification metrics
- Requirement for newly-developed SB verification metrics

A local and national education/outreach campaign was developed to prepare emergency managers, the media and other customers. This important phase of the initiative was accomplished through meetings, brochures and presentations created by team members.

Test conclusions were drawn using feedback from NWS WFO forecasters, emergency managers and external customers, and verification metrics. There were 23 WFOs in the test as shown in the following map (Figure 1):

Figure 1. Evaluation locations.

5. Findings/Issues

5.1 Level of Service

Customer feedback showed the public perception that the level of service for graphical and text information generally improved due to the warning area being more specific. Instead of whole counties being warned, only the actual threat area was warned. This efficiency was dramatically displayed by one Kansas City television station which had software to interpret the polygon information and create an informative and pleasing television graphic (Figure 2). Similar views were displayed on WFO homepages where polygons were overlaid onto radar images and updated several times an hour, whenever the radar images were updated. Some emergency managers stated the SB warning methodology helped them to better ascertain the threat area and therefore the appropriate action required to meet the specific hazard.

WalMart provided an excellent example of the positive benefit (value) of SB warnings to their operations. According to the world's largest vendor, the better defined threat area provided by the SB warning minimizes store "down time". From their national operations center, WalMart can determine which stores within a county require activation of tornado procedures and which stores, in the same county but outside the warning polygon, do not need to activate tornado procedures. Decreasing the number of stores impacted in a county is an excellent example of the SB warning methodology decreasing the area that is falsely alarmed within a county.

Other comments indicated a preference for text products which listed the communities within the polygon (rather than the pathcast) and reference to portions of a county (e.g., northeast Smith County).

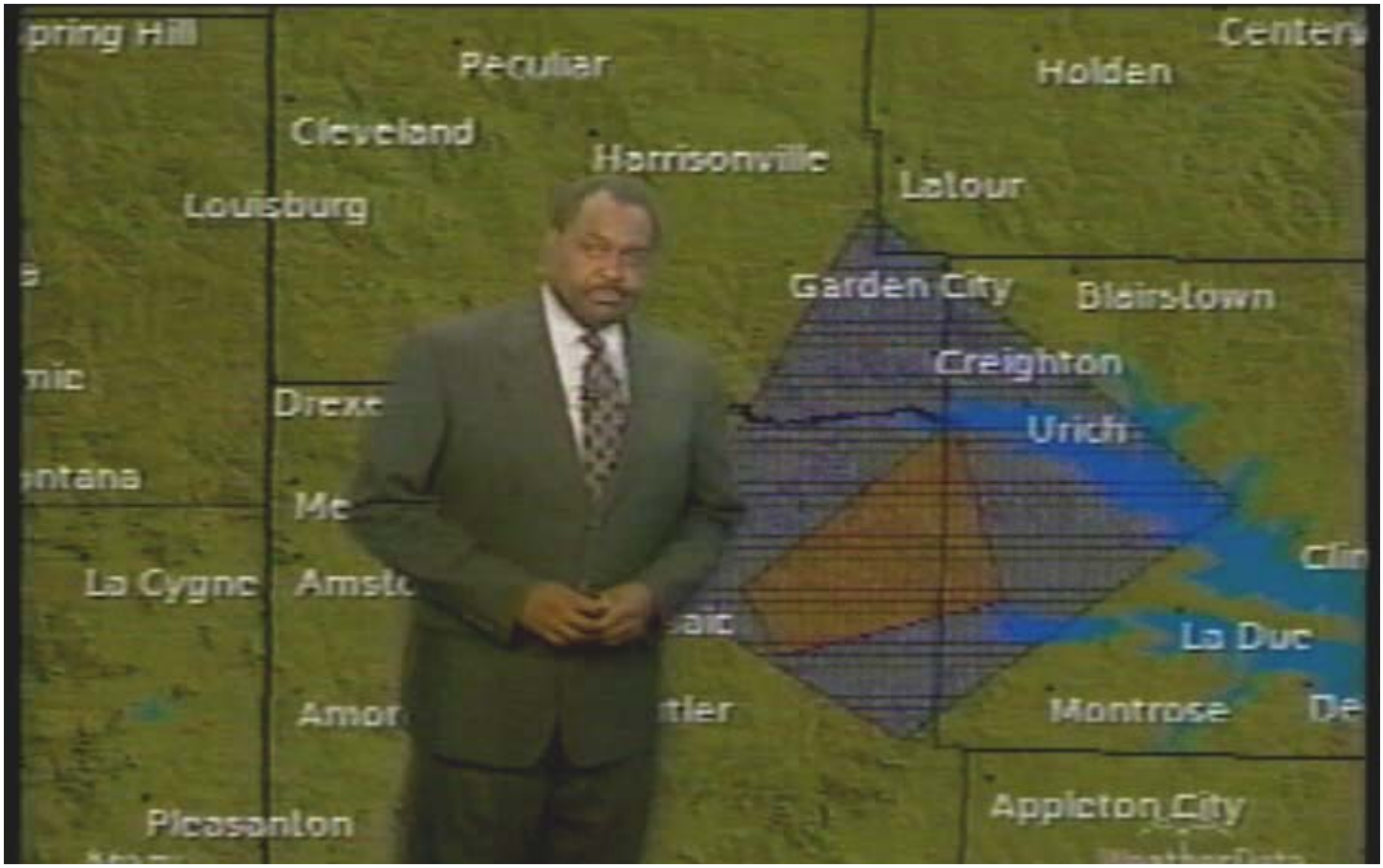

Figure 2. Example television news SB warning graphic.

There were a few negative comments regarding text warnings, particularly when read over local radio stations or NOAA Weather Radio (NWR).

Although customer outreach to educate our partners and customers was conducted nationally and locally, there was occasional confusion experienced by emergency managers (EMs) and the media when multiple SB warnings were in effect for the same county. Having a warning in effect for a county already, the EMs were not sure whether or not they needed to distribute the information in the second warning for the same county. To alleviate this confusion, the team suggests the outreach material distributed for this test be reviewed for enhancements and used to create a Warning Coordination Meteorologist (WCM) portfolio consisting of brochures, presentations and other materials for field offices to utilize in outreach. One such enhancement would be to provide both text and graphical examples of more complicated warning scenarios.

Another issue related to multiple SB warnings in effect for individual counties dealt with the follow-up statements such as Severe Weather Statements (SVS). Wording in follow-up statements was sometimes confusing as it was not always apparent to listeners, which previously issued warning was being referenced. WFO staff attempted to resolve this in real time, which impacted workload (as described in the next section). Multiple warnings for individual counties also caused occasional problems in the NOAA Weather All Hazards Radio broadcast. Changes in dissemination systems, as well as additional outreach and public education, will be needed to better communicate the warning threat area in text and audio. Recommended changes are discussed in Section 8.

5.2 Impact to WFO Operations and Workload

WFO feedback indicated 57% experienced "no change" in workload using the SB warning methodology, while 7% actually noted a "decrease". "Additional workload" was noted by 36% of respondents, and was due to

- Warning operations, mainly in a pulse storm environment
- More complicated NWR operations with legacy systems
- Software limitations
- Dual verification (county and polygon)

In a pulse storm environment, where numerous individual storms or clusters were monitored and managed (i.e., warned and tracked through their expiration or cancellation), forecasters noted some difficulty in keeping up with the number of storms. They also commented that they initially created warning polygons which were too small, resulting in more numerous warnings and further increasing workload. Drawing polygons to closely match county borders and stay within CWA boundaries, further complicated operations. Matching borders was important to ensure no warning area was inadvertently missed, and to ensure SB warnings did not overlap. Overlapping borders resulted in two warnings being in effect for the overlapped area. The AWIPS Local Warnings Overlay was used to manage polygons and it was found to be too slow, particularly in pulse environments.

Having multiple SB warnings in effect for individual counties added another complication, in that WarnGen software did not adequately accommodate this scenario, and forecasters had to take extra precautions to ensure statements followed the correct warning. This was due to WarnGen listing multiple SVSs to select, but not distinguishing one from another in some way. Working with multiple Flash Flood Warnings (FFWs) was even more difficult. Since FFWs did not contain Valid Time Event Coding (VTEC), WarnGen was unable to recognize multiple FFWs in one county as needing separate Flash Flood Statements (FFSs). Therefore, multiple FFSs were not created. This will not be a problem in the future, as hydrologic products will also have VTEC. Numerous other software issues were found and are detailed in Section 5.4.

Coordination and dissemination operations and software are tied to counties (or marine zones) and as such, are programmed to operate with only one type of warning in effect at one time. Having multiple warnings in effect for individual counties required additional work for the WFO Storm Coordinator, the Warning Disseminator, the NWR operator, SKYWARN Net Controllers, and others involved in warning operations. Additionally, with the current county and storm-based warning verification activities in place, WFO staff were more taxed, having to verify for both. Therefore, during workload intensive storm-based warning situations, such as in pulse storm environments, additional staff may need to be employed to more efficiently manage the warning polygons, NWR, and other aspects of warning operations.

5.3 Impact to Customer Operations

For those occasions when multiple warnings were issued for individual counties, customers noted an unwanted increase in EAS activation and a longer NWR cycle time. Regardless, customers preferred the more precise warnings (overall) and would like to see technological advances to mitigate the dissemination issues.

5.4 Software Limitations

Numerous software limitations decreased the efficiency of the SB warning methodology. As stated earlier, the AWIPS Local Warning Display was too slow to efficiently manage polygons, particularly in pulse storm environments. Several Warning Generation software (WarnGen) problems were also noted by forecasters. These included erroneous pathcasts, unintended exclusion of counties, follow-up SVSs that did not automatically match with initial warnings, GIS incompatibilities, and latitude/longitude data being incorrect with certain operations. This section describes the various software issues. Recommendations to resolve many of them are listed in
Section 8.

