STORM BASED WARNINGS: A REVIEW OF THE FIRST YEAR

October 1, 2007 through June 30, 2008

Report from NOAA/NWS, Office of Climate, Water and Weather Services

Executive Summary

October 1, 2007 marked a major milestone for the NWS' Severe Storms Services Program with the operational national implementation of a new Storm-Based Warning (SBW) system. SBWs replaced the existing county-based warning system to alert the public of significant threats due to severe thunderstorms, tornadoes, flash floods and dangerous off-shore conditions. At the heart of the SBW system is the provision of forecaster capability to specifically warn for those areas under the greatest hydrometeorological threat, rather than requiring the warning of entire counties for what are often very small scale events. NWS forecasters indicate these threat areas via the use of computer-drawn "polygons" with specific latitude-longitude coordinates, thereby enabling partner ingest and display using a variety of visual media, including television and the Internet.

An active severe weather period began almost immediately after implementation of SBWs and continued through the first severe weather season. By all standard metrics, SBWs have been a success with levels of performance exceeding expectations. Still, there are significant issues that require continued evolution of software and policy to address.

This report is focused on the period of October 1, 2007 through June 30, 2008 and treats warning performance with respect to severe thunderstorms and tornadoes only. Also, this report was written in mid-September 2008, so the official verification is only available through June 2008. However, this period encompasses a historically active severe weather season, so this report provides a statistically sound evaluation of SBW performance.

To realize the promise of geographically concise, timely, and meteorologically accurate warning information, there are several issues described in this report that the authors feel require continued attention. Three of these issues are targeted for specific action in FY09, as follows:

1. Minimize the use of extremely large SBW polygons. Some SBWs this past year encompassed so many counties/parishes that the associated warning text over-ran character limitations for some of our partners.
2. Reduce the amount of text in call-to-action statements for the same reason articulated in #1.
3. Address the need to clarify the coordination process for issuing SBWs at boundaries of Weather Forecast Office (WFO) responsibility, especially where complex boundaries were involved (such as rivers). There were several instances where confusing warning products were issued between adjoining WFOs County Warning Areas (CWAs) as a storm crossed from one CWA to the next.

1. Background

In the past, dissemination technologies dictated warning by county. The advent of digital technology revolutionized communication. Warning by polygon, unlike textual warnings by county, meshes well with digital communication technologies such as Graphical Information Systems (GIS). Warnings consisting of a set of latitude/longitude vertices are easily transmitted via cell phone or PDA and displayed in various graphical formats.

Ease of digital communication, however, is a secondary benefit. The primary goal of Storm-Based Warnings (SBWs) is to improve our hydrometeorological warning services. The SBW methodology allows the forecaster the opportunity to be spatially specific, thereby eliminating large areas needlessly warned when compared to warning by county. With fewer warnings for a specific area, the public is under warning less often, increasing confidence in the warning and are, therefore, more likely to take action.

In January 2003, NWS first discussed the requirement to provide geographically concise, timely, and storm-specific warning information in a digital format. The concept was approved and a team established to develop and implement the concept. This team has continued to meet regularly since January 2004.

A field evaluation of specific short-duration "Warnings by Polygon" began March 1, 2005 where warnings for tornado, severe thunderstorm, special marine and flash flood warnings at 23 NWS Weather Forecast Offices (WFOs) were verified based on forecaster-defined polygons rather than counties. 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. A large majority of field forecasters, local and national media, emergency managers, members of the scientific community, and private sector vendors of NWS warning information responded positively to this field test. In 2006, the test report recommended that warnings by polygon, renamed "Storm-Based Warnings", be implemented as soon as software supported the change and training was complete.

Initial operating capacity for Storm Based Warnings (SBWs) was reached via deployment of new AWIPS software which was made available to all NWS WFOs concurrent with the beginning of FY08. The implementation date was announced with a press release at the AMS Annual Meeting on January 16, 2007.

In early 2007, managers were given a live presentation on SBWs, and a public web site http://www.weather.gov/sbwarnings/ was established to include presentations, articles, frequently asked questions, and associated links. Training development for forecasters was led by the NWS Warning Decision Training Branch. This training was posted on the DoC Learning Management System on July 1, 2008. Over 1500 NWS personnel completed this training, and the feedback was overwhelmingly positive.

During FY08, the NWS' Performance Management web site has been greatly improved to support both the general public and the field with storm-based warnings. The website can be accessed at https://verification.nws.noaa.gov/index.html.

