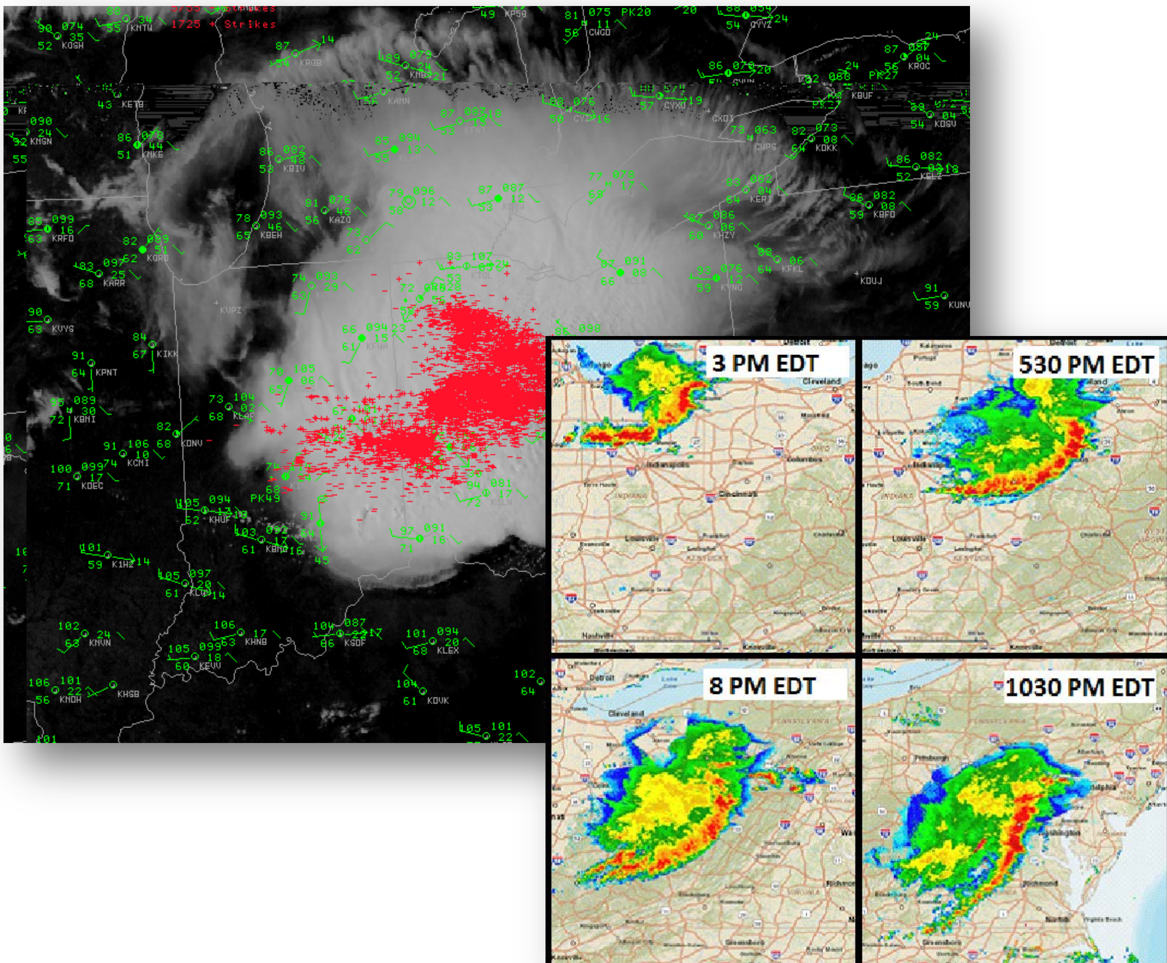
Service Assessment

The Historic Derecho of June 29, 2012



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

Cover Photograph: Visible satellite image at 5 p.m. Eastern Daylight Time (EDT) June 29, 2012, as the derecho moved across Ohio. National Lightning Data Network (NLDN) Cloud to ground (CG) lightning strikes for the 1-hour period, 4-5 p.m. EDT, are plotted in red. Surface observations are plotted in green. Smaller insets show radar reflectivity images of the derecho during the afternoon and evening.

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January 2013

National Weather Service
Laura K. Furgione
Acting Assistant Administrator for Weather Services

Preface

On June 29, 2012, a derecho of historic proportions struck the Ohio Valley and Mid-Atlantic states. The derecho traveled for 700 miles, impacting 10 states and Washington, D.C. The hardest hit states were Ohio, West Virginia, Virginia, and Maryland, as well as Washington, D.C. The winds generated by this system were intense, with several measured gusts exceeding 80 mph. Unfortunately, 13 people were killed by the extreme winds, mainly by falling trees. An estimated 4 million customers lost power for up to a week. The region impacted by the derecho was also in the midst of a heat wave. The heat, coupled with the loss of power, led to a life-threatening situation. Heat claimed 34 lives in areas without power following the derecho.

Due to the significance of this event, the National Oceanic and Atmospheric Administration's National Weather Service formed a Service Assessment Team to evaluate the National Weather Service's performance before and during the event. The findings and recommendations from this assessment will improve the quality of National Weather Service products and services and increase awareness related to severe thunderstorms and intense heat. The ultimate goal of this report is to help the National Weather Service better perform its mission of protecting life and property and enhancing the national economy.

Laura K. Furgione
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January 2013

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Service Assessment Team

The team consisted of the following individuals:

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Executive Summary

On June 29, 2012, a devastating line of thunderstorms known as a derecho (deh REY cho) moved east-southeast at 60 miles per hour (mph) from Indiana in the early afternoon to the Mid-Atlantic region around midnight. The states most significantly impacted were Indiana, Ohio, Kentucky, Pennsylvania, West Virginia, Maryland, Virginia, Delaware, New Jersey, and North Carolina, as well as Washington, D.C. Nearly every county impacted by this convective system suffered damages and power outages. Winds were commonly above 60 mph with numerous reports of winds exceeding 80 mph. Some areas reported isolated pockets of winds greater than 100 mph. The storm resulted in 13 deaths, mainly a result of falling trees. One major impact from the derecho was widespread power outages. More than 4 million customers were without power, some for more than a week after the storms moved through. To make matters worse, the area affected was in the midst of a prolonged heat wave. There were 34 heat-related fatalities in areas without power because of the derecho.

The National Weather Service (NWS) formed a Service Assessment Team to evaluate performance during this event. Due to the widespread nature of this derecho, the team chose to visit the sites and review products and performance only at NWS Weather Forecast Offices (WFO) most impacted by the storms: WFOs Syracuse, IN (hereafter WFO Northern Indiana); Wilmington, OH; Pittsburgh, PA; Sterling, VA; Charleston, WV; and Blacksburg, VA. The team collected data from five other sites on the periphery of the damage path: WFOs Indianapolis, IN; Cleveland, OH; Jackson, KY; Mount Holly, NJ; and Wakefield, VA. A review of the products and services provided by the Storm Prediction Center (SPC) was also conducted along with numerous SPC staff interviews.

Unlike many major tornado outbreaks in the recent past, this event was not forecast well in advance. Warm-season derechos, in particular, are often difficult to forecast and frequently result from subtle, small-scale forcing mechanisms that are difficult to resolve more than 12-24 hours in advance. The National Centers for Environmental Prediction (NCEP) operational forecast models, such as the North American Mesoscale (NAM) and Global Forecast System (GFS), provided little assistance in forecasting this event more than 24 hours ahead of time. However, on the morning of June 29, some high-resolution, convection-allowing models began to provide clues that an intense line of thunderstorms could take the path that was later observed.

Because decision support activities were delayed until close to the event, key partners and decision makers had less time to prepare for the severe winds. In the Mid-Atlantic region, many forecasters thought the derecho would follow climatology and break up crossing the Appalachian Mountains. This past pattern for such events impacted the SPC's outlooks, which did not extend the risk for severe thunderstorms eastward to the Mid-Atlantic coast until the afternoon of June 29. Therefore, WFO products and services, as well as preparedness efforts, were affected because the WFOs followed SPC guidance closely.

Despite the relatively short lead time for forecasting this event, the offices generally did an excellent job issuing warnings. Overall, lead times were greater than 30 minutes, especially on the eastern end of warning polygons. Most of the offices were issuing large warning

polygons to cover the widespread nature of the event and the fast storm motion. All deaths occurred within severe thunderstorm warning polygon boundaries.

Three social scientists were included on this Service Assessment Team to help determine the societal impacts of this event and to suggest improvements to future services. The social scientists worked side by side with other team members participating in a wide range of briefings, interviews, and site visits. Consequently, many of the recommendations in this assessment report incorporate a social science perspective. A common theme that emerged from talking to emergency managers, media, and the public was that although they received the warnings, they were surprised by the intensity of the winds.

The team submitted 13 recommendations to address NWS performance, safety, and outreach programs. In addition, the team identified five best practices. Appendix B includes definitions of facts, findings, recommendations, and best practices followed by a complete listing of findings, recommendations, and best practices found within the main body of the report. Appendices C and D contain information concerning the deaths from the derecho and from heat. Appendix E provides a list of measured gusts greater than 57 mph recorded during this event.

Service Assessment Report

1. Introduction

1.1. NWS Mission

The National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure, which can be used by other governmental agencies, the private sector, the public, and the global community.

1.2. Purpose of Assessment Report

The NWS conducts service assessments of significant weather-related events that result in multiple fatalities, numerous injuries requiring hospitalization, significant impact on the economy of a large area or population, extensive national public interest or media coverage, or an unusual level of attention to NWS operations (performance of systems or adequacy of warnings, watches, and forecasts) by media, the emergency management community, or elected officials. Service assessments evaluate the NWS performance and ensure the effectiveness of NWS products and services in meeting its mission. The goal of service assessments is to better protect life and property by implementing recommendations and best practices that improve NWS products and services.

This document presents findings and recommendations resulting from the evaluation of NWS performance during the historic derecho event of June 29, 2012, which affected the Ohio Valley and Mid-Atlantic States. This derecho resulted in 13 fatalities, caused power outages to over 4 million customers, and indirectly led to 34 additional deaths due to heat-related illnesses in the week following the event.

The objectives of this assessment are to identify significant findings and develop recommendations and best practices related to NWS effectiveness in the following key areas:

- Timeliness, quality, accuracy, and usefulness of NWS forecasts and warnings
- Internal and external coordination and collaboration
- Forecasting and warning procedures at NWS offices
- Collaboration with federal, state, and local agencies

1.3. Methodology

The NWS formed an assessment team on July 5, 2012, consisting of employees from NWS field offices, the NWS Central Region Headquarters office, and members of the social science community. The 12-member team completed the following:

- Performed on-scene evaluations July 13-16, 2012

- Conducted interviews with staff from Weather Forecast Offices (WFOs) Northern Indiana; Wilmington, OH; Pittsburgh, PA; Sterling, VA; Charleston, WV; and Blacksburg, VA; and with the Storm Prediction Center (SPC), all of which had primary responsibility for providing warnings, forecasts, and decision support for Emergency Managers (EM), media, and the general public for this event
- Interviewed members of the media, EMs, and the public to assess services provided by the WFOs
- Collected data from WFOs on the periphery of the damage path including Indianapolis, IN; Jackson, KY; Cleveland, OH; Wakefield, VA; and Mount Holly, NJ, to obtain a complete record of the event and to determine if any facts, findings, recommendations, or best practices pertained to these offices
- Evaluated products and services provided by the WFOs and the SPC
- Developed and agreed upon significant findings and recommendations to improve NWS products and services

After a series of internal reviews, the service assessment is signed by the National Oceanic and Atmospheric Administration's (NOAA) Assistant Administrator for Weather Services and published for public review.

2. Derecho Science and Climatology

A derecho is a complex of thunderstorms or a mesoscale convective system (MCS) that produces large swaths of severe, straight-line wind damage at Earth's surface. Johns and Hirt (1987) set spatial, temporal, and damage limitations when classifying thunderstorm complexes as derechos. Specifically, for an MCS to be classified as a derecho, the following conditions must be met:

- There must be a concentrated area of convectively induced wind damage or gusts greater than or equal to 58 mph occurring over a path length of at least 250 miles.
- Wind reports must show a pattern of chronological progression in either a singular swath (progressive; this event was a classic example) or a series of swaths (serial).
- There must be at least three reports separated by 64 kilometers (km) or more of Enhanced Fujita 1 (EF1 damage) and/or measured convective wind gusts of 74 mph or greater.
- No more than 3 hours can elapse between successive wind damage/gust events.