5.4.1 WarnGen Issues

Experienced radar operators commented that WarnGen pathcasts were often erroneous. This could have been due to several factors, including distance of a community from the centerline of the path, changes in the storm environment, inaccurate data in the Environmental Winds Table, or an inaccurate Storm Relative Motion. As stated in section 5.1, discussions with Emergency Managers have revealed that in general, they prefer a listing of communities within the polygon.

When polygons were drawn to cover a small fraction (e.g., < 20%) of a county/zone area, depending on its configuration, WarnGen did not always recognize that county/zone. This was particularly problematic with follow-up SVSs when the text did not include a county, even though a portion of it was within the polygon.

Follow-up Severe Weather Statements (SVSs) and Marine Weather Statements (MWS) did not always match up with original warnings when multiple warnings were issued for

a given county. This was due to the forecaster selecting the wrong SVS from a list of several SVSs. A better way to discern which SVS or MWS to select is needed. A related problem was that multiple FFWs in a county were not recognized by WarnGen since FFWs do not contain VTEC. Both issues may be resolved through use of the VTEC Event Tracking Number (ETN).

In WarnGen, "right-clicking" to remove a county from a warning polygon sometimes resulted in erroneous latitude/longitude definitions in the warning. Latitude/longitude information in warnings describes the original polygon, unless the "Redo box" function is run prior to product creation. If the "Redo box" function is not run, a substantial portion of a county within a warning polygon can be excluded from the associated text products, or needlessly included.

The river basin display in WarnGen could not incorporate enhanced customized displays from FFMP. Such displays would allow for more precise definition of the flash flood threat area.

Polygons were not automatically truncated at the CWA, land-coastal boundaries, or coastal/offshore boundaries which caused WFO coordination problems and/or inaccurately drawn polygons.

Several incompatibilities were found between GIS and WarnGen which resulted in inaccurate graphical displays. Incompatibilities included

- GIS-compliant polygon ring (vertex) order: clockwise
- Single-point polygons
- Longitude truncation (unique to last longitude point)

Additionally, there were times when the WarnGen polygon and web-based versions of the polygon were incongruent. Occasionally, portions of counties which appeared to be part of the polygon within WarnGen, were outside the polygon on the web-based displays. To resolve this probl em, the resolution of AWIPS shapefiles needs to be increased from the current 1:2,000,000 to 1:100,000. Another issue is that there was no method to view the polygon on the internet before issuing it. Therefore, the team suggests a quality control (QC) script be implemented that would allow a forecaster to review the polygon before issuing it, to ensure it is a valid polygon.

5.4.2 Local Storm Report issues

The Local Storm Reports (LSR) locations database is not identical to the StormDat locations database. From verification and archive perspectives, it is critical that the LSR and StormDat location databases be identical. Concerning verification, if the location databases differ between the two programs, even slightly, there is potential for inconsistencies and errors. In particular, this could occur in situations where the storm report is near the edge of the SB warning area. For example, LSR software may place the storm report just inside the SB warning area, leading the WFO to believe the warning is

verified. However, when final verification is accomplished (using StormDat and assuming differences in the locations databases), the same report may be plotted just *outside* the SB warning area, resulting in not only an unverified warning, but a missed event.

The capability to simultaneously display polygons and LSRs (in AWIPS) is needed. For real-time warning operations and preliminary verification purposes, the capability to simultaneously display SB warning areas and Local Storm Reports (LSRs) is essential. When combined with other available information, this will allow forecasters to make more informed warning decisions, particularly regarding placement and sizing of SB warning areas.

5.5 Dissemination Issues

5.5.1 Internet Services: RIDGE

Displaying the polygon information on the internet in the Radar Integrated Display with Geospatial Elements (RIDGE) was well received by customers and was implemented across the country during the SB warning test period. However, forecasters and customers noted the RIDGE information needed to be updated more frequently. With RIDGE data linked to radar updates, web pages were refreshed on radar cycles approximately once every five minutes, which delayed posting SB warnings to web pages up to five minutes. For this reason, the team suggests the RIDGE information be updated every minute.

5.5.2 NWR and GIS-enabled dissemination systems

As stated in section 5.3, an unintended consequence storm-based warnings on customers was the unwanted increase in EAS activations and the occasional confusion caused by having more than one warning in effect for a particular county. Because NWR sends warning tone alerts only through county FIPS codes and audio, it will be difficult to utilize NWR in its current form with SB warnings. To eliminate confusion and as a first step, the team suggests requiring offices to improve scripting of the warning area to better warn the public that relies on text or audio-disseminated warnings. This could be achieved by focusing the warning text on cities, communities, and well-known landmarks in the polygon area.

The team strongly believes that improvements to the NWR network are overdue, given the current state of technology. For instance, converting NWR broadcasts to an HD Radio broadcast could allow for radios to be alerted by polygon area instead of by county. In addition, such a broadcast could send graphical information to specially equipped receivers. Clearly, this type of technology opens an incredible opportunity to improve warning dissemination. For this reason, our team strongly recommends to be linked with the NWR Improvement Team to explore enhancements to the system.

Many cities and counties now have GIS-enabled equipment to improve communications between first responders and dispatchers. This GIS equipment displays mapping information to first responders, and provides the location and movement of the first responders to the dispatch units. By incorporating SB warnings into the mapping system, both first responders and dispatchers will be able to better pinpoint the locations of severe weather. In addition, they will more efficiently move resources out of danger and first responders into areas that need assistance. To improve warning services, the NWS should hasten its efforts to better utilize GIS in dissemination systems.

5.6 Storm-based Polygon Methodology Training Issues

Although training was conducted prior to the SB warning test, forecasters noted they initially drew SB warnings too small. For example, in pulse storm environments where numerous cells developed in a short time frame, initial SB warnings were sometimes drawn for individual storms. This resulted in an unnecessary increase in WFO staff workload as described in section 5.2. Recommendations are noted in section 8.

5.7 Impact to existing verification metrics

For several years, forecasters have used WarnGen to outline a threat area (polygon) and issue a warning for that area. In the county/zone-based verification system, each county or marine zone within that polygon would count as an individual "warning." In the SB system, the entire polygon represents a single warning, regardless of the number of counties within the polygon. While the SB polygon method is a more accurate depiction of the threat area, and has been shown to significantly decrease the falsely alarmed area, the impact to traditional verification metrics actually indicates a decrease in accuracy. This is due to the fact that in county-based verification, a storm located outside of the warning polygon would still be credited as a "hit" if it occurred in a county that was partly inside the polygon. In SB verification however, this would be recorded as a "missed event".

The Tornado Warning Probability of Detection (POD), a current GPRA measure, was calculated for the test offices for 2005 using both the county method and the storm-based method. The average POD for the county method was 76 and the average POD for the storm-based method was 57. A statistical test of significance was computed on the two datasets and they were found to be statistically different; the POD dropped significantly using the SB verification methodology. The drop in POD concerned team members who felt that true SB warning operations would not be realized if forecasters and managers were concerned about not meeting GPRA goals. For this reason, the team felt SB warnings could not be fully implemented without either a change in the GPRA measures or implementation of a new GPRA goal. A GPRA Goals subteam was formed to review the current GPRA goals and suggest changes if necessary. The GPRA goals team did suggest changes that would more accurately assess the service provided by SB warning operations. These changes were accepted by the NWS director and incorporated into the program planning procedures for changes to take effect in FY08.

5.8 Requirement for newly-developed SB polygon verification metrics

As stated in 5.7, since SB and county/zone-based metrics are statistically different, either a new baseline for existing GPRA metrics is needed or different types of GPRA metrics should be developed. As shown in Figure 3, an improvement in service to the public observed in the evaluation was the decrease in the area falsely warned in the county-based warning system. Therefore, the team recommends developing a metric (GPRA or programmatic) around this improvement in service and tracked as long as the county-based verification system remains in place. One possibility, developed by team member Ken Waters, was the "County Area Ration" (CAR). The CAR will show improvements in warning service provided, and may also reflect the forecaster learning curve as the slope of the improvement curve decreases.