2. Review of 2007-08 Severe Weather Season

The period October 1, 2007 through June 30, 2008 was extremely active in terms of severe weather. To illustrate this, NWS issued 3556 tornado warnings, 2152 flash flood warnings, and 18,420 severe thunderstorms warnings. There were several notable outbreaks of severe weather during the period, including:

- Feb. 5-6, 2008 (Super Tuesday Outbreak)
  - 82 tornadoes in nine states
  - 57 fatalities
- May 10-11, 2008 (Mother's Day Outbreak)
  - Long track EF4 tornado - Picher OK to Neosho MO
  - 22 fatalities
- May 25, 2008
  - Long track EF5 tornado through Parkersburg, IA
  - 9 fatalities
- June 11, 2008
  - Tornado hits Little Sioux Boy Scout Ranch killing 4 - injuring 48
  - 6 total fatalities

Figure 1: Southern California tornado, May 22nd, 2008

Severe weather impacted nearly every forecast area from coast to coast. Two tornadoes damaged areas of Southwestern Washington State in January. Four tornadoes touched down in Southern California on May 22, including the first EF2 rated tornado in California (see Figure 1). An EF4 tornado blasted through Suffolk, Virginia on April 28 injuring over 200 people but amazingly no fatalities. Through six months of the year, 1296 tornadoes have occurred already exceeding the yearly average (see Figure 2).

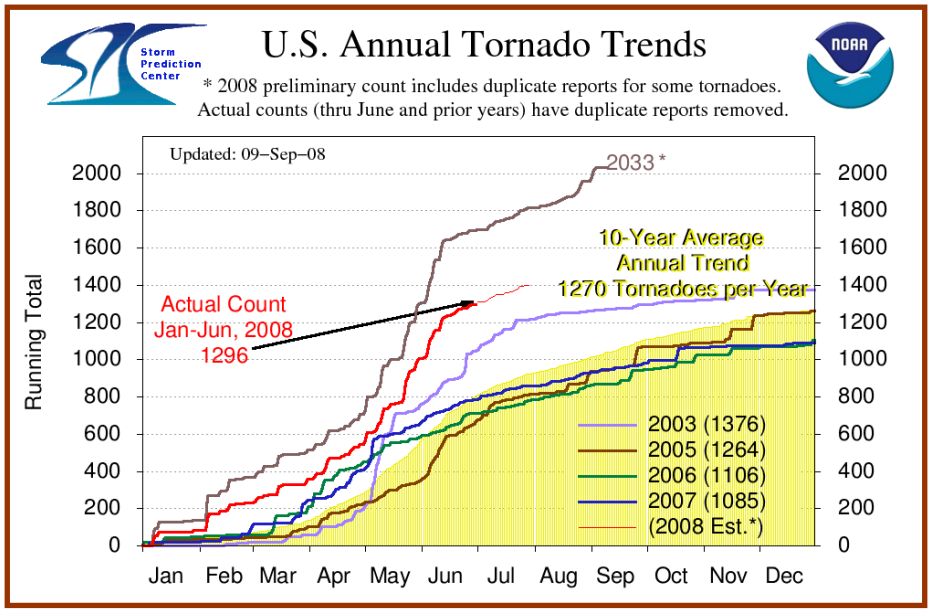

Figure 2: 1296 tornadoes occurred during the January through June period alone. This exceeds the 10 year average for an entire year.

3. The First Year of Storm-Based Warnings – Forecaster Performance

There are several ways to measure the performance of SBWs. This report addresses the historical metrics of Probability of Detection (POD) - the percentage of events that are within a warning, Average Lead Time (LT) - the average time between the warning and the event, and False Alarm Rate (FAR) - the percentage of warnings that do not have an event occur. This report also focuses on the reduction of "Falsely Alarmed Area" as a means to evaluate the success of SBWs in reducing area unnecessarily warned. Finally, we make a qualitative review on an event by event basis, and look at anecdotal evidence.

During 2006 and early 2007, considerable research was done on optimizing SBW metrics to provide the best possible performance feedback to WFO forecasters. The research was based on warning data for the period FY03-FY07 and a comparison to data gathered during the field test. Since SBWs are smaller than their county-based counterparts, it was a statistically significant finding of this research that Tornado Warning Probability of Detection (POD) would be lower because forecasters were being asked to "shoot at a smaller target". When SBW PODs were compared to county-based PODs, the SBW POD was 15-20 percent lower (See Figure 3 below -- difference between the blue line and the solid green line). However, it was estimated that once forecasters were instructed to focus on the polygon, POD would improve by around 10 percent.

Forecasters have to date far exceeded expectations with an improvement of nearly 15 percent over the 5 year average (note jump in solid green line from FY03-07 to FY08). ***This means that forecasters have almost matched their POD performance from the county-based days in the new SBW paradigm – but with much improved service due to reduction in falsely alarmed area.***