Derechos occur year-round but are most common from May to August (Coniglio et al., 2004). Derechos form in a wide spectrum of large-scale weather patterns and occur in a broad range of air mass instability and low to mid-level wind shear (the change of wind direction and speed with height) environments (Evans and Doswell, 2001). The majority of events fall into three jet stream patterns:

- Well-defined approaching upper level disturbance
- Upper-level ridge of high pressure
- Zonal west to east flow

In the last two patterns particularly, the forcing for the development of a derecho can be subtle and difficult to forecast. Forecasters may be aware that a pattern is setting up for a potential derecho, but pinpointing the timing and location of the storms is often problematic because favorable patterns may exist for several days without derecho formation.

For progressive derechos, like this event, a west-to-east oriented surface frontal boundary usually exists. The derecho typically initiates on the north side of the boundary as loosely organized elevated thunderstorms, which eventually grow upscale, forming a large bow shaped echo. The bow echo then moves east-southeastward crossing the front into the warm and very unstable air to the south (Johns, 1993). The storm-scale mechanisms governing the upscale growth and the transition from elevated to surface-based storms are not well understood. The demise of derechos tends to occur when they move into an environment of weaker instability and low to mid-level wind shear (Coniglio et al., 2004).

Coniglio and Stensrud (2004) developed a climatology of derechos for the eastern half of the United States. **Figure 1** displays this derecho climatology for May through August from 1980-2001.

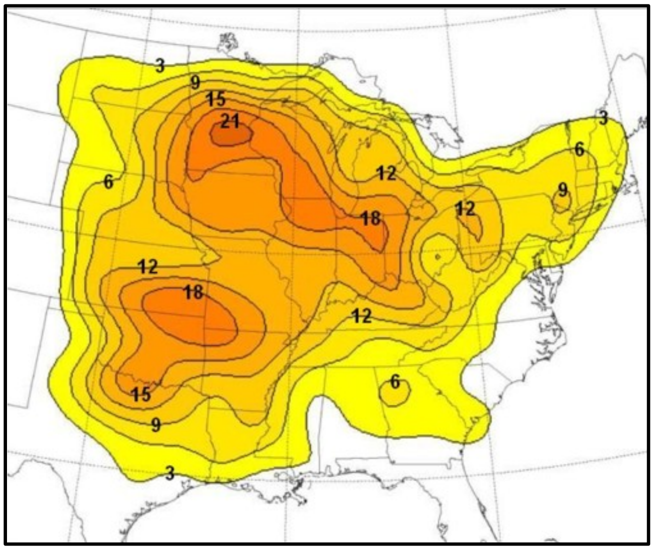

Figure 1: Number of derechos, 1980-2001, May through August

There is a distinct maximum in occurrence from the upper Mississippi Valley in Minnesota southeastward to western Ohio; however, there is a big decrease in frequency east of the Appalachian Mountains. The Appalachian Mountains and the lower climatological potential for derechos east of the mountains were cited by many forecasters as reasons why this derecho might weaken as it approached the Mid-Atlantic region.

3. Event Overview

The large-scale pattern on June 29, 2012, was characterized by a ridge of high pressure aloft over the Southeast and zonal west to east flow associated with the core of the jet stream across the northern tier of states (**Figure 2**). In between these two features was a belt of moderate west to northwest flow aloft (approximately 45 mph) over the Ohio Valley and Mid-Atlantic region. There were no obvious disturbances embedded in the flow to help focus thunderstorm development.

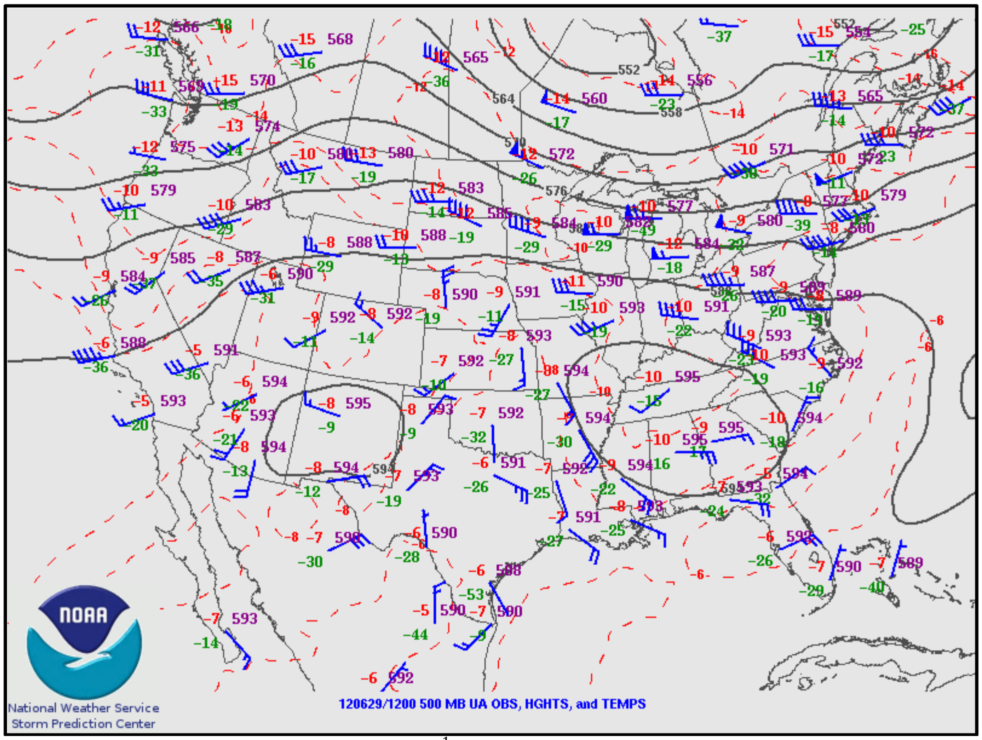

Figure 2: 8 p.m. Eastern Daylight Time[1], June 29, 2012, 500 millibar (mb) chart

At the surface (**Figure 3**), a complex frontal boundary extended from the upper Midwest to the Northeast at 2 p.m. EDT. Atmospheric moisture content was high near the boundary and to the south over the Eastern Seaboard. This fact, along with very warm surface temperatures (the area was in the midst of a heat wave), led to a long corridor of very unstable conditions for the derecho to move through, including areas east of the Appalachians.

[1] All times referenced through the remainder of the document are in Eastern Daylight Time unless otherwise identified.

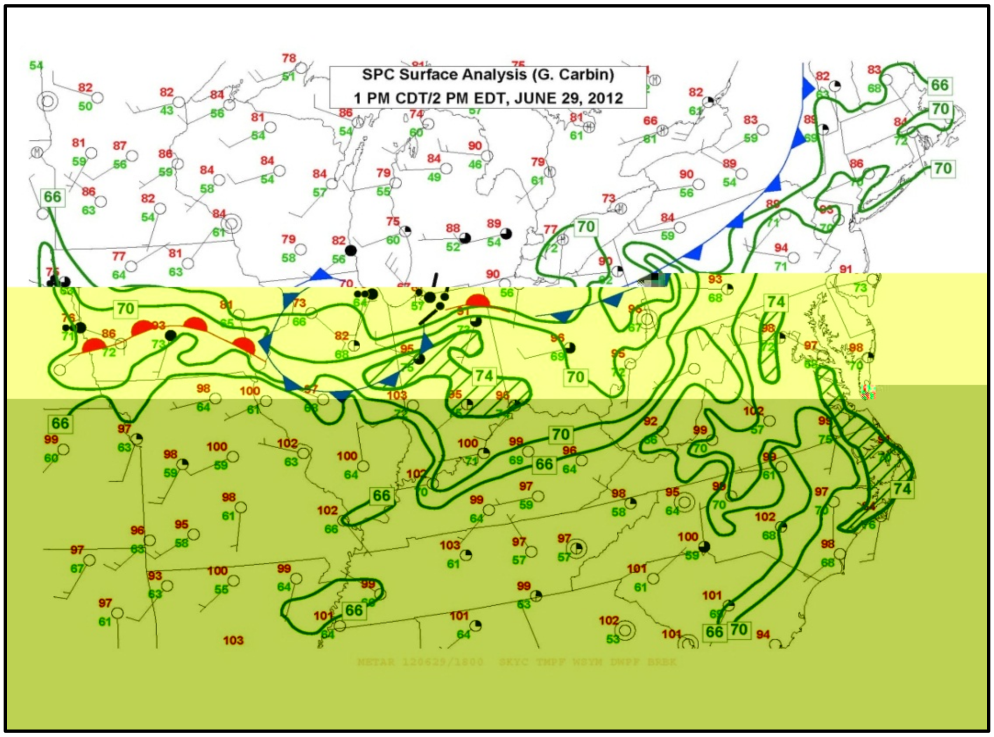

Figure 3: Surface map at 2 p.m., June 29, 2012. Surface dewpoints greater than 66 degrees Fahrenheit (°F) are contoured in green. Courtesy of SPC

Figure 4 is a 12-hour forecast of surface-based Convective Available Potential Energy (CAPE) from the NAM model valid at 8 p.m. on June 29, 2012. Values above 4000 Joules/kilogram (red and white shaded areas) indicate an extremely unstable air mass, the potential for explosive thunderstorm development, and the possibility for a long-lived MCS if storms were to form.

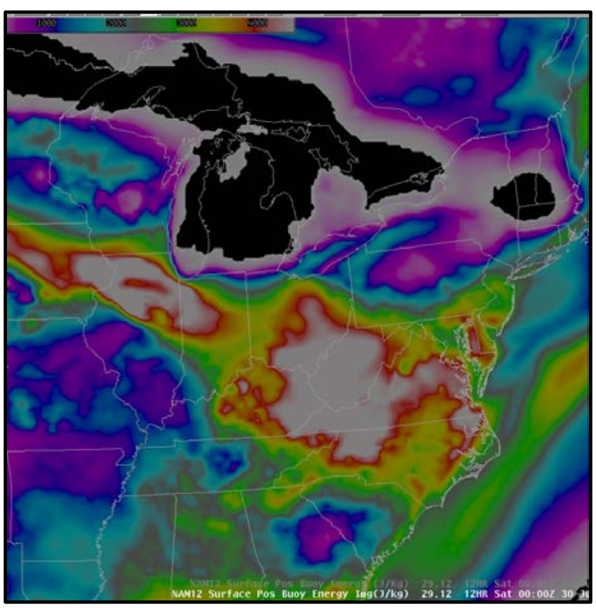

Figure 4: 12-hour forecast of CAPE from the NAM model valid at 8 p.m., June 29, 2012

The initial thunderstorms that formed the derecho developed north of the west-east oriented boundary over Iowa around sunrise (not shown) and became severe in extreme northeast Illinois around noon, June 29. The storms then organized into a large bow echo in eastern Indiana and raced east-southeast at around 60 mph, moving through Ohio, West Virginia, southern Pennsylvania, Maryland, Virginia, Washington, D.C., Delaware, southern New Jersey, and northern North Carolina before moving offshore shortly after midnight eastern time.

Figure 5 displays the progression of the derecho at various time intervals as it moved from Indiana to Maryland.