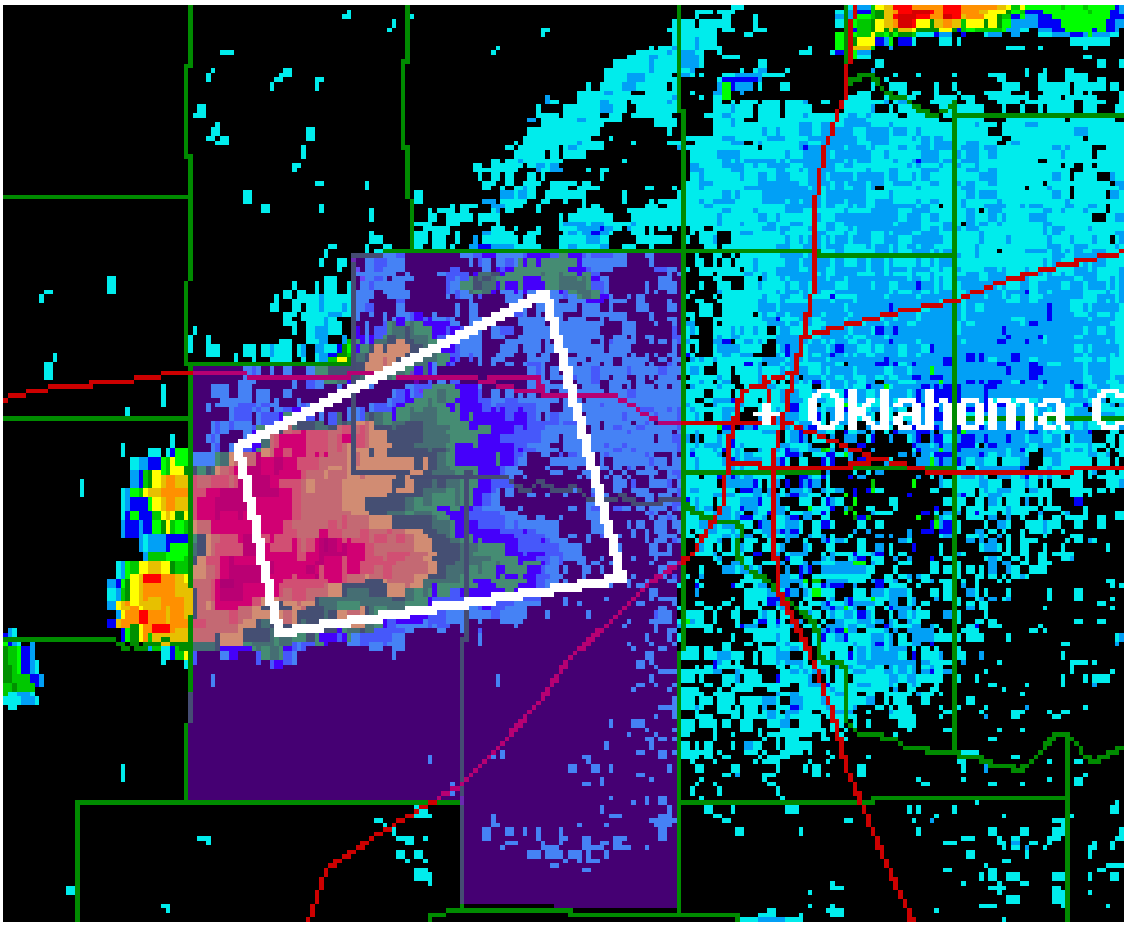

Figure 3. SB Warning (white outline) with warned counties (highlighted)

The **County Area Ratio**, or **CAR**, is defined as the ratio of the area of a SB warning to the area of the warned counties:

$$CAR = 1 - \frac{PA}{\sum CA}$$

Where PA = Area of the SB warning in square miles
CA = Area of the county/counties in square miles

This ratio measures the improvement of reducing the size of warnings by using polygons. The county area consists of the sum of all counties identified by the inclusion of the Universal Geographic Code (UGC) in the text of the warning. It should be noted that it is possible for a SB warning to cover a small portion of a county but still not be "officially warned" by virtue of the UGC in the warning. Also of note is that a few erroneous warnings were issued where the polygon was much larger than the warned county area. This was due to a variety of reasons including instances where the polygon was extended well beyond the issuing forecast office's area either into a neighboring office or possibly offshore. Further details are provided in Appendix F.

6. WFO Survey Results

When forecasters were asked if they encountered any problems with the SB warning method, 53% responded "no". Polygon mechanics accounted for 13% of the problems observed, with WarnGen close behind at 12%. Communications issues were minimal, only accounting for 2% of the problems reported. Problems not fitting into one of the above categories dealt with the following: Follow-ups using Severe Weather Statements (SVS), confusion explaining products to receiving parties, human errors, and other software malfunctions. More details, including specific quotes from WFO forecasters, can be found in Appendix B.

7. Pros and Cons of SB Polygon Warning Methodology

Pros	Cons
Higher quality public warnings through more precise depiction of severe weather threat area(s)	Workload concerns for NWS staff during warning operations (possible increase)
Improvements to warning dissemination (e.g. enabling graphic display of SB warning areas)	Increased Emergency Alert System (EAS) activation, due to anticipated increase in number of warnings issued
Economic savings realized as a result of reduced-size warning areas	Potential confusion on the part of some warning recipients, due to limitations of legacy systems and products
Increased NWS credibility (leading to faster response by warning recipients, ultimately saving lives)	Changes to verification metrics will be needed
Increased public positive response (as observed from media & private sector	

feedback during the SB Warning Evaluation)	
SB Warnings are in line with NOAA's Strategic Plan goals	

8. Recommendations

1. The NWS should move toward implementing the SB warning methodology nationwide.

It is the team's conclusion that although several issues were noted during the SB warning test, the positive benefits of the NWS issuing warnings that depict a more accurate threat area outweigh the short-term problems that need to be addressed. By implementing the SB warning methodology, our customers will be able to take great advantage of the polygons. The media will be able to display the polygons showing the public at large where the area of maximum threat is and better depict who or what is at greatest risk. Emergency managers will be able to make better decisions on what resources may be required and where. Law Enforcement and Fire Departments can know which areas need to be put on alert. Schools can see whether they may or may not need to activate their tornado procedures. Other government agencies and customers, such as the FAA and airlines, will be able to make better risk assessments. For example, airport operators will be able to better ascertain whether or not they need to temporarily shut down an airport; utility companies will be able to initiate backup procedures.

2. Incorporate SB Warnings in enhanced NWR plan

Development of dissemination tools for our partners will be a vital step to making the SB warning approach a success. For example, the NWS will need to work with partners to enhance the NOAA Weather Radio – All Hazards (NWR) so that information is disseminated based on the polygon outline instead of the county outline.

3. Address the following critical WarnGen software issues

    a. Ensure WarnGen displays all active SB warnings when it is engaged to create a new warning. Updates should be immediate.

    b. Ensure polygons are automatically truncated at the CWA, land/coastal boundaries and coastal/offshore boundaries.

    c. Provide the capability for a WFO to send the portion of the SB warning that extends beyond the CWA borders to the other responsible WFO(s) as a collaboration file.

    d. Provide the capability to create a separate Special Marine Warning polygon and a separate land warning polygon (e.g., SVR) when the forecaster draws the polygon across a coastline.

e. Set WarnGen to default to using the Areal Outline, which will list communities within the polygon as opposed to the Pathcast.

f. Provide the capability to reduce the size of the warning polygon. The area removed from the warning polygon shall be described in the cancellation section of the Severe Weather Statement. The remaining original area of the warning polygon shall be contained in the continuation section of the Severe Weather Statement.

g. If there are no communities and there are Interstate roadways within the polygon then WarnGen shall include the Interstate number with the milepost numbers in the text warning product (e.g., INCLUDING/ BORDERING INTERSTATE 90 BETWEEN MILE POST 98 AND 105).

h. If there are no communities, no Interstate roadways, and there are small streams within the polygon, then WarnGen shall provide the WFO the option for WarnGen to include the names of the small streams in the text warning product using the following statement format “FOR RURAL AREAS OF (compass heading (e.g., NORTHEAST) county name, and the word “COUNTY” (e.g., FOR RURAL AREAS OF NORTHEAST HIGH COUNTY)) INCLUDING X1, X2,...Xn” (where Xn are small tributaries (i.e., small streams or creeks)).

i. If there are no communities and there are Interstate roadways and small streams within the polygon, then the capability shall be provided for WarnGen to include the Interstate number with the milepost numbers and provide the WFO the option for WarnGen to include the names of the small streams in the text warning product (e.g., INCLUDING/ BORDERING INTERSTATE 90 BETWEEN MILE POST 98 AND 105 AND X1, X2, Xn. (where Xn are small tributaries (i.e., small streams or creeks)).

j. If there are no communities, no Interstate roadways, and no streams within the polygon, then the capability shall be provided for WarnGen to use the following statement format in the text warning product “FOR RURAL AREAS OF (compass heading (e.g., NORTHEAST) county name, and the word “COUNTY” (e.g., FOR RURAL AREAS OF NORTHEAST HIGH COUNTY)).

k. For flood products (FFW, FFS, FLW, FLS) the capability shall be provided for WarnGen to include the small streams in the text warning product (e.g., AFFECTING X1, X2, Xn. (where Xn are small tributaries (i.e., small streams or creeks)).

l. Ensure WarnGen pathcasts, if used, more accurately describe the path of the storm.

m. Ensure that portions of counties or marine zones are not excluded in the warning if within the polygon.

n. Ensure the "right click" to remove a county also updates the latitude-longitude definition of the polygon.

o. Provide the capability for the FFMP basin map background to be used as the **active** map background for hydrologic warning polygons.

p. Provide the capability to overlay the county map background together with the FFMP basin map background.

q. Enhance WarnGen software to incorporate basin naming hierarchy (as in FFMP) including the names of the streams.

r. Provide the capability to remove river basins from a warning polygon, with the right-click of the cursor, when the cursor is placed over the basin(s) to be removed.

s. Provide the capability for the user to select, from a pick list, archived polygon warnings to be displayed.

t. Ensure WarnGen is GIS-compliant w.r.t. the order that polygon vertices are entered (called ring (vertex) order). Vertices should be entered in clockwise order.

u. Ensure WarnGen does not allow single-point polygons.

v. Ensure longitude truncation is unique to the last longitude point.

w. Provide the capability for combining multiple warnings into one follow-up statement.

x. Ensure the storm's motion information is automatically utilized by WarnGen

y. Provide the capability to automatically include the latitude and longitude of the current location of the storm (i.e., initial storm location) in the warning and statement text products (e.g., INITIAL STORM LOCATION 3568 9105).

z. Provide the capability to automatically include the storm's motion information in the warning and statement text products (e.g., 243/35 in degrees and mph).

aa. Provide the capability for the demographic information for the polygon area to be displayable for forecasters and external users (e.g., using Census data).

bb. Provide the capability for a hazardous weather event impacting multiple, non-contiguous areas, within the CWA, to be issued as one warning polygon.

cc. Provide the capability for warning information to be composed in the CAP format. Ref: http://www.oasis-open.org/committees/download.php/14759/emergency-CAPv1.1.pdf

dd. Provide the capability for warning information to be composed in the RSS format. Ref: http://blogs.law.harvard.edu/tech/rss

4. Increase AWIPS shapefile resolution from 1:2,000,000 to 1:100,000 to ensure better county inclusion.

5. Implement a visual quality control script to review the polygon before issuing it, to ensure it is a valid polygon.

6. Ensure the LSR and StormDat location databases are identical.

7. Develop the capability to simultaneously display polygons and LSRs (in AWIPS).

8. Provide the capability for the forecaster to cursor sample the entire LSR (i.e., upon passing the cursor over the displayed LSR value, the entire LSR is displayed).