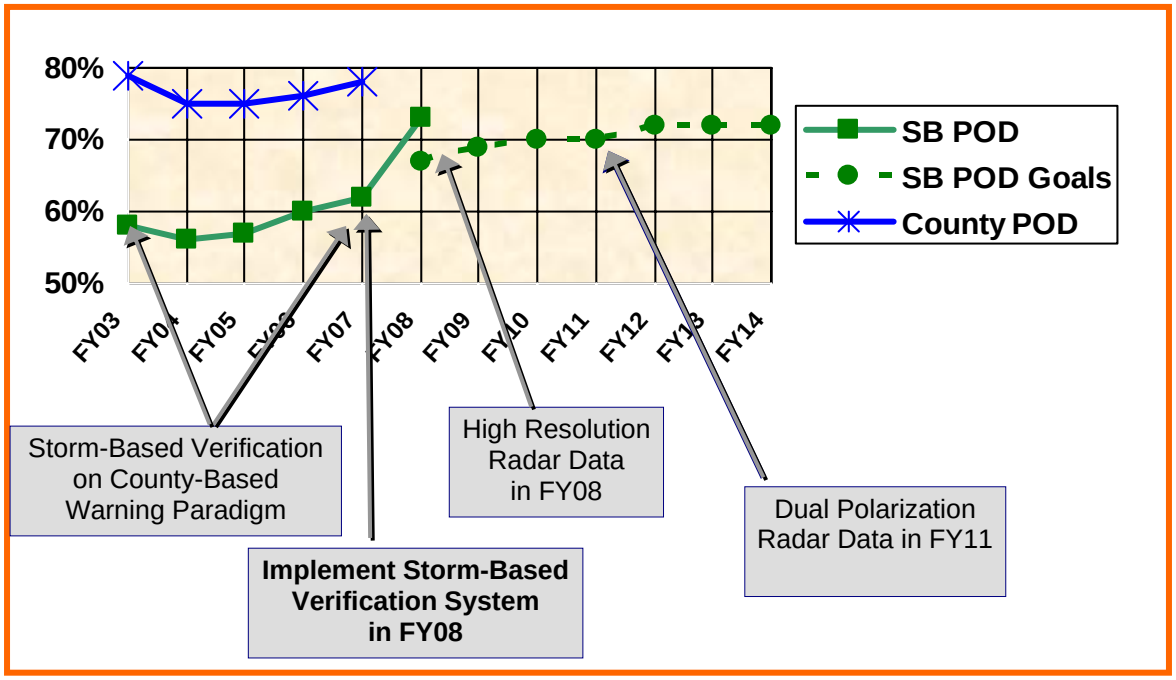

Figure 3: A comparison of county-based tornado warning accuracy (POD) to storm-based tornado warning accuracy (POD). The jump from FY07 to FY08 in storm-based accuracy (solid green line) shows the impact of focusing on the smaller area. This jump far exceeded expectations.

The three metrics tracked in the Government Performance Review Act (GPRA) are tornado warning POD, LT, and FAR. All three of these measures are exceeding the new SBW goals set for FY08 (See Figure 4 --note that the lower the FAR, the better).

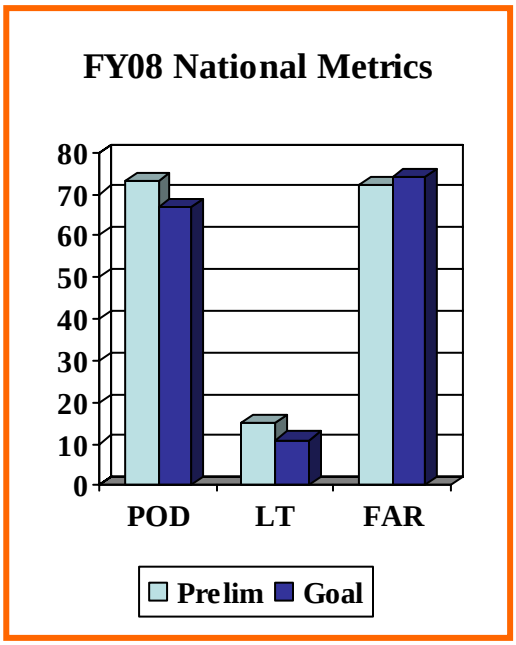

Figure 4: GPRA Tornado Warning Metrics preliminary numbers for Oct. '07 - June '08

Another measure of performance which we have used in our research is the reduction in "Falsely Alarmed Area" (FAA). As our initial test showed a reduction in FAA of about 75% compared to the county-based system, we hoped to see results close to this after the first year of operational use. The latest estimate is that FAA totaled near 67% nationally, or within 8% of the long term goal. This will remain a standing benefit of the storm-based warning system.

Counties are much larger in the Western U.S. and some areas in the Northern U.S. than in the Eastern U.S., therefore it is much easier to show sizeable reductions in FAA in the Western U.S where many Weather Forecast Offices (WFO) storm-based warning areas are more than 90% smaller than the corresponding county warning areas. Even in the worst case, the storm-based warning areas were 36% smaller than the size of county or counties included. The reduction in Falsely Alarmed Area is useful for tracking improvement on a local level from one year to the next, but should not be used to compare one WFO to another due to variance in county/parish size.

Also of value is a qualitative look at storm-based warnings from three perspectives:

- On an event basis,
- Based on comments from NWS Staff and NWS Partners, and
- From NWS Service Assessments.

During this past year, we qualitatively examined the performance of SBWs during a number of high-profile severe weather events (See Figure 5 for an example). For all of these events, forecaster performance in the issuance of storm-based tornado warnings have been consistently excellent, while those issued for severe thunderstorms and flash flood warnings have generally been very good (a small number of exceptions are noted in the "Issues and Recommendations" section below).