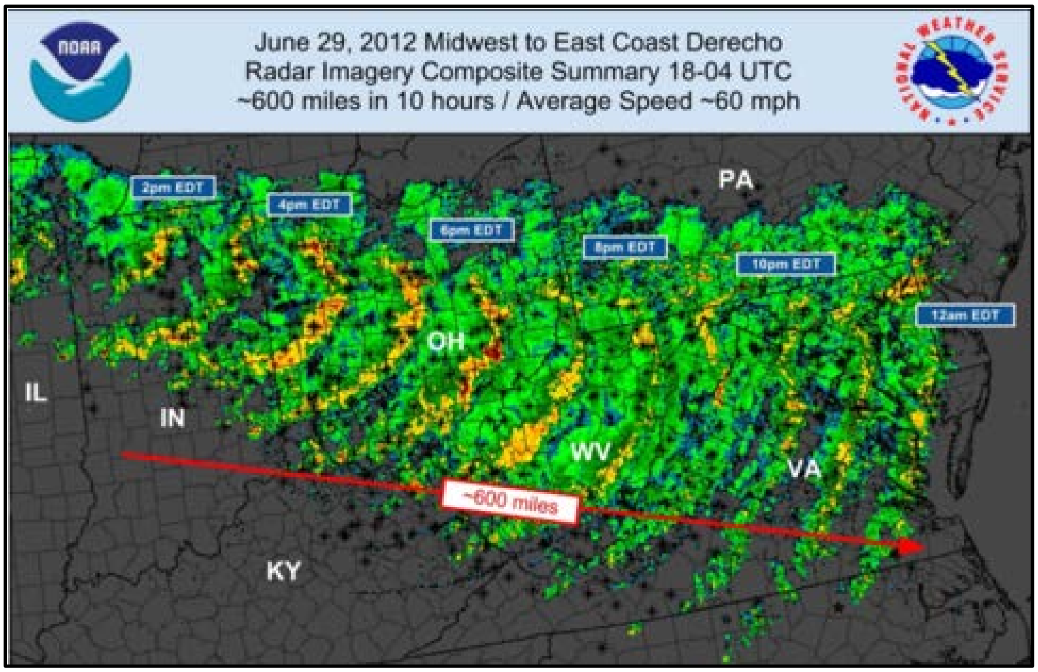

Figure 5: Composite radar imagery showing the path of the derecho. Courtesy of SPC

Figure 6 displays the preliminary severe weather reports from SPC for this event. There were over 1,000 wind damage reports associated with this derecho.

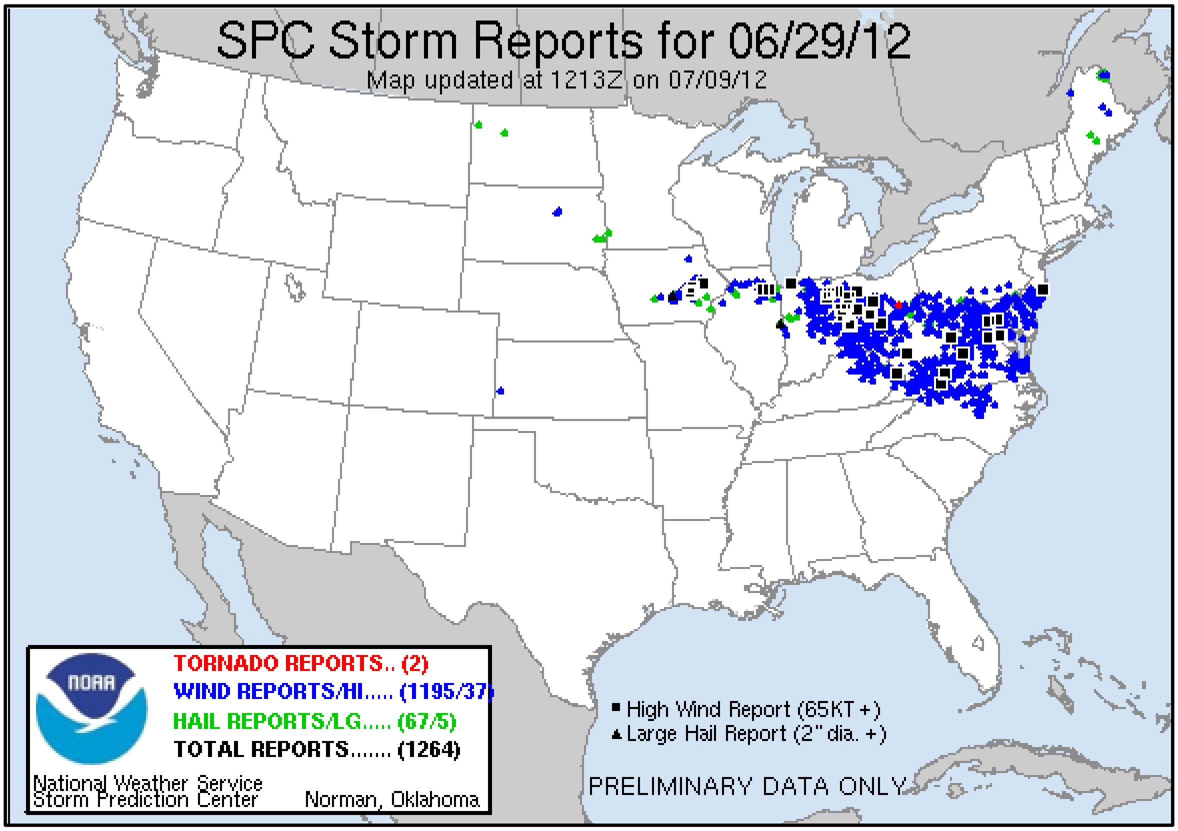

Figure 6: SPC preliminary storm reports for June 29, 2012. Blue dots indicate damaging wind reports. Black squares indicate measured wind gusts 74 mph or greater.

Figure 7 displays the WSR-88D reflectivity and base velocity imagery from Northern Indiana (KIWX) and Sterling, VA (KLWX) as the derecho was moving into the Fort Wayne, IN, and Washington, D.C., areas, respectively. The velocity data show extreme winds in excess of 70 mph at both locations. Nearby Automated Surface Observing System (ASOS) peak wind gusts of 91 mph at Fort Wayne (KFWA) and 71 mph at Dulles International Airport (KIAD) corroborated the radar velocities. Similar winds were reported in southwest Virginia at Roanoke where the ASOS reported a peak wind gust of 81 mph.

Figure 7: WSR-88D Doppler radar reflectivity (left) and base velocity (right) from Northern Indiana (KIWX, top) and Sterling, VA (KLWX, bottom) as the derecho approached Fort Wayne, IN, and Washington, D.C. The bright pink colors in the velocity data indicate wind speeds greater than 70 mph.

4. Facts, Findings, Recommendations, and Best Practices

4.1. Model Performance

Forecasters at the SPC and the WFOs rely heavily on the National Centers for Environmental Prediction (NCEP) operational models to forecast thunderstorms. When models such as the NAM and GFS show a strong signal that thunderstorms will develop in an environment conducive for severe thunderstorms, forecaster confidence is increased that a severe weather event will occur. Typically, forecasters are looking for a coherent precipitation area generated by the models that persists and, in the case of a derecho, moves downstream.

For this event, the 12-km grid-length NAM and approximately 27-km grid-length GFS models did not produce much in the way of precipitation for the time the derecho was occurring. As an example, **Figure 8** is a 12-hour forecast of accumulated precipitation from the NAM valid at 8 p.m. on June 29, 2012. It is obvious from the lack of precipitation displayed that this model was of little use to forecasters trying to anticipate the timing and location of this derecho. The 27-km GFS model (not shown) for the same time period also did not show a strong signal for an MCS or derecho. This lack of signal in the NCEP models from 3 days prior right up to the event significantly impacted the preparation and content of forecasts, outlooks, and decision support.

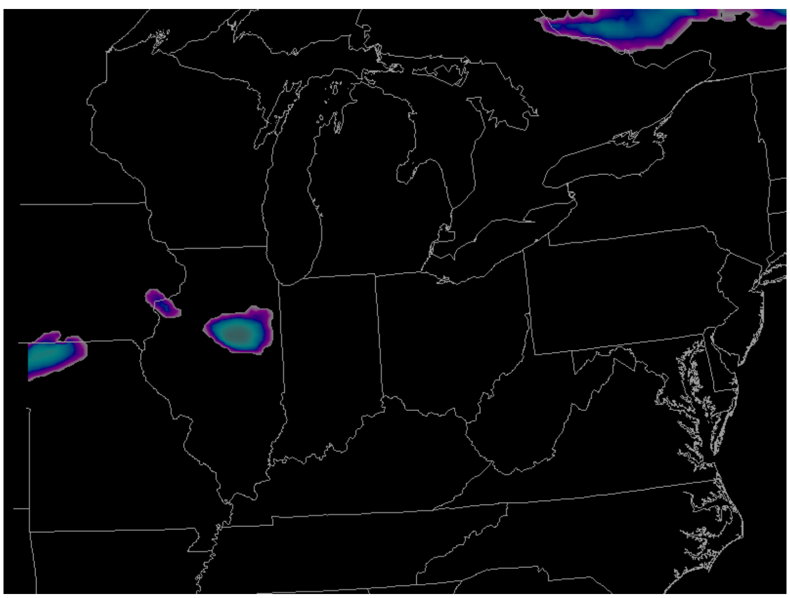

Figure 8: 12-hour forecast of precipitation accumulation from the NAM model valid at 8 p.m., June 29, 2012

On the day of the event, some of the high-resolution convection-allowing models (CAMs) that can explicitly simulate some aspects of thunderstorms, showed signs an MCS would develop and move across the area later affected. Some forecasters at the impacted WFOs were paying close attention to the output of the High Resolution Rapid Refresh Model (HRRR). The HRRR is an experimental 3-km CAM initialized from the 13 km Rapid Refresh (RAP) model and includes radar reflectivity in the data assimilation. It is the only radar-initialized model running routinely at this time. Beginning about 15 hours prior to the event, the HRRR began depicting an MCS over the general region impacted. Forecasters at the WFOs were monitoring the HRRR model runs as they became available, but had some doubts about the model's depiction of a bow echo. These doubts were due to past erratic performance and the lack of a signal from the larger-scale GFS and NAM models.

Figure 9 displays a 10-hour forecast from the HRRR showing radar reflectivity at 5 p.m., June 29 along with the observed radar reflectivity. The figure shows at this time the HRRR was accurately simulating the derecho across the eastern Ohio Valley. Subsequent runs of the HRRR (not shown) also depicted the derecho remaining intact as it crossed the Appalachian Mountains into Virginia and Maryland. A 4-km version of the NAM, also a CAM and run at 6-hr intervals, showed an MCS, but the model lacked consistency from one run to the next. Overall, it appeared WFOs used the CAMs; however, the degree of use varied from one forecaster to another. In addition, it was not clear that all forecasters fully understood the CAM strengths and limitations.

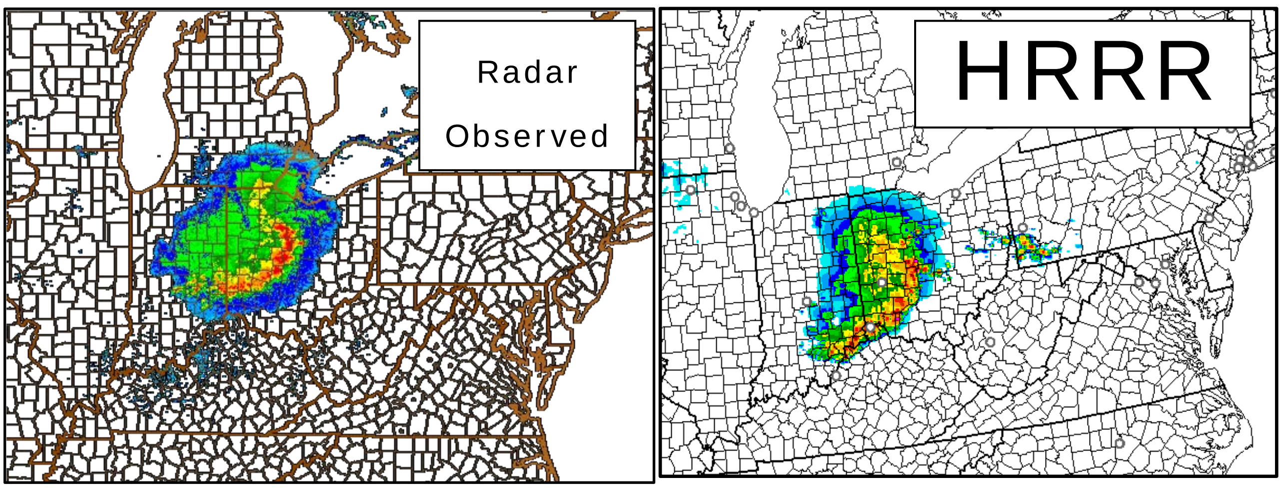

Figure 9: Observed radar reflectivity (left) and 10-hour forecast from the HRRR of radar reflectivity (right) valid at 5 p.m., June 29, 2012

After conducting interviews with numerous SPC staff members, it became obvious SPC staff believe relying on a single CAM, such as the HRRR, for a convective forecast can be a bad practice because convective-scale predictability is often low, especially in weakly forced situations. In these forecasters' experience examining these models daily, the output is not consistently reliable. As a result, SPC staff use an ensemble approach with the CAMs. An ensemble compares multiple models verifying at the same time or takes the average of several model solutions at a specific time. The SPC generates a seven-member ensemble of CAMs to help with its Day 1 convective outlooks (the thunderstorm outlook for the current day discussed in the next section). Some of the members, however, are either experimental or superseded by higher priority model runs at NCEP, such as tropical cyclone model runs. Further, there is no ensemble of CAMs available to help with the Day 2 convective outlook (the thunderstorm forecast for tomorrow). Day 2 ensemble CAM output could increase forecast lead time for derechos such as the one examined here.