9. The capability shall be provided to restrict the alert of the SB warning via NOAA Weather Radio (NWR) to just the area encompassed by the warning.

10. Provide the capability to produce legacy verification scores (e.g., POD, LT) for SB warnings.

11. Provide the capability to produce spatial verification scores (e.g., False Alarm Reduction Area) using GIS technology.

12. Further WFO staff training is necessary prior to SB warning implementation. The training must be interactive, utilizing Weather Event Simulator scenarios covering a variety of situations, including:

a. Isolated supercells
b. Squall lines
c. Pulse single-cell storms
d. Flash Floods
e. Marine, lake or coastal waters thunderstorm or squall line scenarios

The training should include the following:

a. Threat area recognition
b. Strategies for proper SB warning design in various convective situations
c. Strategies for SVSs in various situations (e.g., multiple warning types)
d. Strategies (or Procedures) for dealing with storms crossing CWA borders
e. Strategies for allowing the issuance of adjacent polygons.
f. Polygon/County/Zone warning verification procedures
g. Procedures for polygon aerial description (in terms of towns within the threat area, portions of large metro areas in places (e.g., Chicago, New York)

13. Add the SB Warning concept to the WCM Course curriculum.

    SB warning interpretation will be an integral part of WCM training of NWS product users. As such, it should be added to the curriculum of the WCM course.

14. Enhance the outreach material used for the SB warning test. Provide both text and graphical examples of scenarios that are more complicated due to current county-based communications.

15. Until software issues can be resolved, additional staff should be deployed during workload intensive SB warning situations to better manage the polygons, CRS and other warning operations.

16. Prior to the convective season or SB warning implementation, WFO staff should investigate ways to streamline CRS dissemination operations.

17. The NWS should hasten its efforts to better utilize GIS, including collaboration with the private sector to modernize dissemination systems.

18. Update NWS policy regarding FFW/FFSs to incorporate VTEC.

19. Task OS52 to develop appropriate verification measures.

20. Re-charter SB Warning Team to develop implementation plan and timeline

Appendix A – Statement of Need

Statement of Need **Revision**

1.1.1 Title: Warning by Polygon

1.1.2 Contacts: Mark Tew, W/OS22, 301-713-1867 x 103
Jannie Ferrell, W/OS22, 301-713-1867 x 135
Mike Looney (CRH)
Noreen Schwein (CRH)
Brent MacAloney (NWSH)
Jeff Lorens (WRH)
Joe Schaefer (SPC)
Pete Wolf (WFO Jacksonville, FL)
Steve Naglic (WFO Columbia, SC)
Mike Coyne (WFO Huntsville, AL)
Ken Waters (PRH)

1.1.2.1 Submitting Authority: Leroy Spayd (W/OS2)

1.1.3 Description:

The NWS mission is to provide weather forecast and warnings for the protection of life and property and to provide weather information for the Nation's economic well-being. There is a continuing need to improve the specificity and accuracy of warnings for tornadoes, severe thunderstorms and flash floods. NWS currently issues and disseminates warnings for these hazards using geopolitical (county/zone) boundaries. Verification and dissemination methods are currently tied to county-based warnings.

Geographically based SB warnings are essential to effectively warn for severe weather and flash floods. SB warnings show the specific meteorological threat area and are not restricted to geopolitical (e.g., county, marine zone) boundaries. By focusing on the true threat area, polygons will help improve NWS warning accuracy and quality. SB warnings will promote improved graphical warning displays, and in partnership with the private sector, support a wider warning distribution through cell phone alerts, pagers, web-enabled Personal Data Assistants (PDA), etc.

SB warnings also support the NOAA Strategic Plan goal to "employ scientific and emerging technological capabilities to advance decision-support services and educate stakeholders."

1.1.4 Justification:

1.1.4.1 Origination, Documentation, and Drivers:

Mandates for warning and forecast services include:

- U.S. Code Title 15 Chapter 9 for warning and forecast services – Directs National Weather Service to forecast the weather, issue storm warnings, etc.
- FEMA's Federal Response Plan – Tasks Department of Commerce to acquire and disseminate weather data, forecasts, and emergency information.
- BLM Interagency Agreement – Identifies NWS as the official source of meteorological information.

1.1.4.2 Linkages:

Providing better short-duration warning service supports the Weather and Water goal in NOAA's Strategic Plan including the goal's outcomes:

- Reduced loss of life, injury, and damage to the economy.
- Better, quicker, and more trusted weather and water information to support informed decisions.
- Increased satisfaction with quality of weather and water information and services.
- Employ scientific and emerging technological capabilities to advance decision-support services and educate stakeholders.

1.1.5 Existing capabilities/capacities and limitations related to the need:

The NWS issues four different types of short-duration warnings: Tornado, Severe Thunderstorm, Flash Flood, and Special Marine Warnings. These warnings indicate severe weather is occurring or expected within the next few hours after issue time for locations in the warned area. Warnings are issued for an entire county, marine zone or cluster of counties/zones. Therefore, even if only a small portion of the county is affected, essentially the entire county receives the warning.

Verification is important for the agency as it is used as a performance measure. Verification of warnings is also county-based or marine zone-based. If an event such as a tornado or other severe weather occurs within the valid warning time within the warned county, then it is considered a verified warning. Variability of county size limits the value of verification measures to gage the quality of warning services.

1.1.6 Benefits and Performance Impact:

1.1.6.1 Performance Measure Impacts:

Warnings impact the following five GPRA Goals:

- Tornado Warning lead time
- Tornado Warning accuracy
- Tornado Warning False Alarm Rate
- Flash Flood Warning Lead Time

- Flash Flood Warning Accuracy

Funding of SB Warnings will significantly reduce Warning False Alarm Area (by at least 50 percent nationally).

It is not known at this time if there will be a significant impact on current GPRA measures. However, changing verification from county-based to polygon-based methods will provide a more accurate measure of warning services.

1.1.6.2 Socio-economic Impacts:

SB warnings will:

- Provide a better quality warning to the public by reducing the area and number of people unnecessarily warned.
- More accurately depict the severe weather threat area.
- Promote warning dissemination improvements.
- Provide economic savings as a result of reduced warning areas.
- Improve public response as only areas of imminent threat are warned.

More accurate warnings will increase credibility, leading to faster response, and ultimately saving lives.

1.1.7 Key Customers and Stakeholders:

1.1.7.1 Customers:

Improved short-duration warning service will benefit:

- State and local emergency managers and local officials charged with public preparedness and response decisions for extreme events, hazardous spills, and homeland security issues.
- Private sector providers.
- Weather sensitive businesses (e.g., transportation, energy, agriculture)
- Broadcasters and other media.
- General public
- Mariners

1.1.7.2 Stakeholders:

Stakeholders include:

- Federal, state, and local government agencies
- Academia
- Private/Public interests
- CIO – website support
- SEC – AWIPS support

1.1.8 Supporting Information:

- Proposal/Team Charter to the Operations Sub-Committee of the Corporate Board (June 2004)
- SB Polygon Warning Brochure (October 2004)
- Manuscript on SB Polygon Weather Warnings – Waters, et al., 2005 AMS San Diego, CA.(January 2005)
- Interim report to the Operations Sub-Committee of the Corporate Board (August 2005)
- Final report to the Operations Sub-Committee of the Corporate Board (TBD)

Appendix B – SB Warning Feedback WFO Survey Summary

SURVEY OVERVIEW

During the 2005 SB warning test, the OCWWS Performance Branch (OS52) used a web form to collect feedback from forecasters at WFOs involved in the test. Various questions were asked of the forecaster regarding such topics as their shift time, type of weather occurring, thoughts on the SB warning process, problems encountered, and any success stories. Participation in answering the survey was not mandatory, but encouraged.

In total there were 105 surveys submitted during the SB warning test. That is an average of 4.5 surveys returned per participating office.

FORECASTER BACKGROUND

An even number of surveys were submitted by forecasters working in the 6am-6pm and 6pm-midnight time periods, which combined accounted for 91% of the feedback. Only 9% of those surveys returned fell into the midnight-6am time period.

The majority of feedback received occurred in conjunction with SB warnings issued for linear and pulse severe thunderstorms. These events accounted for 64% of all events. Tornado events accounted for 19% of the warnings, whereas special marine and flash flood events accounted for less than 1% of all events generating feedback. 16% of the feedback was associated with events that did not fit solely into any of the above categories.

70% of those forecasters who responded were working the radar during the event resulting in the issuance of a SB warning. Severe weather coordinators and those in charge of communications accounted respectively for 23% and 4% of those surveys submitted. Feedback from others included a hydrologist, aviation forecaster, and the person in charge of the short term forecast desk.

SURVEY RESULTS

When the forecaster was asked if they encountered any problems with the SB warning method, 53% responded “no”. Polygon mechanics accounted for 13% of the problems, with WarnGen close behind at 12%. Communications issues were minimal, only accounting for 2% of the problems reported. Problems not fitting into one of the above categories had to deal with the following: Follow-ups using Severe Weather Statements (SVS), confusion explaining products to receiving parties, human errors, and other software malfunctions.