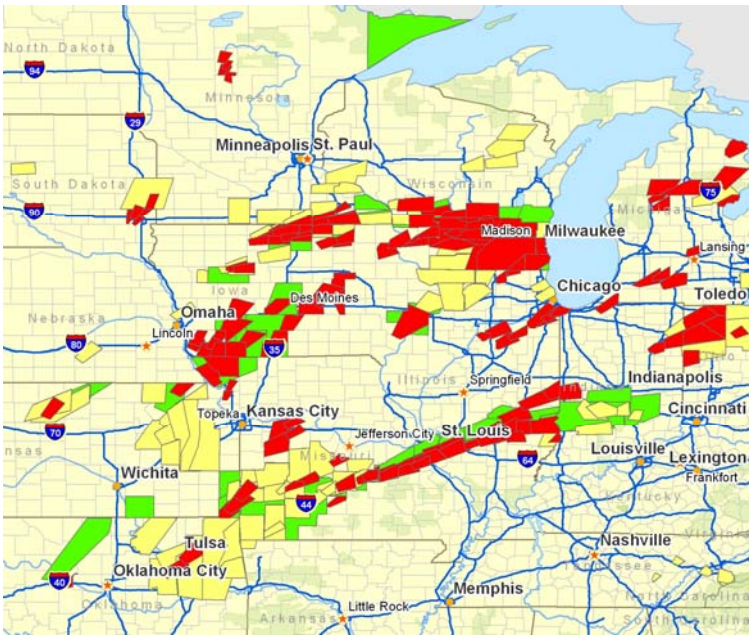

Figure 5: Note the tornado warnings (red) follow the storms with a slight overlap. Also note the severe thunderstorm warnings shaped like a squall line evolution in NE KS.

Although the change to storm-based warnings is not without controversy, comments from NWS Staff and Partners have been overwhelmingly positive. Here is an example:

- From Winford Sherman, Fire Chief of the Malden, Missouri
  "*Storm-based warnings have changed emergency response for the better in terms of severe weather warnings. Our town sits on the northern edge of Dunklin County* (note this county is long north to south, yet narrow east to west), *and more severe weather passes through the southern part of the county than through the northern part. There has been a noticeable reduction in warnings for northern Dunklin County. This reduction makes a difference for my fire department."*

From the draft of the Feb 5-6 "Super Tuesday" Tornado Outbreak Service Assessment:

- "*This* (storm-based warning) *approach substantially reduced the geographic area under Tornado Warnings during the event.*

4. Issues and Recommendations for FY09

Issue 1 -- Too Many Counties/Parishes

Based on our experience during this first year of SBW use, a small percentage of severe thunderstorm warnings (<1%) and flash flood warnings (~5%) contain more than a dozen counties/parishes. For many partners, this has caused problems in transmitting text warnings over mobile devices and television text crawls. There are so many locations listed that the basis of the warning is delayed or in some cases truncated altogether. This issue was raised by The Weather Channel at the June NWS Partners Meeting, and by others at the AMS Broadcasters Conference.

From the official notes of the OCWWS feedback session at the 2008 AMS Broadcasters Conference: *"Polygon warnings…great support amongst participants but improvements still needed. Broadcasters are not able to effectively communicate warning on non-graphical systems such as screen crawls."*

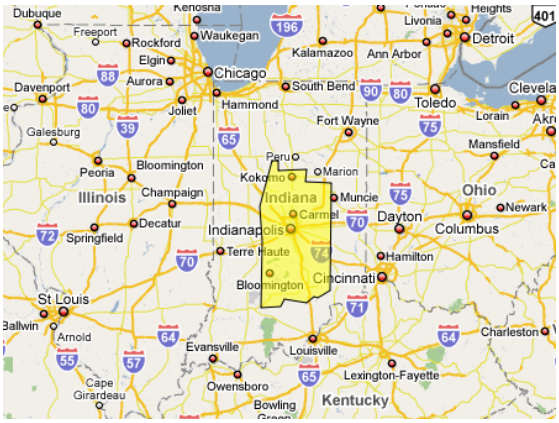

Figure 6: Severe thunderstorm warning for 26 counties in Indiana. Note the length of the location text on the right.