Fact: Numerous WFO and SPC forecasters interviewed felt the NCEP operational models, such as the NAM and GFS, were of little value forecasting this derecho. As a result, SPC and WFO forecasters did not anticipate and forecast this event well in advance, affecting the preparation of forecasts and outlooks and initiation of decision support activities. The lack of anticipation also impacted staffing levels at some of the WFOs for this event.

Fact: On the day of the event, some of the convection-allowing models, including the HRRR, were depicting an MCS in the general area eventually affected.

Fact: SPC forecasters prefer an ensemble approach when evaluating convection-allowing model output rather than looking at an individual model.

Finding 1: SPC creates a seven-member ensemble of convection-allowing models to help with the Day 1 Convective Outlook, but some of the members are experimental and others are sometimes superseded by higher priority model runs at NCEP. There is currently no ensemble of convection-allowing model data to help with the Day 2 Convective Outlook, which could help provide additional lead time for events such as this derecho.

Recommendation 1a: The NWS should invest in infrastructure that would provide the computational resources to operationally run the convection-allowing models, and network resources that would allow delivery of the model output to forecasters.

Recommendation 1b: The Environmental Modeling Center (EMC) should work with SPC to develop a fully supported ensemble of high-resolution, convection-allowing models that cover the Day 2 Convective Outlook time period. EMC should then make these data available to WFOs.

Finding 2: Some forecasters at the impacted WFOs were using the convection-allowing models on the day of the event, particularly the experimental HRRR; however, the use and understanding of these models varied.

Recommendation 2: WFOs should add to their required training for forecasters the Cooperative Program for Operational Meteorology, Education and Training (COMET®) module, "Effective Use of High Resolution Models." WFO managers should provide sufficient time for their forecasters to complete the training.

4.2. SPC Products and Services

The SPC's Day 3 Convective Outlook issued in the early morning hours of June 27, valid for June 29, included low probabilities for severe weather, 5 percent within 25 miles of a point, (**Figure 10**) for the region impacted by the derecho. This is below the 15 percent threshold for a Slight Risk of severe thunderstorms, SPC's lowest severe risk category. An excerpt of the text follows:

FORECAST SOUNDINGS ALONG THE BOUNDARY AT 00Z/SAT IN THE OH VALLEY SHOW MLCAPE VALUES ABOVE 3000 J/KG WITH 40 TO 50 KT OF DEEP LAYER SHEAR SUGGESTING SUPERCELLS WILL BE POSSIBLE. HOWEVER...THE MAGNITUDE OF THE SEVERE THREAT REMAINS UNCERTAIN DUE TO WARM AIR ALOFT AND A LACK OF LARGE-SCALE ASCENT. ANY STORM THAT CAN DEVELOP IN SPITE OF THESE LIMITING FACTORS COULD HAVE AN ISOLATED SEVERE THREAT LATE FRIDAY AFTERNOON.

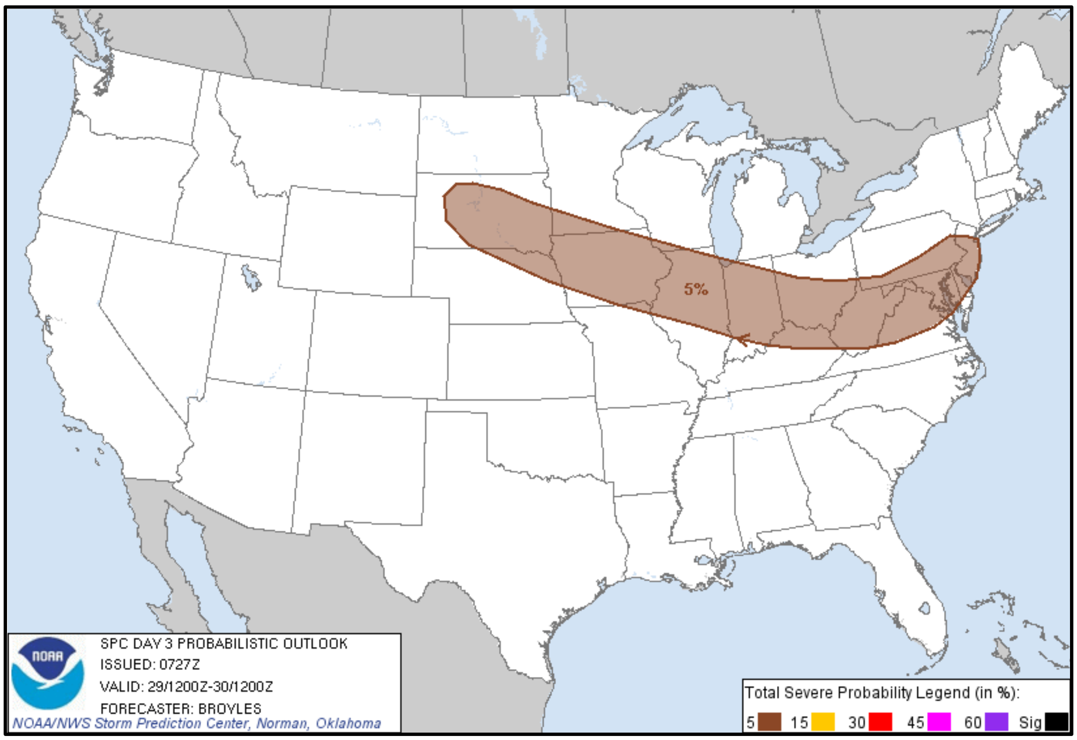

Figure 10: 3:30 a.m., Day 3 Convective Outlook valid June 29, 2012

The same was true for the two Day 2 outlooks issued the following day, the second of which was issued at 1:30 p.m. on June 28 (**Figure 11**).

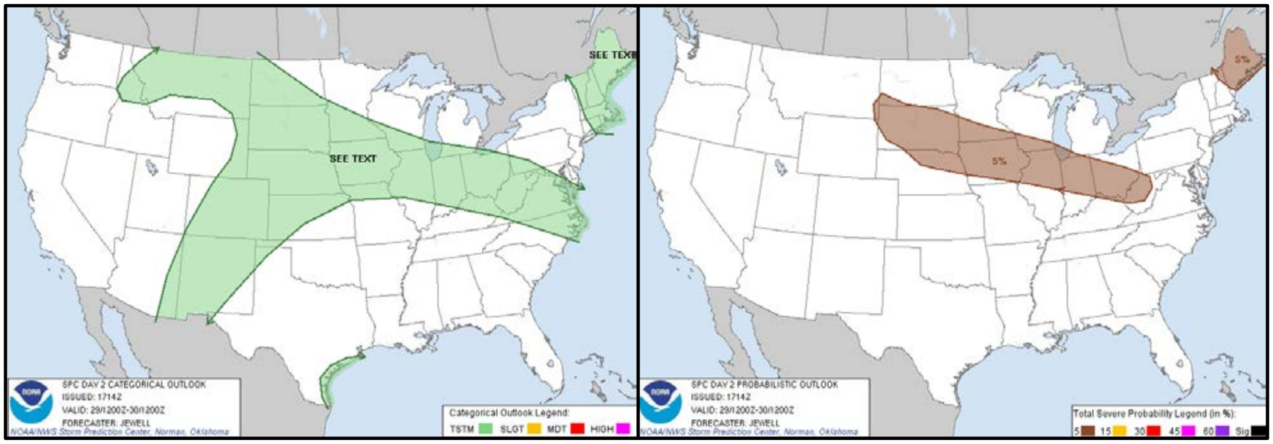

Figure 11: SPC's 1:30 p.m., Day 2 Convective Outlook for June 29, 2012: left is categorical outlook, right is probability of all severe weather

The discussion included the following text: `"SHEAR AND INSTABILITY WILL CONDITIONALLY SUPPORT SEVERE HAIL AND WIND ACROSS THE ENTIRE AREA...BUT THERE WILL BE NO LARGE SCALE SUPPORT FOR WIDESPREAD SEVERE WEATHER."`

The initial Day 1 Outlook issued at 2 a.m., on June 29 included a Slight Risk for severe thunderstorms from Iowa southeastward to western Ohio (not shown), which captured the western area the derecho struck but not areas to the east, including Baltimore and Washington, D.C. The 9 a.m. outlook (**Figure 12**) expanded the slight risk to include Baltimore and Washington, D.C., and added an enhanced region of damaging wind probabilities (30 percent) across the Ohio Valley. SPC Forecasters were now beginning to see evidence of an MCS in the CAMs.

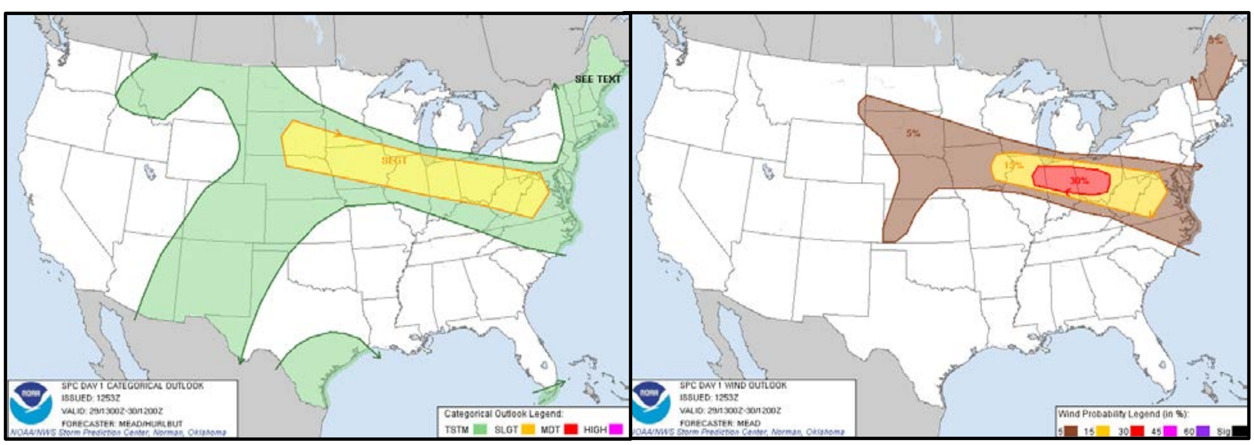

Figure 12: The 9 a.m., June 29, 2012, SPC Day 1 Convective Outlook (left) and damaging wind probabilities (right).

There were no changes made to the forecast after SPC issued the 12:30 p.m., Day 1 Convective Outlook; however, as the event began to unfold, the SPC dramatically heightened the risk potential in its graphical and text forecasts. At 4 p.m., the SPC upgraded the Day 1 Outlook to Moderate Risk downstream of the derecho to the spine of the Appalachians and extended the Slight Risk to the Mid-Atlantic coast. At 9 p.m., the Moderate Risk was extended to the Chesapeake Bay (**Figure 13**).

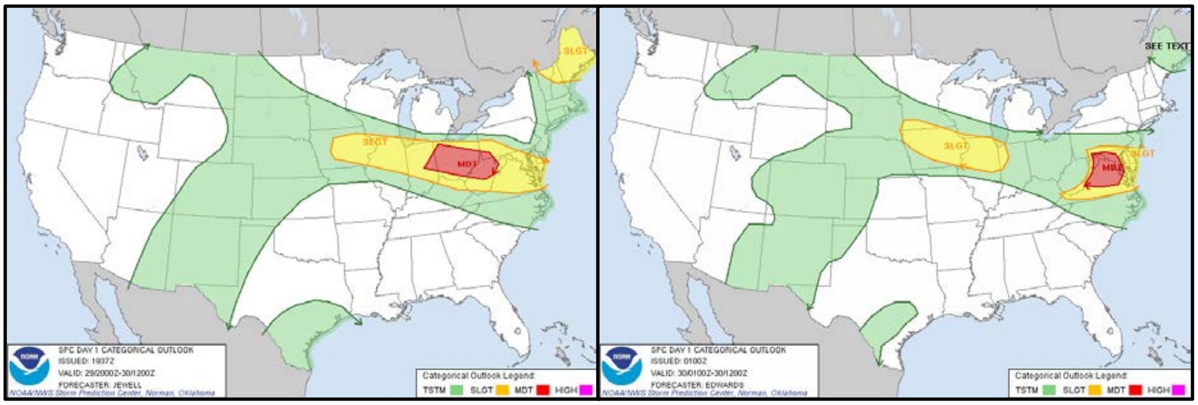

Figure 13: The 4 p.m., June 29, 2012, Day 1 Convective Outlook (left) and the 9 p.m., Day 1 Convective Outlook (right) issued by the SPC.