Below are some specific quotes received on what worked well during the SB warning process:

> *“It was very easy to warn by storm rather than by county. There were several instances where it was great to ignore the county boundaries -- made things much easier!”*

"I basically made small parallelograms, which made it easy to continue warnings down stream."

"The follow-up statements worked quite well in trimming the polygons from the initial position forward...which reduces the event for the people initially at risk."

"The polygon warning approached worked well as a storm moved into the triple point of three counties. I did not have to worry about which county to issue for; I could simply issue the warning for the area that looked to be the most threatened by the storm."

"There was a greater likelihood that your initial warning polygon could go for close to its duration before another warning for the same cell needed to be issued. In the county-based philosophy there seems to be such a concern with false alarms that we don't warm counties too far upstream to limit this possibility. The latter thinking mostly likely necessitates having to issue more overall warnings."

The survey results showed mixed results when it came to workload impact. Almost two-thirds of those surveyed (64%) reported no impact or a decreased workload when using the SB warning methodology. On the other hand, 36% of those surveyed felt an increase in workload.

Feedback from customers regarding the SB warning method was minimal with 85% of responders reporting no feedback was received. The media did account for 9% of the feedback reported, while emergency managers accounted for just 4%.

Below are some specific quotes we received regarding customer feedback:

"Feed back has been varied. Most of the media like the polygon approach, especially if they have the capability of displaying it. Only a few find it to be confusing. With at times more warnings coming out, I have heard of one complaint from a weather radio listener said that he turned off his radio due to the number of warnings."

"A couple of EMA's and 24-hr warning point dispatchers were confused as to whether or not they were still under a warning when one warning for the county was cancelled/expired and another warning remained in effect."

"They think it is a good idea, but their alarms will still sound for the entire county even if only a portion of a county is affected."

When responding to a question about warnings issued near the WFO's county warning area (CWA) border and the coordination effort with that neighboring WFO, 88% of the feedback stated coordination was no problem. 8% said the coordination effort took more time and 4% said it was more difficult.

Below are some specific quotes we received regarding coordination with neighboring WFOs:

"Didn't even think to coordinate in the heat of battle but did ascertain that polygons did not cross into adjacent CWA. This required a little more time but was not a hindrance to warning issuance."

"Other CWA's were issuing warnings in our area. This would sometimes lead to a warning overlap."

"The pace was extremely hectic and fast and there was little or no time to coordinate in this environment."

"In an attempt to put a warning out quickly, concern about the CWA boundary required with the polygon caused additional composition time."

Appendix C. SB Polygon Warning Evaluation Regional Feedback Summaries

Besides the WFO survey feedback (Appendix B), the regional representatives on the team asked the SB Warning Test WFOs in their regions, for general comments regarding the test; what worked well and what did not. Summaries of the comments follow:

1. Central Region
2. Southern Region
3. Eastern Region
4. Western Region

1. Central Region

- **Staff Comments and Issues**
  - Methodology to issue SB warnings not really a change in operations.
  - Overall, forecasters were in favor of warning by polygons but concerned about county vs. polygon verification.
  - Staff preferred warning by polygon and not having to worry about whether or not to include a small portion of a county.
  - Some increase in workload occurred for convective/pulse storms where management of numerous polygons was difficult. This was often due to the initial polygon being drawn too precisely for individual storms.
  - There was concern that some customers who only hear the warning (e.g., no computer or television available) would be confused as to where the threat area actually is.
- **User response/comments**
  - EMs were able to make better decisions, however, there was some concern for over-warning.
  - There was a general acceptance from television media although not all were able to create related graphics. Some are encouraging vendors to enhance their technology.
  - Radio stations were not as accepting due to the increased number of EAS activations in a county.
  - Storm Call, a national alerting company, used the polygons to call subscribers within the polygon vs. the entire county. Ref. http://www.stormcall.us/ and http://www.wibc.com/localweather/stormcall.aspx
- **NWR dissemination issues**
  - To the best of our knowledge, most vendors are not prepared to display/disseminate SB warnings.
  - Web displays often had significant time delays
  - Text-based products need improvement for better communicating the threat area.
  - WFO Kansas City (Pleasant Hill) suggested we consider adding a digital burst of LAT/LON coordinates to the warning tone sequence for NWR. That way, NWR receivers with built-in GPS technology could be set to tone without having to program counties (i.e., a ‘set it and forget it’ capability that would even work when traveling). Mike Hudson (WCM) has been talking to a technician at

Midland radio about the cost feasibility of that approach, and he believes it could be done.

- **Verification comments/impacts**
  - WFO staff workload is increased when performing both county and SB verification.
  - The area warned decreased which decreased the number of people falsely warned.
  - One WFO found their POD decreased with SB verification. Analysis showed it was due to polygons being too small and/or inaccurate LSR locations.
- **Recommendations**
  - Work with private sector to enhance NWRs such as what was suggested by WFO Kansas City (Pleasant Hill).
  - Provide more training to improve forecasting for the actual threat area.
  - Develop a better method to display warnings in AWIPS (or WarnGen) to ease workload in creating follow-up statements and warnings.
  - Develop a method to display FFMP customized basins in WarnGen.
  - NWS should keep up with increasing technological needs of users
  - NWS should modify verification techniques for SB warnings.

2. Southern Region

- **WFO Jackson:**
  - Overall, I think the polygon warnings are a good concept, and is something we should strongly look at as an agency. I don't think it had any real negative impacts on operations, and from talking to customers and partners I can certainly see its potential benefits. Having said that, I do think that some caution is warranted in certain situations.
  - For example, during Hurricane Rita we put out about 350 county TOR warnings to cover storms which produced over 50 confirmed tornadoes. However, these storms were much smaller than the typical supercell, and lined up in such a way that there were numerous times that counties were under multiple warnings. For example, at one point, Warren County, MS had three tornado warnings in effect for it at one time, and 6 warnings issued in a 90 minute period. I think this does have the potential to cause confusion to EMs and the media, and we had some feedback indicating this. To me, the best way to handle this is to let forecasters know during training for the polygon concept that there will be certain situations where the forecaster will be better off from a service and science perspective going back to the more "traditional" mindset and just covering an entire county for multiple storms, rather than trying to nitpick each storm when there are several severe/tornadic cells affecting the same county at the same time. We ran into similar issues with the April 6th tornado outbreak.
  - Obviously, in the short term all of this has an impact on our county-based FAR, and I hope this is being stressed to NWSH and those evaluating our GPRA goals (Tom, this may be relevant to y'all). For example, we've preliminarily calculated our polygon based FAR for the Rita event at around .75, which I think is fairly reasonable given the challenges of a tropical cyclone environment. However, our

county based FAR is .86. I am guesstimating that we put out about 45 more county warnings using the polygon system than we would have if we were focusing on counties, and this would have resulted in a reduction of our FAR by about 3 or 4 percentage points.
Hope this helps - I will send anything else we come up with.

- **WFO Midland:**
  - Overall, the Midland office was pleased with the Polygon Warning effort. In fact, our office participated in the polygon warning approach long before the NWS had any plans to do so in such a coordinated effort. With some of our counties being quite large, it was only necessary that we highlight only the portion of the county that we deem threatened by severe weather.
  - We would like to see this policy continue for all offices and for the foreseeable future. We feel that it is very important that the polygon initiative be kept alive. We saw only positive things come from it.
  - One thing to note however, I have found that many of our forecasters had a hard time extending warnings beyond multiple counties at a time, unless absolutely necessary, because they were afraid of the verification problem. If we continue with this effort, we must be sure to update the current system so that we are verifying by polygon and not by county. Doing so alleviates some of the pressures of the geopolitical boundary game we face.

- **WFO Little Rock:**
  - Regarding your request for information about the polygon experiment at WFO Little Rock, the old saying "no news is good news" definitely applies.
  - The forecasters very much preferred doing the warnings using the polygons rather than the old county-based way. In fact, I had even written Mike Looney asking if the experiment could be continued so that we could keep doing the “Warnings by Polygon”. There did not seem to be much effect on workload.
  - The only problem that I know of dealt with NOAA Weather Radio. When a second warning of the same kind was issued for a county, the second warning kicked the first one off NWR. Obviously, this is a serious concern that will need to be corrected.
  - In summation, the forecasters are more than eager for warning by polygon to become the permanent way of issuing warnings in NWS.

- **WFO San Angelo:**
  - WFO San Angelo likes the polygon warnings for the following reasons:
    - Polygon warnings provide more specific information to our customers.
    - Warned area with polygons is significantly lower than with county-based warnings.
    - Polygon warnings added only a small amount of workload during warning phase of operations.
    - Polygon warnings significantly reduced the workload during verification phase.
  - Based on our contact with the media:

        - The TV station which could display the polygons on air...loved them.
        - The TV stations which could not display them on air were indifferent to them.
    - Emergency managers liked them because they could better see the threatened area.
    - Recommendations:
        - Proceed with implementing polygon warnings nation-wide.
        - Fix the problems which delayed the polygon overlays on the RIDGE radar site.
          Implement the sectorized warnings on All-Hazards Radio.