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THE NATIONAL WEATHER SERVICE IN INDIANAPOLIS HAS ISSUED A

* SEVERE THUNDERSTORM WARNING FOR...
  BARTHOLOMEW COUNTY IN CENTRAL INDIANA...
  THIS INCLUDES THE CITY OF COLUMBUS...
  BOONE COUNTY IN CENTRAL INDIANA...
  CLINTON COUNTY IN CENTRAL INDIANA...
  THIS INCLUDES THE CITY OF FRANKFORT...
  WESTERN DECATUR COUNTY IN CENTRAL INDIANA...
  HAMILTON COUNTY IN CENTRAL INDIANA...
  HANCOCK COUNTY IN CENTRAL INDIANA...
  HENDRICKS COUNTY IN CENTRAL INDIANA...
  HOWARD COUNTY IN CENTRAL INDIANA...
  THIS INCLUDES THE CITY OF KOKOMO...
  JOHNSON COUNTY IN CENTRAL INDIANA...
  MADISON COUNTY IN CENTRAL INDIANA...
  THIS INCLUDES THE CITY OF ANDERSON...
  MARION COUNTY IN CENTRAL INDIANA...
  THIS INCLUDES THE CITY OF INDIANAPOLIS...
  MORGAN COUNTY IN CENTRAL INDIANA...
  WESTERN RUSH COUNTY IN CENTRAL INDIANA...
  SHELBY COUNTY IN CENTRAL INDIANA...
  THIS INCLUDES THE CITY OF SHELBYVILLE...
  TIPTON COUNTY IN CENTRAL INDIANA...
  WESTERN DELAWARE COUNTY IN EAST CENTRAL INDIANA...
  WESTERN HENRY COUNTY IN EAST CENTRAL INDIANA...
  EASTERN CARROLL COUNTY IN NORTH CENTRAL INDIANA...
  BROWN COUNTY IN SOUTH CENTRAL INDIANA...
  JACKSON COUNTY IN SOUTH CENTRAL INDIANA...
  THIS INCLUDES THE CITY OF SEYMOUR...
  LAWRENCE COUNTY IN SOUTH CENTRAL INDIANA...
  THIS INCLUDES THE CITY OF BEDFORD...
  MONROE COUNTY IN SOUTH CENTRAL INDIANA...
  THIS INCLUDES THE CITY OF BLOOMINGTON...
  JENNINGS COUNTY IN SOUTHEAST INDIANA...
  EXTREME NORTHEASTERN OWEN COUNTY IN WEST CENTRAL INDIANA...
  EXTREME SOUTHEASTERN PUTNAM COUNTY IN WEST CENTRAL INDIANA...
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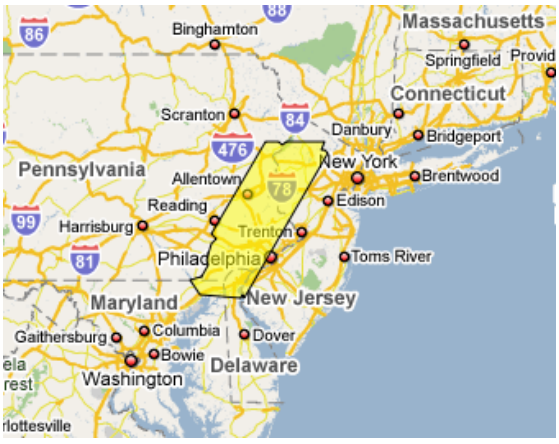


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THE NATIONAL WEATHER SERVICE IN MOUNT HOLLY NJ HAS ISSUED A

* SEVERE THUNDERSTORM WARNING FOR...
  EXTREME NORTHWESTERN MERCER COUNTY IN CENTRAL NEW JERSEY...
  SOUTHEASTERN BERKS COUNTY IN EASTERN PENNSYLVANIA...
  EASTERN LEHIGH COUNTY IN EASTERN PENNSYLVANIA...
  NORTHAMPTON COUNTY IN EASTERN PENNSYLVANIA...
  NORTHERN CECIL COUNTY IN NORTHEAST MARYLAND...
  SOUTHEASTERN MONROE COUNTY IN NORTHEAST PENNSYLVANIA...
  NORTHERN NEW CASTLE COUNTY IN NORTHERN DELAWARE...
  WESTERN MORRIS COUNTY IN NORTHERN NEW JERSEY...
  NORTHWESTERN SOMERSET COUNTY IN NORTHERN NEW JERSEY...
  HUNTERDON COUNTY IN NORTHWEST NEW JERSEY...
  SOUTHERN SUSSEX COUNTY IN NORTHWEST NEW JERSEY...
  WARREN COUNTY IN NORTHWEST NEW JERSEY...
  BUCKS COUNTY IN SOUTHEAST PENNSYLVANIA...
  CHESTER COUNTY IN SOUTHEAST PENNSYLVANIA...
  DELAWARE COUNTY IN SOUTHEAST PENNSYLVANIA...
  MONTGOMERY COUNTY IN SOUTHEAST PENNSYLVANIA...
  WESTERN PHILADELPHIA COUNTY IN SOUTHEAST PENNSYLVANIA...
  NORTHWESTERN GLOUCESTER COUNTY IN SOUTHERN NEW JERSEY...
  NORTHWESTERN SALEM COUNTY IN SOUTHERN NEW JERSEY...
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Figure 7: Severe thunderstorm warning for 19 counties in Pennsylvania...location text on the right.

Due to the size of counties, large warnings in the Western U.S. do not produce this problem. There are systemic issues in the Western U.S. which naturally produce larger polygons (such as, poor low level radar coverage and sparse population). The usefulness of tracking overall polygon size (see Figure 8 below) is to note improvement from year to year rather than in comparison from one County Warning Area (CWA) to another.