There were two severe thunderstorm watches that contained strong wording for this event: Watch #436 (issued at 3:05 p.m.) for much of Ohio, parts of Kentucky, and western West Virginia, and Watch #438 (issued at 6:35 p.m.), which covered areas east of the Appalachians including Washington, D.C. (**Figure 14**).

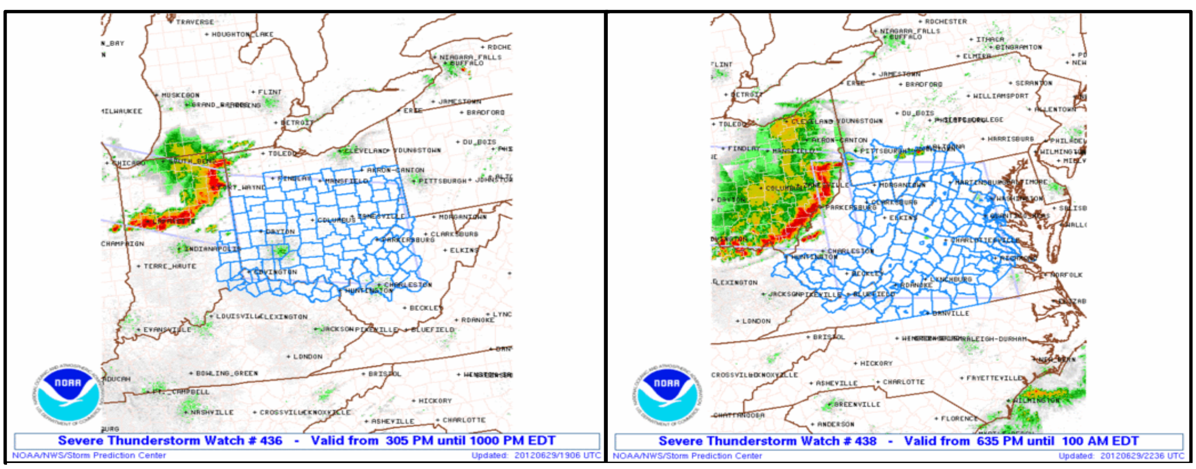

Figure 14: Severe Thunderstorm Watches issued during this event

The text discussion of Watch #436 included the following: "A DEVELOPING MCS/BOW ECHO ACROSS INDIANA IS EXPECTED TO MOVE ESEWD THROUGH THE AFTERNOON/EVENING AT ROUGHLY 50 KT. THE STORM ENVIRONMENT DOWNSTREAM FEATURES STRONG INSTABILITY AND SUFFICIENT DEEP-LAYER FLOW/SHEAR TO MAINTAIN AN ORGANIZED MCS...AND THERE WILL BE THE POTENTIAL FOR WIDESPREAD DAMAGING WINDS /SOME SIGNIFICANT/ WITH THIS BOWING SYSTEM THROUGH THIS EVENING."

Likewise, the text of Watch #438 continued the strong wording**:** "FAST MOVING AND DAMAGING DERECHO OVER OH HAS RESULTED IN WIDESPREAD DAMAGING WINDS. THIS SYSTEM WILL CONTINUE TO TRACK EAST-SOUTHEASTWARD ACROSS THE WATCH AREA THIS EVENING. STORMS MAY LOSE SOME INTENSITY AS THEY MOVE ACROSS THE APPALACHIANS...BUT MOIST AND VERY UNSTABLE AIR MASS OVER VA SUGGESTS THAT THREAT OF AT LEAST SCATTERED SEVERE WIND GUSTS WILL CONTINUE."

There were a few concerns with some of the watches issued for this event. Severe Thunderstorm Watch #438 included Washington, D.C., but not Baltimore. Steve Rubin, WMAR-TV Baltimore, said, *"We pay strong attention to NWS watches and warnings. We all assumed that since we were not under a watch, the storms would die before getting to Baltimore."* He went on to say the station's staff was unsure if they needed to stay through the night to monitor the weather system or if the mountains would *"kill"* the storms like they *"always"* do. At the time Severe Thunderstorm Watch #438 was issued the derecho was just approaching the Appalachian Mountains and was still many hours away from Baltimore. Forecasters at the SPC and WFO Sterling coordinating the watch, much like the Baltimore media, were still uncertain if the derecho would remain intact crossing the Appalachians. Severe Thunderstorm Watch #438 was large in areal extent, allowed for considerable downstream movement of the derecho, and plenty of time for the SPC, the WFOs, and the media to monitor the derecho's progress throughout the evening. The reflectivity, IR satellite cloud tops, and the National Lightning Detection Network's cloud-to-ground lightning strokes all weakened/diminished as the derecho crossed the Appalachians (although wind damage continued) especially on the derecho's south flank, but all three of these indicators later re-intensified over northern Virginia and Maryland.

At about 9:45 p.m., the Lead Forecaster at WFO Sterling called the SPC to coordinate adding the rest of the WFO's Maryland counties, up to the Chesapeake Bay, including the city of Baltimore, in Severe Thunderstorm Watch #438. The storms were nearing the east edge of the watch boundary. SPC asked if WFO Sterling would rather be in a new watch about to be issued, Severe Thunderstorm Watch #439, but the WFO opted for the quicker method of extending Watch #438 locally, via the Watch County Notification (WCN). The MIC at WFO Sterling indicated that had watch #439 been issued earlier, the WFO's preference would have been to include those Maryland counties in the new watch. The extension of Severe Thunderstorm Watch #438 was issued at 9:51 p.m. by WFO Sterling, and SPC issued Severe Thunderstorm Watch #439 at 10:10 p.m. (**Figure 15**). The lead time for the area where the watch was extended was not substantial. Severe thunderstorm warnings were issued for a part of that area as early as 10:10 p.m. by WFO Sterling, and damage reports started coming in prior to 11:00 p.m.

WWUS61 KLWX 300151
WCNLWX

WATCH COUNTY NOTIFICATION FOR WATCH 438
NATIONAL WEATHER SERVICE BALTIMORE
MD/WASHINGTON DC
951 PM EDT FRI JUN 29 2012

MDC003-005-009-013-025-027-037-510-300500-
/O.EXA.KLWX.SV.A.0438.000000T0000Z-120630T0500Z/

THE NATIONAL WEATHER SERVICE HAS EXTENDED
SEVERE THUNDERSTORM
WATCH 438 TO INCLUDE THE FOLLOWING AREAS UNTIL 1
AM EDT SATURDAY

IN MARYLAND THIS WATCH INCLUDES 7 COUNTIES

IN CENTRAL MARYLAND

ANNE ARUNDEL HOWARD

IN NORTH CENTRAL MARYLAND

CARROLL

IN NORTHERN MARYLAND

BALTIMORE HARFORD

IN SOUTHERN MARYLAND

CALVERT ST. MARYS

IN MARYLAND THIS WATCH INCLUDES 1 INDEPENDENT
CITY

IN NORTHERN MARYLAND

BALTIMORE CITY

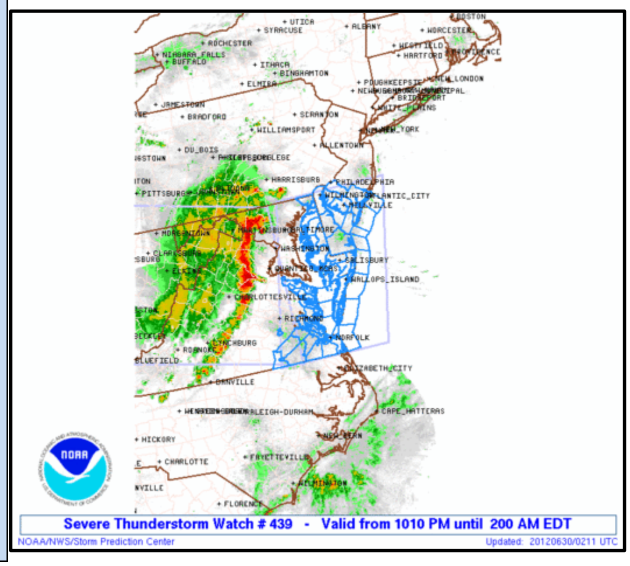

Figure 15: Local extension of Severe Thunderstorm Watch #438 by WFO Sterling at 9:51 p.m. (left), and SPC's issuance of Severe Thunderstorm Watch #439 (right) at 10:10 p.m.

A similar situation occurred early in the event in northwest Ohio. Severe Thunderstorm Watch #435 (not shown) was issued by the SPC at 12:50 p.m. for northern Illinois and northern and central Indiana to the Ohio border. This watch omitted WFO Northern Indiana's six Ohio counties. At 2:15 p.m., WFO Northern Indiana, in collaboration with SPC, locally extended Severe Thunderstorm Watch #435 eastward into four of its northwest Ohio counties: Allen, Paulding, Putnam, and Van Wert. A Severe Thunderstorm Warning was issued for Paulding and Van Wert Counties at 2:48 p.m., 38 minutes after the watch extension. Van Wert County EM Director Rick McCoy stated that the "*warnings came right on the heels of the watch.*" Both counties recorded damages about 30 minutes after the warnings were issued, or about an hour after the watch extension.

Finding 3: WFOs Northern Indiana and Sterling, VA, locally extended severe thunderstorm watches issued by the SPC for counties downstream (east) of the derecho via the WCN; however, there was limited lead time between the issuance of the WCN and the issuance of warnings for the new counties in the watch.

Recommendation 3: SPC and the WFOs should collaborate more closely during these kinds of events. Either SPC should issue watches or WFOs should extend them locally at least 1 hour before warnings are necessary in situations such as this derecho, where it is apparent additional watches will be required downstream.

4.3. WFO Pre-Event Services

The Weather-Ready Nation initiative focuses NWS attention, resources, and expertise toward the key function of providing Decision Support Services (DSS) for a range of NWS partners, including pre-weather event briefings, briefings to elected officials and EMs, critical incident support staff at venues, storm spotter training, and the certification of StormReady communities.

EMs and other partners interviewed cited workshops or briefings held by local WFOs, virtually or in-person, as particularly helpful. This type of outreach allows the NWS to ensure that its community partners are adequately prepared for severe weather and creates a feeling of trust in NWS forecasts. For this derecho, however, DSS and other pre-planning activities were limited because of the difficulty SPC and the WFOs had forecasting the event.

Interviews with forecasters at the affected offices revealed they rely heavily on SPC guidance to forecast severe thunderstorms. Some forecasters mentioned they are willing to deviate from what SPC is forecasting, but only to a limited degree. In addition, forecasters at the WFOs said the NCEP operational models were not showing much in the way of forcing or a precipitation signal for June 29 in the days leading up to the event, so it appeared the potential for a significant severe weather episode on June 29 would be minimal.

Instead, during the morning of June 29, forecasters, especially in the Mid-Atlantic, were focusing more on the possibility for significant severe weather on Saturday, June 30 (including widespread wind damage) in their products and discussions.

On June 29, SPC issued a Slight Risk of severe thunderstorms for June 30 covering much of the Ohio Valley and Mid-Atlantic region in both its Day 2 Convective Outlooks. In its 1:30 p.m. discussion, the SPC forecaster wrote: "ONE DISTINCT SHORTWAVE TROUGH IS EXPECTED TO BE OVER THE IN/OH AREA...AND WILL SPREAD EWD ACROSS PA...WV/VA...AND INTO THE DELMARVA BY 00Z. THIS FEATURE WILL COMBINE WITH AMPLE MOISTURE AND INSTABILITY TO PRODUCE POTENTIALLY SIGNIFICANT SEVERE WIND."