3. Eastern Region

- From a staff perspective, the uniform comment across the board was the ability to strategically place the convective warnings, in geographic specific areas, and not desensitize the pubic in areas which had little or no threat
- .It was difficult to follow one warning with another and line up the boxes so that there were neither overlaps nor gaps. The Local Warnings plot often lagged being displayed before a new warning was being issued. It would be nice to have some automation so that adjacent warnings in effect at the same time had no overlap.
- Forecasters suggested that WarnGen have the capability of showing active convectively drawn polygons (perhaps in different colors) when you are in the WarnGen Polygon Drawing Mode for a new warning or follow-up statement.
- The future verification logistics, of polygon specific warnings, is still somewhat fuzzy. Develop software that takes the LSR's and plots them over the polygons.
- Offices who reside in a pulse environment area saw a significant increase in workload issues from radar ops, to documentation, to dissemination, to verification.
- Using AERIAL descriptions and NOT PATHCAST always worked best. Storm track algorithms were often not on target in terms of both timing and location.
- Quick samplings from our media partners reveal they preferred the SB Polygon Methodology in "tightening" the warning area, to reduce aerial false alarm.
- However, there was concern across the board that the private sector, from the broadcast media to NWR vendors, will not have the software (TV Mets) or products (graphical display NWR's) ready to support the SB program next year.
- In the end, all offices support moving ahead with SB warnings!

4. Western Region

- Overall – polygons are a better approach/methodology than county-based (short-fused) warnings. WR's "Polygon Evaluation WFOs" recommendations were strongly in favor of proceeding with the SB polygon methodology.
- In WR, this approach has been generally followed for some time now, and with some exceptions, this evaluation did not require forecasters to employ a "new or different" methodology – they had been doing this for some time now. The very large size of many counties in WR makes the SB polygon method a sensible approach. In most cases, there is great benefit gained by the reduced warning area (hence reduced False Alarm Area).

For the most part, there was little problem indicated with a "county-based" mind-set. The vast majority of the SB warnings were issued based on the threat.

- There were occasional problems identified with methods for defining initial polygons, particularly regarding scattered convection situations (decision to draw few large polygons vs. a larger number of small polygons). Although this was a frequent remark, many comments indicated this will likely be resolved with additional experience.
- In some cases, e.g. where convection was widespread, with multiple polygons in a single county, some confusion was reported, particularly with regard to communicating warning location and status. Dispatchers in some large rural counties at times became confused.
- "Feedback" (forecaster) comments mostly indicated "no change in workload". Few comments were received (11), but the quality of feedback was high – in many cases the feedback was very detailed and specific. Of the responses, only one indicated workload had increased. The others indicated "no change" or "decrease." Workload increases were mainly indicated with respect to scattered convection situations involving several SB warnings active at once. In addition to factors already noted, keeping NWR current with multiple warnings and statements became difficult at times.
- **WFO Feedback (in addition to information previously provided, WR WFOs offered the following specific feedback):**
    - **Glasgow:** WFO Glasgow had an extremely active severe weather season, particularly in June. Again, dealing with scattered convection was at times difficult, in terms of how to draw the polygons (i.e. many small vs. few large, polygon shape, etc.) and also dealing with occasional confusion associated with multiple warnings in a single county. Also, how to handle overlapping polygons or replacing smaller polygons with large ones became an issue, e.g. storms moving toward each other or coalescing into a line. Overall, though, SB polygon methodology is favored. Other issues:
        - A polygon "cut-off" feature is needed for situations where a polygon is extended (inadvertently or otherwise) across CWA boundaries. Although WarnGen does not generate text for the portion extending into adjoining CWAs, the full polygon can be seen in AWIPS (local warnings) and also via the lat-long coordinates in the text warning.
        - Re: Multiple warnings for single counties – the MRD number (in CRS) needs to be tied to the VTEC event number.
        - Verification was easier, particularly for polygons extending across multiple counties. Only one event was needed to verify the polygon – no need to verify in each county.
    - **Pendleton:** Not much opportunity to evaluate, but:
        - SB Polygon approach overall was better because it narrows the area of focus (w/respect to large counties).
        - There were multiple occasions when a storm developed just outside the polygon and it was not feasible to draw another one due to space/time constraints. This will likely be overcome with increased experience.
    - **Pocatello:** For the most part, felt the polygon approach was better, particularly with respect to larger counties.

- **Tucson:** There was little that differed from procedures in previous monsoon seasons since "polygon-like" warning methods have been followed for quite a while. Overall, SB warnings and verification are a good thing for all concerned.
    - The only significant problem involved follow-up statements. Procedures differed for SVRs and FFWs, since SVSs had VTEC and FFSs did not. WarnGen was unable to recognize two FFWs in one county as needed separate FFSs. This is not anticipated to be a problem in the future, as hydro products will also have VTEC.
- **Salt Lake City:** Have been using the polygon approach for quite a while now. Again, with very large counties, having multiple warnings in a single county is not uncommon. Therefore, this evaluation did not require any significant change in operating procedures or philosophy. "Polygons are definitely the way to go."
- **San Joaquin Valley (Hanford):** Relatively little severe weather, and thus only a few opportunities to evaluate.
- **Missoula:** Relatively little severe weather, and thus only a few opportunities to evaluate.

Appendix D - Forecaster Evaluation Form

Forecaster Evaluation Form

INSTRUCTIONS:

This survey is designed to obtain feedback from individuals who worked the event rather than a consolidated response from the warning team. Your responses are crucial to the success of the SB warning initiative.

It is understood that response is voluntary and may not be immediate (i.e., immediately following the event). However, a response as soon as possible following the event best serves the goal of evaluation.

QUESTIONS:

Select your WFO:

- *dropdown menu listing all WFOs participating in test*

Select the shift you worked:

- *Midnight to 6am*
- *6am to 6pm*
- *6pm to Midnight*

Which of the following best describes the event?

- *Tornado – super cell*
- *Tornado – other*
- *Severe Thunderstorm – linear*
- *Severe Thunderstorm – pulse*
- *Flash Flood*
- *Special Marine Event*
- *Other (please describe)*

Select your role during the event:

- *Severe weather coordinator*
- *Radar analysis*
- *Communications*
- *Other (please describe)*

The following questions apply to the use of a SB warning approach compared to a county-based warning approach. When answering, please briefly describe why you responded yes or no to a question.

If a specific aspect of the SB warning approach worked well during the event please describe below:

- *free form text box given for answer*

Did you encounter any problems:
- *no problems encountered*
- *yes, with WarnGen*
- *yes, with polygon mechanics*
- *yes, with warning team communications*
- *yes with other (please describe)*

Which best describes the change in workload when compared to the county based warning approach:
- *no change*
- *increase*
- *decrease*

Did you receive any polygon-specific feedback during the event:
- *no feedback received*
- *yes, from the media*
- *yes, from an emergency manager*
- *yes, from the public*
- *yes, from other (please describe)*

If you selected a positive response, please describe.
- *free form text box given for answer*

If you issued a SB warning near a CWA boundary, describe the coordination with the adjacent WFO:
- *no problem*
- *required additional time*
- *difficult*

If you selected difficult, please briefly describe:
- *free form text box given for answer*

Do you have any additional comments:
- *free form text box given for answer*

Appendix E - 2005 Verification Metrics from Evaluation

WFO	County Hits	County Misses	Total County Events	Polygon Hits	Polygon Misses	Total Polygon Events	County POD	Polygon POD	TEST OFFICE
ABQ	3	1	4	0	4	4	0.75	0.00	NO
ABR	11	2	13	4	9	13	0.85	0.31	NO
AFC	0	0	0	0	0	0	0.00	0.00	NO
AFG	0	0	0	0	0	0	0.00	0.00	NO
AJK	0	0	0	0	0	0	0.00	0.00	NO
AKQ	9	9	18	7	12	19	0.50	0.37	YES
ALY	0	1	1	0	1	1	0.00	0.00	NO
AMA	14	1	15	13	2	15	0.93	0.87	NO
APX	0	0	0	0	0	0	0.00	0.00	NO
ARX	10	7	17	5	13	18	0.59	0.28	NO
BGM	1	1	2	1	1	2	0.50	0.50	NO
BIS	11	6	17	6	11	17	0.65	0.35	NO
BMX	50	16	66	38	26	64	0.76	0.59	NO
BOI	0	0	0	0	0	0	0.00	0.00	NO
BOU	12	7	19	10	9	19	0.63	0.53	NO
BOX	0	0	0	0	0	0	0.00	0.00	NO
BRO	4	6	10	4	6	10	0.40	0.40	NO
BTV	0	0	0	0	0	0	0.00	0.00	NO
BUF	2	0	2	1	1	2	1.00	0.50	NO
BYZ	5	0	5	3	2	5	1.00	0.60	NO
CAE	9	0	9	9	0	9	1.00	1.00	YES
CAR	0	0	0	0	0	0	0.00	0.00	YES
CHS	4	2	6	2	4	6	0.67	0.33	NO
CLE	1	0	1	1	0	1	1.00	1.00	NO
CRP	6	3	9	4	5	9	0.67	0.44	NO
CTP	8	1	9	7	1	8	0.89	0.88	NO
CYS	8	0	8	4	4	8	1.00	0.50	NO
DDC	46	10	56	32	22	54	0.82	0.59	YES
DLH	4	1	5	4	1	5	0.80	0.80	NO
DMX	33	9	42	23	17	40	0.79	0.58	NO
DTX	1	0	1	1	0	1	1.00	1.00	NO
DVN	1	2	3	1	2	3	0.33	0.33	NO
EAX	16	2	18	15	3	18	0.89	0.83	YES
EKA	0	0	0	0	0	0	0.00	0.00	NO
EPZ	0	2	2	0	2	2	0.00	0.00	NO
EWX	3	0	3	2	1	3	1.00	0.67	NO
EYW	0	2	2	0	2	2	0.00	0.00	NO
FFC	23	9	32	19	13	32	0.72	0.59	NO
FGF	75	9	84	52	29	81	0.89	0.64	NO
FGZ	1	6	7	0	7	7	0.14	0.00	NO
FSD	7	3	10	3	7	10	0.70	0.30	NO
FWD	8	2	10	6	4	10	0.80	0.60	NO
GGW	0	2	2	0	2	2	0.00	0.00	YES
GID	19	4	23	18	5	23	0.83	0.78	NO