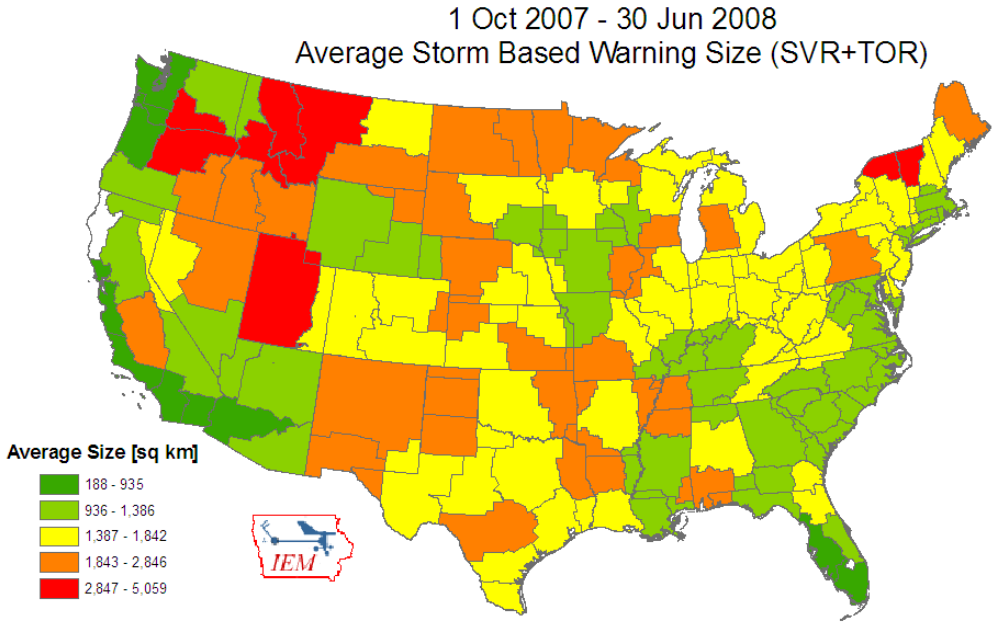

Figure 8: Average polygon size by County Warning Area for the period October 2007 through June 2008. Several factors impact average warning size including whether storms are more commonly individual supercell storms vs squall lines, population density, radar coverage, etc.

Recommendations for Issue 1 -- Too Many Counties/Parishes

In collaboration with the regions and NWS HQ, include a new instruction in NWSI 10-511 and NWSI 10-922 that tornado, severe thunderstorm and flash flood warnings should be limited to **12** counties/parishes.

Include this issue in Advanced Storm Based Warning Training to be released February 1, 2009.

Issue 2 -- Too Many Call-To-Action Statements

Some warnings include a considerable amount of text mainly due to numerous "Call-To-Action" statements (see Figure 9). This issue also negatively impacts text warnings delivered over mobile devices, and television text crawls. This can also negatively impact NOAA All-Hazard Radio cycle times.

BULLETIN - EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE MOBILE AL
211 PM CST SUN FEB 17 2008

THE NATIONAL WEATHER SERVICE IN MOBILE HAS ISSUED A

* TORNADO WARNING FOR...
SOUTHEASTERN CRENSHAW COUNTY IN SOUTH CENTRAL ALABAMA...

* UNTIL 230 PM CST

* AT 207 PM CST...NATIONAL WEATHER SERVICE DOPPLER RADAR INDICATED A SEVERE THUNDERSTORM CAPABLE OF PRODUCING A TORNADO NEAR BULLUCK... OR ABOUT 11 MILES SOUTH OF LUVERNE...MOVING NORTHEAST AT 50 MPH.

* THE POSSIBLE TORNADO WILL OTHERWISE IMPACT MAINLY RURAL AREAS OF THE SOUTHEASTERN CRENSHAW COUNTY.

THIS IS SERIOUS. NUMEROUS DAMAGE REPORTS CONTINUE TO FLOW INTO THE NWES OFFICE IN MOBILE ALABAMA. TAKE COVER NOW!

THE SAFEST PLACE TO BE DURING A TORNADO IS ON THE LOWEST FLOOR OF A STURDY BUILDING...PREFERABLY IN AN INTERIOR HALLWAY OR A ROOM SUCH AS A CLOSET OR BATHROOM. IF POSSIBLE...GET UNDER A WORKBENCH OR OTHER PIECE OF STURDY FURNITURE. USE BLANKETS OR PILLOWS TO COVER YOUR BODY AND ALWAYS STAY AWAY FROM WINDOWS. IN ADDITION TO THE TORNADO...THIS STORM IS CAPABLE OF PRODUCING LARGE DAMAGING HAIL OR DAMAGING STRAIGHT LINE WINDS.