Figure 16 shows the storm reports for June 30. Much of the Ohio Valley and Mid-Atlantic regions were free of severe weather because the derecho on June 29 stabilized the atmosphere in its wake. This event highlights the difficulty forecasters currently face in assessing the potential for extreme wind events in the summer and the need for better tools to improve forecasting capability.

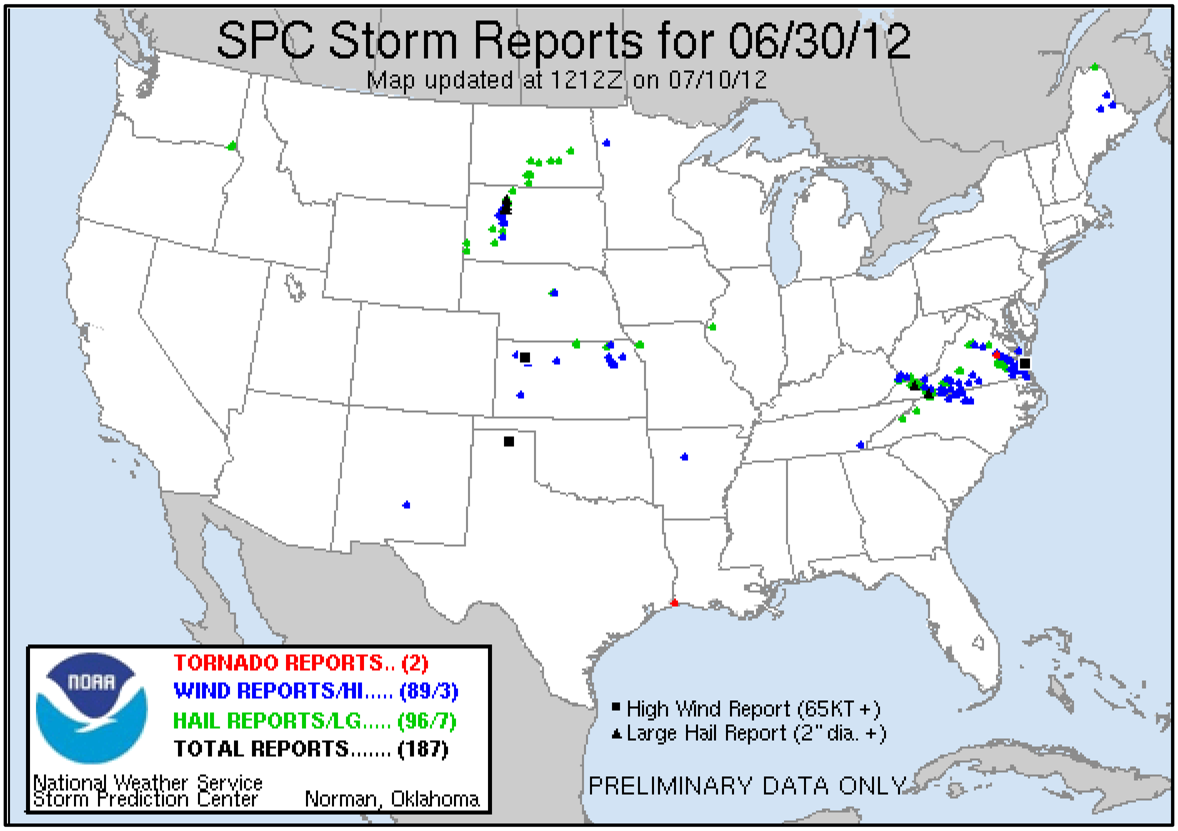

Figure 16: SPC Storm Reports for Saturday, June 30, 2012

Two offices *did* provide beneficial pre-event information to decision makers: WFO Wilmington and WFO Pittsburgh. On Wednesday, June 27, WFO Wilmington briefed partners via email about thunderstorm potential that Friday (2 days hence): *"There are signals that on Friday [June 29] that as a weak front slips into the area…there may be just enough spark to initiate a cluster of storms moving through portions of Ohio/Indiana/Kentucky. Timing and area affected are extremely low confidence…but the weather setup is such that if something can get going…the setup is primed for a higher level damaging wind event that may cause widespread wind damage."*

In addition, the 4:47 p.m. Area Forecast Discussion (AFD) issued by WFO Wilmington on June 27 included the following text: "IF WEAK SYSTEMS IN INCREASINGLY NWLY MID LEVEL FLOW CAN ERODE CAPPING...A HIGH END DAMAGING WIND MCS EVENT IS POSSIBLE...AS THE SYNOPTIC SETUP WILL BE AN IDEAL DERECHO TYPE ENVIRONMENT WITH EXTREME INSTABILITY ON THE EDGE OF THE CAP AND STRONG NWLY MID LEVEL FLOW." Despite the expression of significant uncertainty, this language captured the attention of EMs and other decision makers.

On June 27, staff at WFO Wilmington, OH, and the EM for Gallatin County, KY, began coordinating with regard to a NASCAR race to be held at Kentucky Speedway on the evening of June 29. An estimated 30,000 spectators attended the race, thousands of whom were camping in tents at the site. As the derecho was approaching, the Warning Coordination Meteorologist (WCM) was in frequent contact with the EM, providing updates on the progress of the storm.

The WFO provided 30 minutes of lead time for the track, enough time for people to seek shelter. Despite damage at the track, no injuries were reported. As a testament to how crucial this support turned out to be, the EM working the Speedway venue said: *"it would have been too late if Mary Jo [the WCM] had not called when she did."*

WFO Pittsburgh issues briefing packages to core partners when significant weather is occurring or expected. These packages are sent via email and consist of annotated slides that are easy to interpret. A briefing package was sent on the midnight shift the morning of June 29. Included in the material were graphics from the 4 km NAM model showing an MCS moving across the Appalachians and the southern portion of Pittsburgh's County Warning Area (CWA) during the early evening hours of June 29. This briefing package gave decision makers some advance notice that severe thunderstorms were a possibility later in the day.

4.4. WFO Warning Services

All of the WFOs were staffed sufficiently to provide warning services for this event; however, because this event was not anticipated well in advance, some offices could have been better prepared and benefitted from additional staffing to handle the high volume of incoming phone calls and to monitor NWSChat (discussed in section 4.5) and social media. In a few WFOs, the day shift went home for a period because the derecho was still several hours away and there remained uncertainty about whether the MCS would remain intact crossing the Appalachians. Forecasters then returned to the office during the evening as the derecho approached. The team found no significant lapses in warning services related to the level of staffing at each of the WFOs. WFO Wilmington was particularly well staffed with 10 people working the event. Duties were assigned during the morning hours on June 29. Staff members had very specific roles and responsibilities. One staff member was designated as the Warning Coordinator who oversaw the WFO severe weather operations and maintained situational awareness for the office without getting bogged down in specific duties.

During the event, all the offices visited used sectorized warning operations by either dividing the duties by product type (i.e., one person issuing warnings and another issuing follow-up statements), or by geographic area (i.e., one person issuing warnings and follow-up statements north and another person issuing warnings and follow-up statements in the south).

Best Practice: WFO Wilmington staffed for the derecho well ahead of time, defining clear roles and responsibilities and selecting a Warning Coordinator.

Figure 17 shows the warning polygons issued for this derecho. For the most part, warning forecasters appropriately chose to issue large polygons for this event. Overall, storm-based lead times were excellent and exceeded 30 minutes; however, the team found several examples where the leading edge of the derecho was already exiting the eastern edge of one polygon before the next polygon was issued downstream. This essentially led to zero or negative lead time for residents on the western fringes of some polygons. In these situations, the polygons generally were not overlapped. It appeared some of the warning forecasters, especially early in the event, were challenged by the rapid forward progress of the derecho. WFO Sterling had average lead times of up to 1 hour, but employed a different strategy. They chose to overlap warning polygons by up to 50 percent. This resulted in many locations receiving two warnings for the derecho as it moved through.

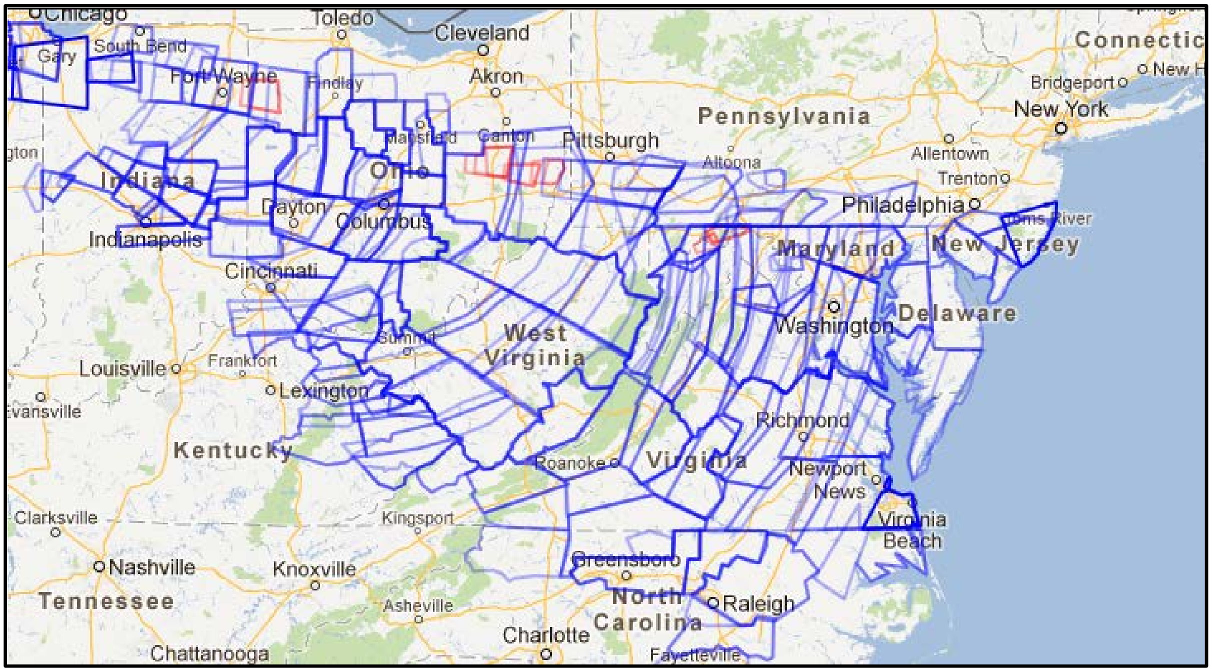

Figure 17: Google Map of warning polygons issued for the event. Darker line segments are where multiple polygons share a common boundary. Blue polygons are severe thunderstorm warnings, red are tornado warnings.

Finding 4: Many WFOs had some difficulty keeping up with the rapid forward progress of the derecho, which was approximately 60 mph. This resulted in minimal lead time near the western fringes of several warning polygons issued for this event. Two warning techniques were employed at the WFOs: an overlapping and non-overlapping polygon methodology.

Recommendation 4: The Warning Decision Training Branch (WDTB) should develop a computer-based training module that defines and demonstrates the optimal warning polygon methodology for rapidly moving MCSs such as this derecho. WFO training plans should be updated to include this module for FY13, and NWS mangers should provide time for warning forecasters to complete the training.

The large polygons presented some challenges because of the number of counties (and in some cases independent cities) they captured. Some forecasters indicated that the number of counties was considered when determining the size of warning polygons. **Figure 18** shows the top portion of a Severe Thunderstorm Warning from WFO Charleston for this event. Fifteen counties were included in the warning. NWS Directive 10-511, WFO Severe Weather Products Specification, states that WFOs should limit the number of counties/parishes in a severe thunderstorm warning to 12 or less to match Emergency Alert System (EAS) limits; however, the team found there were no issues with EAS activation or media Web crawls related to warnings with more than 12 counties. Despite the lack of issues, the warning format produced by the Advanced Weather Interactive Processing System (AWIPS) software program WarnGen contains considerable amounts of redundant location text, resulting in long NOAA Weather Radio-All Hazards (NWR) broadcast cycles for large polygons.