WFO	County Hits	County Misses	Total County Events	Polygon Hits	Polygon Misses	Total Polygon Events	County POD	Polygon POD	TEST OFFICE
GJT	0	4	4	0	4	4	0.00	0.00	NO
GLD	16	2	18	10	9	19	0.89	0.53	NO
GRB	13	11	24	6	17	23	0.54	0.26	NO
GRR	0	2	2	0	2	2	0.00	0.00	NO
GSP	8	6	14	8	6	14	0.57	0.57	NO
GUM	0	0	0	0	0	0	0.00	0.00	NO
GYX	0	2	2	0	2	2	0.00	0.00	NO
HFO	0	2	2	0	2	2	0.00	0.00	NO
HGX	3	3	6	2	4	6	0.50	0.33	NO
HNX	1	1	2	1	1	2	0.50	0.50	YES
HUN	2	0	2	3	0	3	1.00	1.00	NO
ICT	39	1	40	30	11	41	0.98	0.73	YES
ILM	0	1	1	0	1	1	0.00	0.00	YES
ILN	2	1	3	1	2	3	0.67	0.33	YES
ILX	3	3	6	3	3	6	0.50	0.50	NO
IND	11	1	12	10	2	12	0.92	0.83	YES
IWX	3	2	5	3	2	5	0.60	0.60	YES
JAN	113	11	124	93	32	125	0.91	0.74	YES
JAX	8	3	11	5	6	11	0.73	0.45	NO
JKL	0	1	1	0	1	1	0.00	0.00	NO
LBF	10	4	14	7	7	14	0.71	0.50	NO
LCH	0	0	0	0	0	0	0.00	0.00	NO
LIX	13	4	17	8	9	17	0.76	0.47	NO
LKN	0	0	0	0	0	0	0.00	0.00	NO
LMK	5	1	6	4	2	6	0.83	0.67	NO
LOT	0	0	0	0	0	0	0.00	0.00	YES
LOX	1	1	2	0	2	2	0.50	0.00	NO
LSX	7	5	12	2	9	11	0.58	0.18	NO
LUB	22	5	27	15	9	24	0.81	0.63	NO
LWX	6	0	6	6	1	7	1.00	0.86	NO
LZK	57	5	62	48	15	63	0.92	0.76	YES
MAF	11	2	13	7	6	13	0.85	0.54	YES
MEG	6	4	10	7	3	10	0.60	0.70	NO
MFL	3	3	6	2	4	6	0.50	0.33	NO
MFR	0	1	1	0	1	1	0.00	0.00	NO
MHX	4	0	4	3	1	4	1.00	0.75	NO
MKX	21	1	22	18	4	22	0.95	0.82	NO
MLB	4	3	7	2	5	7	0.57	0.29	NO
MOB	29	1	30	20	10	30	0.97	0.67	YES
MPX	27	5	32	22	10	32	0.84	0.69	NO
MQT	1	1	2	0	2	2	0.50	0.00	NO
MRX	0	0	0	0	0	0	0.00	0.00	NO
MSO	0	0	0	0	0	0	0.00	0.00	YES
MTR	0	2	2	0	2	2	0.00	0.00	NO
OAX	0	0	0	0	2	2	0.00	0.00	NO
OHX	18	1	19	16	3	19	0.95	0.84	NO

WFO	County Hits	County Misses	Total County Events	Polygon Hits	Polygon Misses	Total Polygon Events	County POD	Polygon POD	TEST OFFICE
OKX	0	1	1	0	1	1	0.00	0.00	NO
OTX	0	0	0	0	0	0	0.00	0.00	NO
OUN	19	3	22	15	7	22	0.86	0.68	NO
PAH	24	7	31	20	10	30	0.77	0.67	NO
PBZ	0	1	1	0	1	1	0.00	0.00	NO
PDT	3	0	3	1	2	3	1.00	0.33	YES
PHI	0	0	0	0	0	0	0.00	0.00	NO
PIH	2	4	6	1	5	6	0.33	0.17	YES
PQR	0	0	0	0	0	0	0.00	0.00	NO
PSR	0	0	0	0	0	0	0.00	0.00	NO
PUB	3	5	8	2	6	8	0.38	0.25	NO
RAH	5	0	5	4	1	5	1.00	0.80	NO
REV	0	1	1	0	1	1	0.00	0.00	NO
RIW	2	2	4	0	4	4	0.50	0.00	NO
RLX	0	0	0	0	0	0	0.00	0.00	NO
RNK	3	2	5	3	2	5	0.60	0.60	NO
SEW	0	1	1	0	1	1	0.00	0.00	NO
SGF	11	10	21	6	14	20	0.52	0.30	NO
SGX	2	6	8	0	9	9	0.25	0.00	NO
SHV	4	2	6	2	4	6	0.67	0.33	NO
SJT	12	0	12	3	9	12	1.00	0.25	YES
SJU	0	0	0	0	1	1	0.00	0.00	NO
SLC	1	3	4	0	4	4	0.25	0.00	YES
STO	4	11	15	2	13	15	0.27	0.13	NO
TAE	17	5	22	12	10	22	0.77	0.55	NO
TBW	8	9	17	6	11	17	0.47	0.35	NO
TFX	2	2	4	2	2	4	0.50	0.50	NO
TOP	15	3	18	14	4	18	0.83	0.78	NO
TSA	8	4	12	7	5	12	0.67	0.58	NO
TWC	0	1	1	0	1	1	0.00	0.00	YES
UNR	4	3	7	1	6	7	0.57	0.14	NO
VEF	0	1	1	0	0	0	0.00	0.00	NO

All WFOs	County Hits	County Misses	Total County Events	Polygon Hits	Polygon Misses	Total Polygon Events	County POD	Polygon POD
TOTALS	**1021**	**319**	**1340**	**758**	**576**	**1334**	**0.76**	**0.57**

WFO	County Hits	County Misses	Total County Events	Polygon Hits	Polygon Misses	Total Polygon Events	County POD	Polygon POD
TEST	**364**	**57**	**421**	**281**	**142**	**423**	**0.86**	**0.66**
NON TEST	**657**	**262**	**919**	**477**	**434**	**911**	**0.71**	**0.52**

Appendix F

DEFINITION OF SEVERE WEATHER METRIC

"COUNTY AREA RATIO"

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May 8, 2006

Introduction

A new performance measure is needed to measure improvement in issuing severe weather warnings using polygons rather than counties. For several years the National Weather Service (NWS) has been using polygons to describe the primary threat area for tornado (TOR), severe thunderstorm (SVR), flash flood (FFW), and special marine warnings (SMW). However, for many of the warnings issued the polygon has basically just been the shape of the county, somewhat defeating the purpose of defining a polygon for the warning area. Therefore a new performance measure, **County Area Ratio**, has been created.

Definition

The **County Area Ratio**, or **CAR**, is defined as the ratio of the area of a SB warning to the area of the warned counties:

$$CAR = 1 - \frac{PA}{\sum CA}$$

Where PA = Area of the SB warning in square miles
CA = Area of the county/counties in square miles

This ratio measures the improvement of reducing the size of warnings by using polygons. The county area consists of the sum of all counties identified by the inclusion of the Universal Geographic Code (UGC) in the text of the warning. It should be noted that it is possible for a SB warning to cover a small portion of a county but still not be "officially warned" on by virtue of the UGC in the warning. Also of note is that a few erroneous

warnings were issued where the polygon was much larger than the warned county area. This was due to a variety of reasons including instances where the polygon was extended well beyond the issuing forecast office's area either into a neighboring office or possibly offshore.

Data and Methodology

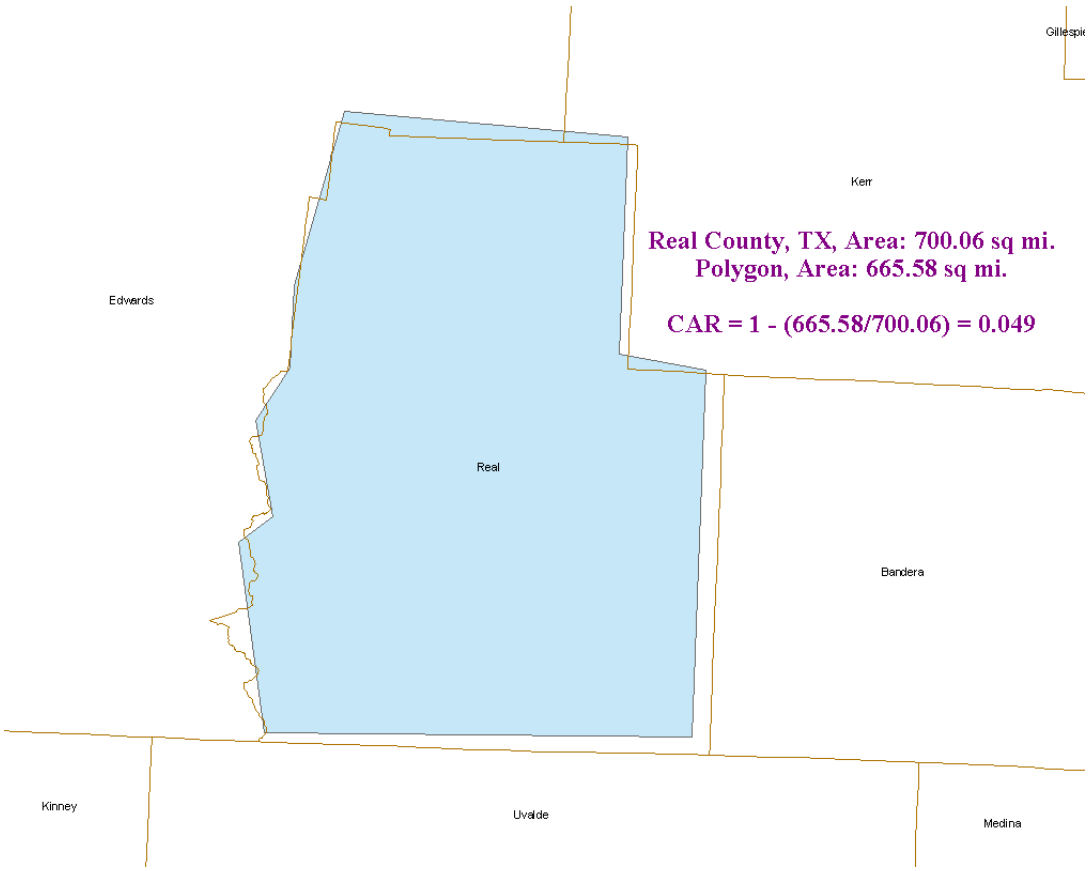
Data are the official text warnings issued by the National Weather Service for 2004 and 2005 (through September). The data set included 53,835 warnings for this 21 month period. The polygon information located at the end of the warning bulletins was extracted and converted into Geographic Information System (GIS) shapefile format. GIS software was then used on the full set of warnings to calculate the area in square miles of each warning and exported to a spreadsheet. Using the same GIS software, a field is populated with the sum of the county areas that each warning is issued for. Finally, a CAR is produced for each warning and the sum of both fields is used to calculate a national CAR value.