IF YOU ARE IN MOBILE HOME...EVACUATE IT AND GET ON THE LOWEST FLOOR OF A NEARBY STURDY BUILDING OR IN AN UNDERGROUND STORM SHELTER. IF NO SUBSTANTIAL SHELTER IS AVAILABLE AND A TORNADO IS FAST APPROACHING... SEEK SHELTER IN A CULVERT...DITCH OR LOW DEPRESSION AND COVER YOUR HEAD WITH YOUR HANDS.

HEAVY RAINFALL MAY BE OBSCURING THIS TORNADO. TAKE COVER NOW! IF YOU WAIT TO SEE OR HEAR IT COMING...IT MAY BE TOO LATE TO GET TO A SAFE PLACE.

DO NOT USE YOUR VEHICLE TO TRY TO OUTRUN AN APPROACHING TORNADO. ANY SIZE OF VEHICLE CAN BE EASILY BE TOSSED AROUND BY TORNADIC WINDS. IF YOU ARE CAUGHT IN THE PATH OF A TORNADO...LEAVE THE VEHICLE AND SEEK SHELTER IN A STRONG BUILDING. IF NO SAFE STRUCTURE IS AVAILABLE... SEEK SHELTER IN A CULVERT...DITCH OR LOW DEPRESSION AND COVER YOUR HEAD WITH YOUR HANDS. DO NOT USE HIGHWAY OVERPASSES FOR SHELTER. OVERPASSES DO NOT PROVIDE PROTECTION FROM TORNADIC WINDS.

A TORNADO WATCH REMAINS IN EFFECT UNTIL 800 PM CST SUNDAY EVENING FOR

SOUTHWESTERN ALABAMA AND NORTHWEST FLORIDA.

TOO MUCH TEXT

Figure 9: Example of multiple call-to-action statements (highlighted) in a tornado warning.

Recommendations for Issue 2 -- Too Many Call-To-Action Statements

AWIPS Build OB9 will include new "Call-To-Action" tags both before and after these statements. This will allow partners to more easily parse these statements, and if desired remove them from cell phone text and television text crawls.

Include this issue in Advanced Storm Based Warning Training to be released February 1, 2009.

Issue 3 -- Boundary (CWA and Marine/Land) Issues

Most boundaries between WFOs county warning areas (CWA) are political boundaries that follow county lines. These are often rivers or other irregularly shaped boundaries. Since all warnings stop at the CWA boundary, this produces odd shaped polygons, and more importantly an inconsistent service for communities along these boundaries (see Figure 10). This is a frequent and reoccurring problem.

This issue is also a finding in the draft Super Tuesday Service

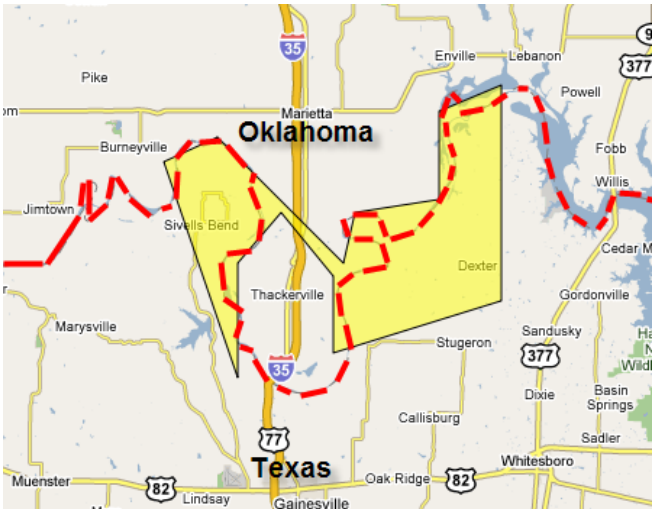

Figure 10: Severe thunderstorm warning polygon from the Fort Worth, TX for a storm moving along the Red River that is the boundary of the Norman, OK and Fort Worth, TX CWAs.

Assessment. This finding notes that an office being able to rapidly coordinate with its neighboring office on a single warning along a CWA boundary would result in a better service and potentially save lives.

There is a similar issue along complex Marine/Land boundaries. There is a limit of 20 points to a polygon (per partner request). Therefore to graphically describe these complex boundaries with so few points produces very odd results (see Figure 11).