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WUUS51 KRLX 292234
SVRRLX
OHC053-087-WVC005-007-011-013-015-021-035-039-043-053-079-087-105-
292330-
/O.NEW.KRLX.SV.W.0071.120629T2234Z-120629T2330Z/

BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDER
STORM WARNING
NATIONAL WEATHER SERVICE CHARLESTON WV
634 PM EDT FRI JUN 29 2012

THE NATIONAL WEATHER SERVICE IN CHARLESTON HAS ISSUED A

* SEVERE THUNDERSTORM WARNING FOR...
  NORTH CENTRAL BOONE COUNTY IN WEST VIRGINIA...
  WEST CENTRAL BRAXTON COUNTY IN WEST VIRGINIA...
  NORTHEASTERN CABELL COUNTY IN WEST VIRGINIA...
  CALHOUN COUNTY IN WEST VIRGINIA...
  THIS INCLUDES THE CITY OF GRANTSVILLE...
  NORTHWESTERN CLAY COUNTY IN WEST VIRGINIA...
  SOUTHERN GILMER COUNTY IN WEST VIRGINIA...
  JACKSON COUNTY IN WEST VIRGINIA...
  THIS INCLUDES THE CITY OF RIPLEY...
  KANAWHA COUNTY IN WEST VIRGINIA...
  THIS INCLUDES THE CITIES OF...NITRO...CHARLESTON...
  NORTHEASTERN LINCOLN COUNTY IN WEST VIRGINIA...
  SOUTHERN MASON COUNTY IN WEST VIRGINIA...
  PUTNAM COUNTY IN WEST VIRGINIA...
  THIS INCLUDES THE CITY OF WINFIELD...
  ROANE COUNTY IN WEST VIRGINIA...
  THIS INCLUDES THE CITY OF SPENCER...
  WIRT COUNTY IN WEST VIRGINIA...
  THIS INCLUDES THE CITY OF ELIZABETH...
  SOUTH CENTRAL GALLIA COUNTY IN SOUTHEAST OHIO...
  EAST CENTRAL LAWRENCE COUNTY IN SOUTHEAST OHIO...
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Figure 18: Severe thunderstorm warning issued by WFO Charleston for 15 counties, 3 more than the 12 county system limit

Finding 5: The current severe thunderstorm warning format used by the AWIPS software program, WarnGen, results in considerable redundant text in the warning location portion, leading to long NWR broadcast cycles during MCS events such as this derecho.

Recommendation 5: NWS Headquarters should develop a new warning format that eliminates redundant text in the location portion of severe thunderstorm warnings.

Currently, WarnGen is configured to allow a maximum of 20 vertices when configuring a warning polygon for dissemination. This configuration is in line with NWS Directive 10-511. The 20 vertex limit resulted in a damage report occurring outside of a warning polygon in WFO Sterling's CWA during this event. The team discovered this limit is insufficient at times when warnings are drawn along irregularly-shaped coastlines. **Figure 19** is a Google Map representation of a portion of a severe thunderstorm polygon drawn over southeast Maryland, on the western shore of the Chesapeake Bay, during this event. The damage report that was outside of the polygon due to the 20 vertex limitation is represented by a star.

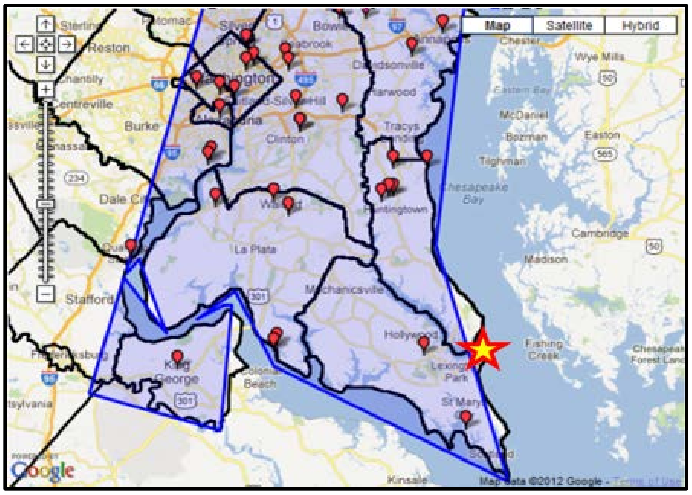

Figure 19: Google representation of WarnGen polygon where damage report (i.e., the star) fell outside warning polygon because of 20 vertex limit

Finding 6: WarnGen is currently configured to allow a maximum of 20 vertices for warning polygon generation. This limit forced WFO Sterling to exclude parts of the western shore of the Chesapeake Bay from its warning.

Recommendation 6: The minimum number of vertices needed to issue warnings along irregular coastlines needs to be determined. NWS Headquarters should then make the necessary adjustments to WarnGen software.

The vast majority of the warnings for this event contained wind speed wording above the lower boundary threshold of 60 mph. Many warnings included winds of up to 80 mph in the warning text. In some of its warnings, WFO Wilmington included the wording: "THESE ARE DANGEROUS STORMS! IF YOU ARE NEAR THEIR PATH...YOU SHOULD PREPARE FOR VIOLENT STRAIGHT LINE WINDS AS DESTRUCTIVE AS A TORNADO."

Likewise, WFO Wakefield stated in several of its warnings: "THESE STORMS HAVE A HISTORY OF PRODUCING WIDESPREAD DAMAGING WINDS ACROSS WESTERN VIRGINIA. THIS IS AN EXTREMELY DANGEROUS SITUATION. SEEK SHELTER NOW INSIDE A STURDY STRUCTURE AND STAY AWAY FROM WINDOWS. THESE STORMS HAVE THE POTENTIAL TO CAUSE SERIOUS INJURY AND SIGNIFICANT DAMAGE TO PROPERTY."

WFO Blacksburg included very strong wording in some of its warning text including: "THIS STORM HAS THE POTENTIAL TO CAUSE SERIOUS INJURY AND SIGNIFICANT DAMAGE TO PROPERTY. MOVE TO A BASEMENT OR TO AN INTERIOR ROOM ON THE LOWEST FLOOR OF A STURDY SHELTER NOW. EVACUATE MOBILE HOMES AND MOVE INSIDE A STURDIER STRUCTURE. IF NONE IS AVAILABLE SEEK SHELTER IN A DITCH OR OTHER LOW SPOT AND COVER YOUR HEAD."

Other WFOs used similar strong wording in their warnings. Despite the use of strong (i.e., enhanced) wording in many of the warnings, people were almost universally surprised by the ferocity of this derecho, including members of the EM community, the media, and the general public. For example C.W. Sigman, the Deputy Emergency Manager for Kanawha County, WV, stated, *"We were warned that there was a severe thunderstorm, but didn't know the severity of the event."*

Even though the Sterling office referenced winds of up to 80 mph in its warnings for the Washington, D.C., area, Chuck Bell of WRC-TV Washington, D.C., stated, *"We were expecting thunderstorms, hail and wind, but I don't think the NWS saw the hurricane force winds coming."*

The team conducted numerous interviews with the public along with a few focus groups to gain an understanding of how the greater population viewed and responded to this event. The results of this investigation are discussed in detail in Section 5. Many of the respondents believed the warnings were inadequate for this event. They wanted a clear indication of the intensity and severity of the storms in the warning text (e.g., they wanted to know if the storms would be extreme or typical). Most people interviewed were surprised by the intensity of the winds and damage.

These statements emphasize the need for wording in warnings that achieves the appropriate response. The NWS Central Region is conducting an Impact-Based Warning (IBW) Project in which severe thunderstorm and tornado warnings issued by two Kansas WFOs and three Missouri WFOs contain specific impacts expected to result from a given severe storm or tornado. An example is contained in Appendix F. The goal of the experiment is to provide more information to decision makers and to improve the public response to warnings. Interviews with EMs from this event indicated there was a need for this type of information.

On June 28, 2012, FEMA activated Wireless Emergency Alerts (WEA) for the NWS to begin triggering 90-character alerts on WEA-cabable cell phones for a predefined set of NWS warning types. Throughout the area impacted by the derecho, however, citizens were not alerted for severe thunderstorms via WEA because they are not part of the predefined set. The NWS triggers WEA by pushing machine-coded and specially tagged Common Alerting Protocol (CAP) messages to FEMA's Integrated Public Alert and Warning System (IPAWS) for processing and forwarding to wireless carriers. Since NWS CAP messages are constructed through the post-processing of NWS warnings, forecasters have no explicit control over which CAP messages are tagged to trigger WEA nor do forecasters have control of the 90-character WEA message content.

The NWS Central Region puts threat tags (expected maximum hail size and wind gusts) at the bottom of severe thunderstorm warnings (Appendix F), which could be used in post-processing to trigger WEA for high-end severe thunderstorms. Future NWS warning tools could allow forecasters to natively control which warnings trigger WEA as well as the content of the WEA message.

Finding 7: Despite the use of enhanced wording in many of the warnings, nearly everyone interviewed was surprised by the intensity of the winds with this derecho. As a result, most people surveyed did not take any special precautions as the storms moved through their area.

Recommendation 7: To promote a better public response, the NWS should experiment with new approaches for highlighting impact-based wording in severe thunderstorm warnings, especially during unusual events. NWS should collaborate closely with social scientists to develop wording clearly defining impacts of storms based on their severity.

Finding 8: Starting June 28, 2012, the day prior to the derecho, NWS began triggering 90-character Wireless Emergency Alert (WEA) messages for a predefined set of NWS warning types. Tornado warnings trigger WEA, but severe thunderstorm warnings currently do not.

Recommendation 8a: The NWS should implement agency-wide the threat tags used at the bottom of Central Region warnings. NWS should then leverage those tags to trigger WEA for extreme severe thunderstorm events such as this derecho.

Recommendation 8b: Future NWS warning tools should allow WFO forecasters to natively control which warnings trigger WEA as well as the content of the WEA message.

All of the WFOs involved successfully disseminated damage information via the Local Storm Report (LSR). One office in particular, WFO Northern Indiana, stood out by providing exceptionally timely LSRs. Between 1:48 p.m. and 7:03 p.m., Friday, June 29, WFO Northern Indiana issued a remarkable 69 LSRs, more than 10 per hour. Many of these products contained either significant damage information or strong measured wind gusts. This information was cited by decision makers as being invaluable for situational awareness. The Northern Indiana LSRs also were used by WFOs downstream to monitor the developing derecho's intensity.

Best Practice: WFO Northern Indiana issued exceptionally timely and frequent LSRs during and immediately after the derecho moved through its forecast area.

WFOs Indianapolis and Jackson issued graphical Nowcasts for this event, a visual representation of the significant weather expected over a 2- to 3-hour period. These Nowcasts were posted prominently on NWS Web pages. **Figure 20** is a graphical Nowcast issued by WFO Indianapolis during the beginning stages of the derecho. The graphic provides useful, easy-to-understand information for decision makers and the public.

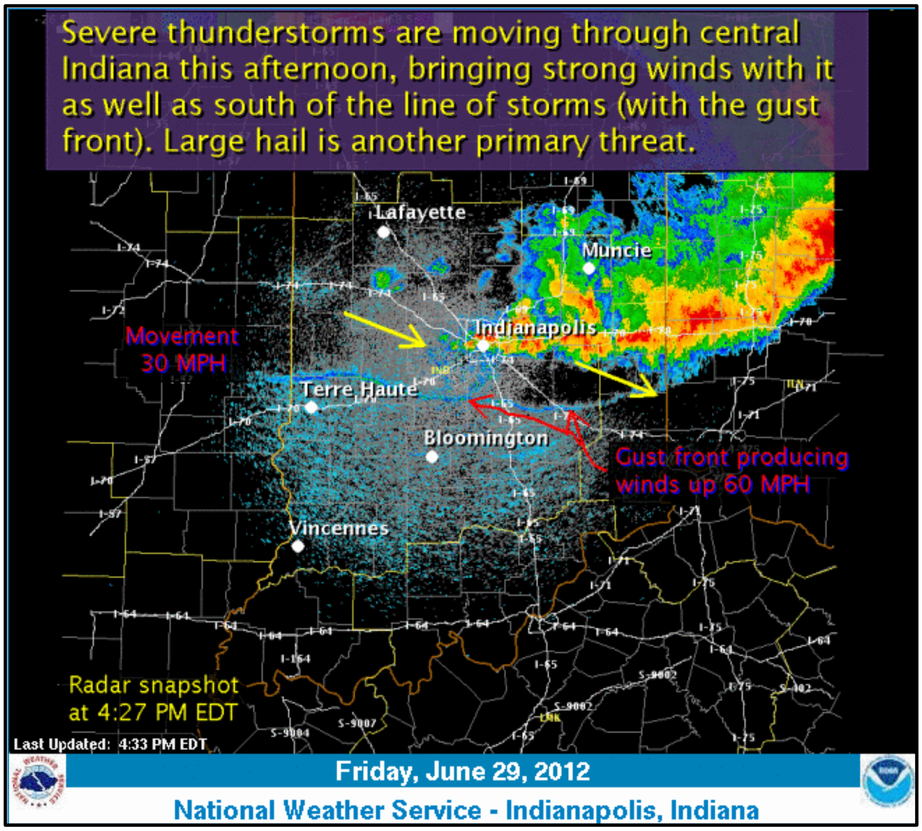

Figure 20: Graphical Nowcast issued by WFO Indianapolis during this event

Best Practice: WFOs Indianapolis and Jackson issued graphical Nowcasts during this event, providing useful short-term information on the derecho for decision makers and the general public.