The use of GIS greatly simplifies this task and allows for a high degree of precision in computing these values. In addition, GIS enables further complex analysis such as verification of warnings against actual occurrences of severe weather.

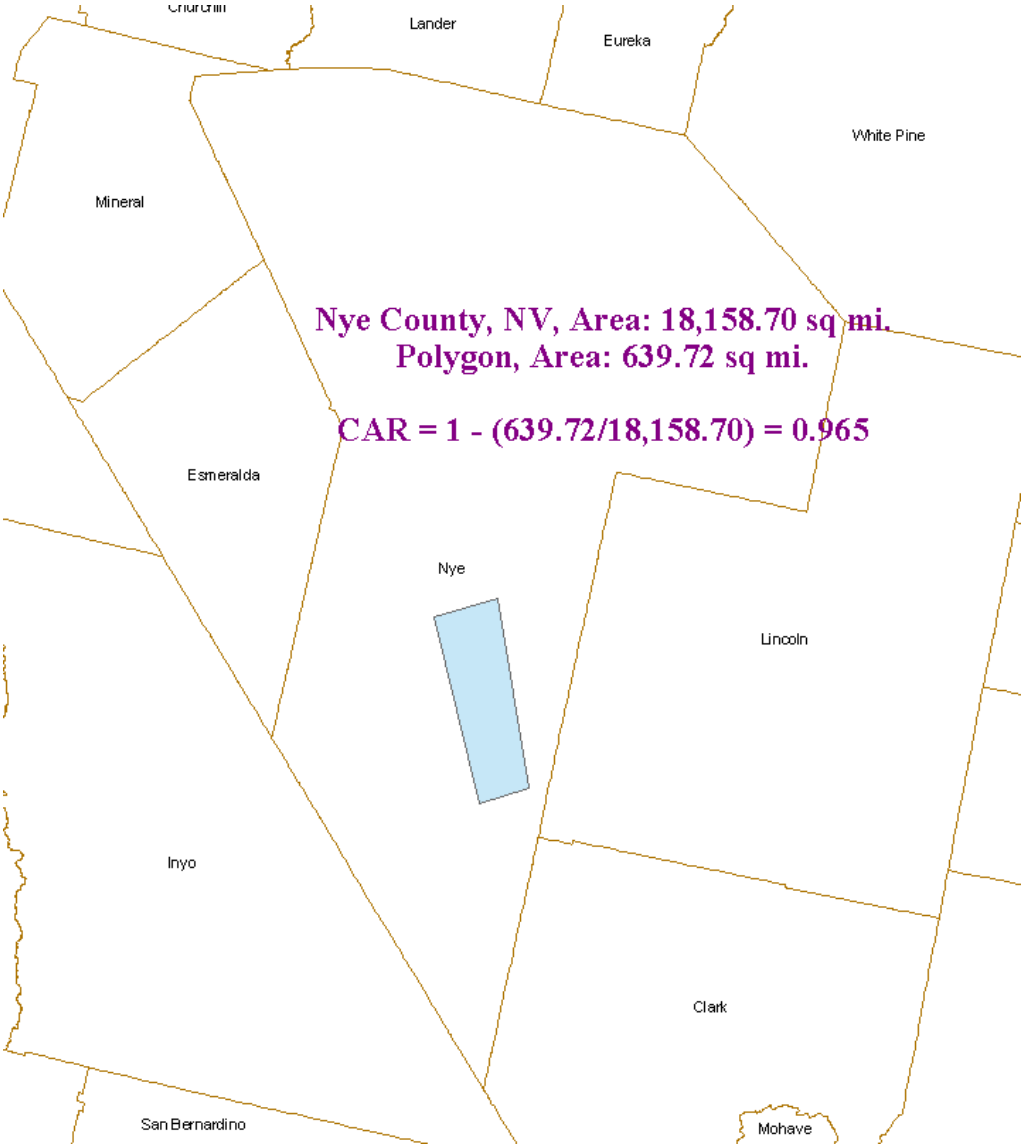
Examples

Following are three different examples showing how the CAR is computed.

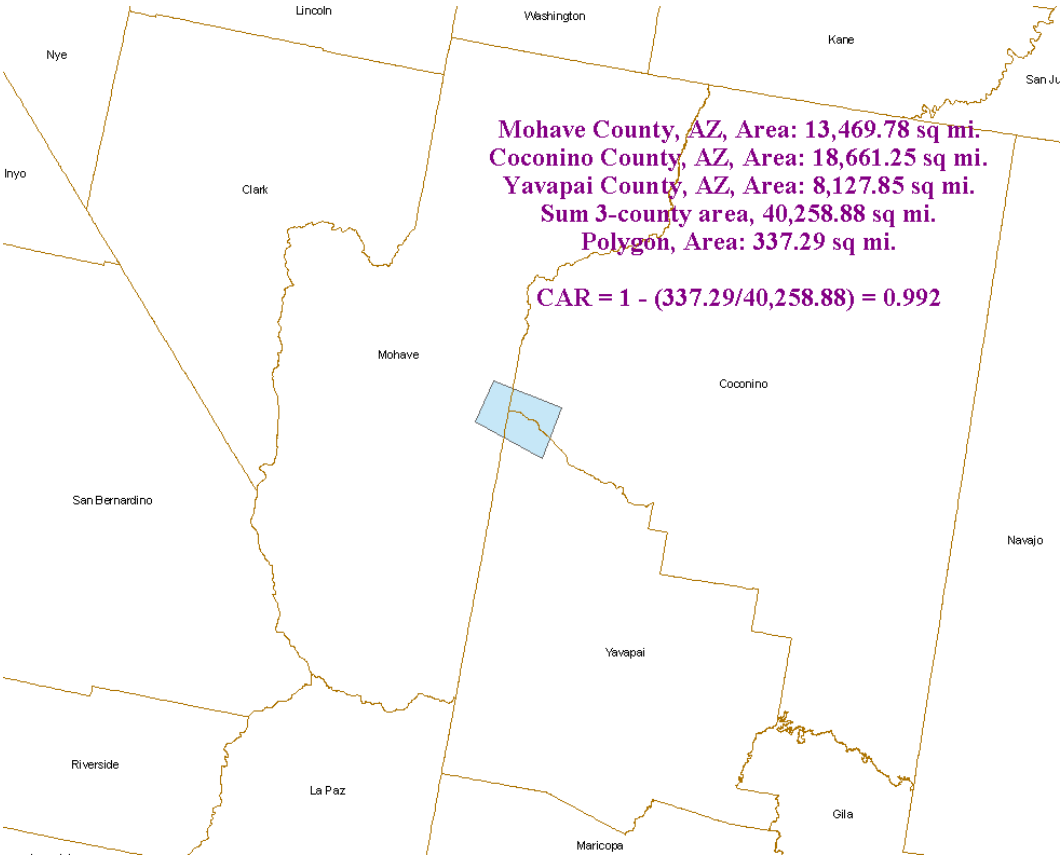
Example 1: One-county warning with the polygon largely emulating county boundaries.



Example 2: One-county warning with a polygon as a small subset of the county.



Example 3: A three-county warning with a small polygon at the junction of the three counties.



Analyses

To date, the CAR has been computed for all TOR, FFW, and SVR warnings for the 2004 and most of the 2005 season. Data has not been calculated for SMWs due to the fact that these warnings are issued over water and therefore a comparison of polygon area to county area would not be useful. Results have shown a typical average CAR of 70%, thus indicating that on average, polygons tend to be issued for only 30% of an average county area. However, as the examples above indicate, there is a substantial variance in these numbers. In general, CARs tend to be larger for the western U.S. due to the large county area size in the west.

	2004	2005 (thru Sept 30)
CAR	63.79%	69.95%

Conclusion

Initial work with the CAR metric has shown it to have significant value in measuring the tendency for an office to issue “Warnings by Polygon” rather than by county. Values of the CAR near zero indicate warnings with polygons that emulate county areas. Values of the CAR just under one are at the other end of the spectrum describing situations where a relatively small polygon was defined within a subset of one or more counties. Computing values of CAR provides the needed objective measure of the effectiveness of the NWS’ SB Polygon Warning initiative.