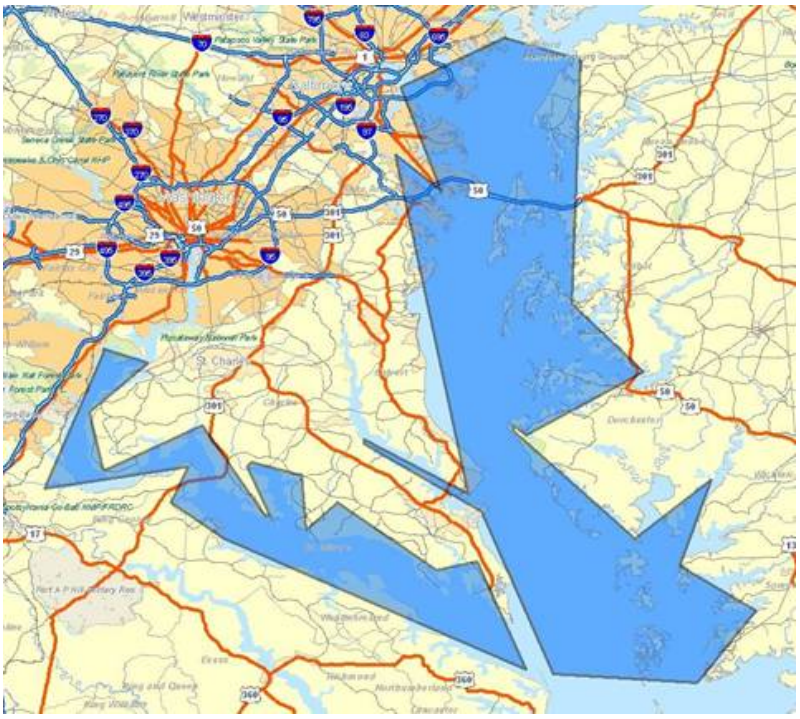

Figure 11: Two special marine warnings (blue) for Chesapeake Bay and Potomac River. Note the small spike for the Patuxent River.

Recommendations for Issue 3 -- Boundary (CWA and Marine/Land) Issues
There are both complex coordination and dissemination issues associated in resolving issues with oddly-shaped polygons. The final solution might not be available until the AWIPS II Next Generation Warning Tool is available, but the current AWIPS software can support a limited test of the coordination and dissemination issues.

We recommend that the collaboration and coordination issues of inter-CWA warnings be first prototyped as a Hazardous Weather Testbed activity in the spring of 2009. Consideration should also be given to a field test with two offices (with regional assistance) participating in a limited test along a few bordering counties where these boundary issues commonly occur. With extensive prior coordination both internally and externally among key partners in the media and emergency management, warnings would be issued by one WFO that extends slightly into another CWA.

5. Challenges and Recommendations for FY10 and Beyond

There are several additional challenges associated with optimizing SBWs as we move into the future. This report identifies the following six issues and includes an associated recommendation with each issue.

1. Defining User Needs -- The Next Generation Warning Workshop, to be held at the National Weather Center in Norman, OK on December 2-4, 2008 is an initial step to gaining a better understanding of user needs for watch, warning and advisory services.

2. AWIPS Software Limitations -- Current forecaster tools such as WarnGen were not designed for storm-based warnings. Rather than continued evolution of this software, the NWS should strongly support a complete redesign of these tools in the form of the Next Generation Warning Tool.

3. Local Storm Report Issues -- Current software does not support, and current policy does not meet, NWS and partner needs for accurate and timely real-time storm reporting (LSR) that is integral to the warning process. The NWS should support a redesign of the LSR Graphical User Interface, and work with partners to design more flexible formats.

4. Dissemination Issues -- NWS Warnings are still viewed as archaic due to the use of WMO standards of using all capital letters, etc. Warning information should be delivered in a modern format such XML (Extensible Markup Language) and CAP (Common Alerting Protocol).

5. The NOAA Weather Radio and Emergency Alert System (EAS) are still county-based systems. The NWS should continue to work to modernize NOAA Weather Radio and work with partners in FEMA and the FCC to implement digital EAS.

6. Multiple Warnings in a single area can cause confusion. Formats, such as XML and CAP, offer the potential for a section in a warning that contains a list of all warnings valid for the same area or county. The NWS should research solutions to limit confusion caused by multiple warnings in the same area.

6. Summary

We evaluated forecaster performance and user reaction to the new SBW system for the period October 1, 2007 through June 30, 2008. This very active severe weather period supported a very thorough test, and provided us with clear ideas for future improvement. By standard measures, storm-based warnings have been a success with levels of performance exceeding expectations. In a qualitative sense, the transition to storm-based warnings has been successful with the support of most NWS staff and partners.

To realize the promise of geographically concise, timely, and meteorologically accurate warning information, there are several issues that require continued evolution of software and policy. Three of these issues are targeted for specific action in FY09. The remainder of these issues will be further defined in FY09, with specific solutions targeted for FY10 and beyond, and largely dependant on the development of AWIPS II and the Next Generation Warning Tool.

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7. Additional References

Ferree, John T., D. Freeman, E. Jacks, and J. M. Looney, 2007: **Storm-based Warnings-Changes to NWS Warnings for the Digital Age,** 35th Conference on Broadcast Meteorology, http://ams.confex.com/ams/pdfpapers/120818.pdf

Jacks, Eli and J. Ferree, 2007: **Socio-Economic Impacts of Storm-based Warnings,** AMS Second Symposium on Policy and Socio-economic Research, http://ams.confex.com/ams/pdfpapers/120849.pdf

Waters, Ken R., 2007: **Verification of National Weather Service warnings using geographic information systems,** 23rd Conference on IIPS, http://ams.confex.com/ams/pdfpapers/116773.pdf