WFO Sterling issued two strongly worded Special Weather Statements (SPS) alerting the public about the derecho: one at 7:47 p.m. while the derecho was in West Virginia and the other at 9:35 p.m. when the derecho was beginning to affect the Washington, D.C., metropolitan area. The text of the 9:35 p.m. SPS is included in **Figure 21**. Both SPSs gave advance notice the derecho was coming and provided additional storm impact information to supplement the warnings issued. To give the public advance notice the MCS was approaching, WFO Cleveland issued several SPSs for counties downstream of the derecho up to 2 hours before issuing warnings.

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935 PM EDT FRI JUN 29 2012

...EXTREMELY DANGEROUS THUNDERSTORMS TO IMPACT  BALTIMORE
AND WASHINGTON REGION THIS EVENING...

AT 9:30 PM...A LINE OF SEVERE THUNDERSTORMS PRODUCING DAMAGING
WIND GUSTS WAS CROSSING WESTERN MARYLAND AND THE EASTERN PANHANDLE
OF WEST VIRGINIA. THIS LINE OF THUNDERSTORMS IS EXPECTED TO HIT
CENTRAL MARYLAND AND THE WESTERN SUBURBS OF WASHINGTON DC BETWEEN
10 AND 10:30 PM...THE INTERSTATE 95 CORRIDOR INCLUDING WASHINGTON
DC AND BALTIMORE BETWEEN 10:30 AND 11 PM...THEN REACH THE
CHESAPEAKE BAY BETWEEN 11:30 AND MIDNIGHT.

THIS LINE OF STORMS HAS A HISTORY OF PRODUCING MAJOR WIND DAMAGE
ACROSS WESTERN MARYLAND AND EASTERN WEST VIRGINIA DUE TO WIND
GUSTS OVER 75 MPH...ALONG WITH PROLIFIC CLOUD TO GROUND LIGHTNING.

THIS IS A PARTICULARLY DANGEROUS SITUATION THIS EVENING. RESIDENTS AND
VISITORS TO THE REGION SHOULD START PLANNING NOW TO PROTECT LIFE
AND PROPERTY THROUGH SEEKING SHELTER IN A STURDY BUILDING WHEN
WARNINGS ARE ISSUED FOR YOUR AREA.

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Figure 21: SPS issued by WFO Sterling as the derecho approached the D.C. metro area

Best Practice: WFO Sterling issued two high-impact SPSs to provide advance warning of the derecho that struck the region during the evening of June 29. Likewise, WFO Cleveland issued several SPS up to 2 hours ahead of the derecho to give advance notice of its arrival.

In summary, the team found NWS warnings for this event, with a few exceptions, were very good. The team identified a few best practices through the course of this investigation. The team also determined there is a need for impact-based warnings to better convey the expected threat from severe thunderstorms, and that a redesign of the warning template is needed to reduce redundancy in the location information of the warning text.

4.5. NWSChat and Social Media

NWSChat is an Instant Messaging program used by NWS staff to share critical weather information essential to the NWS's mission of saving lives and property. Information is exchanged in real-time between the NWS and the media and/or EMs— especially during high impact severe weather and hydrologic events. This sharing of information is beneficial to all parties involved and to the public who receives warnings during high impact events.

It was clear that NWSChat was used to some degree at all locations, but WFOs Northern Indiana and Wilmington, OH, made the most extensive use of it. These WFOs assigned more available staff to NWSChat during the event. The team determined the media and EMs preferred the personal interaction with NWS staff that NWSChat provided. Jonathon Conder from WANE-TV Fort Wayne, IN, said, *"NWSChat is the best thing in the world for severe weather coverage."* Fred Griffin, an EM from Wayne County, IN, stated, *"NWSChat has been a real benefit."*

Best Practice: WFOs Northern Indiana and Wilmington aggressively used NWSChat during the derecho event.

The affected WFOs used Facebook and Twitter for information sharing. Social media messages are generally shorter than many of the NWS products. This shortening may be the result of medium constraints (e.g., the 140-character limit of Twitter) or of commonly accepted protocols (e.g., overly long status updates are disdained by many Facebook users). The team found that Facebook and Twitter messages recast NWS product information in easy-to-understand terms.

Shorter messages also increase the use of heightened, sharper language. Regular users of social media have learned to create attention-grabbing messages. In addition, digital and social media also allow the use of images and encourage feedback and even dialogue. Thus, when a severe weather product includes brief but highly image-driven language, such as *"90-mile-per-hour winds that will likely topple trees,"* this message is more likely to be of interest and disseminated across various media platforms, resulting in more appropriate public actions.

The team found all offices visited used both Facebook and Twitter to convey severe weather information, but for many offices, Twitter was a newly implemented tool. Some WFOs had been using Twitter for only 1-2 weeks prior to the derecho. Several of the offices sent out severe weather information via Facebook and Twitter using the software program *Hootsuite*, which allows the user to monitor multiple information feeds and post to Facebook and Twitter simultaneously. Several of the offices received damage information back through social media, but the amount was tempered by the widespread loss of power and cell service from the derecho. WFO Cleveland indicated it received several reports via Twitter in and around its warning area during this event, often before receiving reports from spotters.

Finding 9: Nearly all conversations with members of the media highlighted the usefulness of Facebook and Twitter in reaching the public and in receiving observations and damage reports throughout the viewing area.

Recommendation 9: NWS should expand the use of social media for reaching the public and receiving observations and damage reports during high-impact events. NWS should consider a virtual volunteer program to support social media operations similar to the SKYWARN program.

4.6. Service Backup

WFO Charleston, WV, required extended service backup because it lost communications after the derecho. Service backup occurs when a WFO is incapable of performing part or all of its operational functions and its sister WFO assumes those responsibilities. The backup occurred in multiple periods over several days and involved both the primary backup office, WFO Pittsburgh, PA, and the secondary backup office, WFO Jackson, KY. WFO Pittsburgh handled routine forecast products and WFO Jackson issued short-fuse warnings, as necessary. Initial full service backup took place around 11:30 p.m. on June 29 when WFO Charleston experienced its first communications failure. Service backup ended around 6:30 a.m. on June 30 when WFO

Charleston regained communications. WFO Charleston lost communications again from 11:30 a.m. until 1:45 p.m. and WFOs Pittsburgh and Jackson once again provided service backup.

At 7:15 p.m. on June 30, communication lines went down for a third time. Arrangements had been made to send two staff members from WFO Charleston to WFO Pittsburgh to operate remotely because the outage was expected to last several days. The two WFO Charleston staff members arrived at WFO Pittsburgh and assumed WFO Charleston operations at approximately 11 a.m. on July 1.

A severe weather event developed during the evening and the two detailed Charleston forecasters issued 18 warnings for the WFO Charleston CWA. Based on interviews with one of the WFO Charleston forecasters (at WFO Pittsburgh), they needed more help during the evening hours of July 1 when the severe weather event and routine product deadlines were peaking; however, they were able to keep up with the severe weather impacting their County Warning Area. They ended their shift at 11 p.m. on July 1 and returned at 10 a.m. on July 2. During that time, WFO Pittsburgh used extra staff to maintain WFO Charleston's operations. WFO Charleston resumed full operations around 4 p.m. on July 2. The two WFO Charleston forecasters stayed at WFO Pittsburgh until July 3 at 9:30 a.m., when it was clear WFO Charleston's communications problems had been resolved.

Outgoing communications from WFO Sterling were lost on Saturday afternoon, June 30. WFO Sterling's primary backup, WFO Mt. Holly, NJ, took over for WFO Sterling for a 28-hour period ending early Sunday evening, July 1. The WFO Sterling MIC held a conference call with his staff at approximately 4:30 p.m., Sunday, to discuss a plan to send staff to Mount Holly; however, communications were restored shortly after the call so the plan was not carried out.

4.7. Spotter Activation and Training

The NWS has an extensive network of volunteer observers, or storm spotters, who are trained in their local communities to offer real-time observations or ground truth for WFO forecasts and warnings. Throughout the severe weather season, this spotter network is activated prior to or during a high-impact event, which means these individuals volunteer to report their weather observations to the local WFO as a way to verify warnings. Many EMs said spotter networks were not activated for this derecho or that they were not made aware of the activation. Because this event's impact on local communities resembled the impact of a tornado, such activation could have better prepared these EMs to engage with their communities.

Another key aspect of developing a reliable and useful spotter network is continuing and comprehensive training. The derecho is a relatively rare severe weather event, and many EMs and storm spotters reported feeling caught off guard about the nature and intensity of the event. Specifically, they want better instruction on the conceptual model of a derecho and more details about the science, for example, that it can occur during a drought. They would like this education to include an emphasis on impacts or other information explaining why this severe weather event is significant (e.g., a derecho is a large scale, multi-state event that could lead to widespread power outages).

Finding 10: EMs felt that information regarding the derecho was not covered in-depth during spotter training and that providing this information along with impacts would enable them to better plan for these events.

Recommendation 10: WFO WCMs in areas susceptible to derechos should supplement their spotter training program with information on derecho science, identification, and impacts.

4.8. StormReady® Program

The NWS designed the StormReady program to help communities better prepare for and mitigate effects of extreme weather-related events. StormReady also helps establish a commitment to creating an infrastructure and systems that will save lives and protect property. StormReady recognition for a county means that the county has complied with the criteria for warning coordination as established by the NWS. This criteria includes:

- Establishing a 24-hour warning point and emergency operations center
- Having more than one method of receiving severe weather forecasts and alerting the public
- Creating a system that monitors local weather conditions
- Promoting the significance of public readiness through community seminars
- Developing a formal hazardous weather plan that includes training severe weather spotters and holding exercises

One of the goals of this assessment was to determine if the warning and response process for this derecho differed in StormReady-recognized counties versus counties not recognized. The team found that counties that were not StormReady-recognized were doing most things needed for recognition and many were close to completing the necessary requirements. While there was evidence that StormReady counties were better prepared for the derecho and more able to respond in its aftermath, the link was not as strong as in several previous service assessments for tornado outbreaks.

4.9. Equipment Failures

As a result of the widespread significant winds associated with this derecho, many of the NWS equipment assets were incapacitated up to several days after the event. NWR transmitters were hit particularly hard. This downtime kept vital information from reaching the public. For example, WFO Sterling lost eight NWR transmitters, some of which took several days to restore because of the widespread power outages. **Table 1** shows the details of the NWR outages in WFO Sterling's CWA for this event.

Table 1: NWR outages in WFO Sterling's CWA caused by the derecho

Transmitter	Date of Outage	Date Restored	Reason for Outage
Manassas, VA	June 29, 2012	July 04, 2012	No power or phone lines to site
Baltimore, MD	June 29, 2012	July 02, 2012	No power or phone lines to site
Hagerstown, MD	June 29, 2012	July 02, 2012	No power or phone lines to site
Frostburg, MD	June 29, 2012	July 01, 2012	No power or phone lines to site
Fredericksburg, VA	June 29, 2012	July 03, 2012	No power or phone lines to site
Washington, D.C.	June 29, 2012	July 04, 2012	No power or phone lines to site
Moorefield, WV	June 29, 2012	July 02, 2012	No power or phone lines to site
Charlottesville, VA	June 29, 2012	June 30, 2012	No power or phone lines to site

This team fully supports recommendation Number 7 from the *"The Historic Tornadoes of April 2011"* service assessment that states: *"NWS should ensure the Weather Radio Improvement Project includes backup NWR capabilities that do not rely on local or regional power or communications infrastructure."* Other equipment platforms significantly affected included ASOS and Terminal Doppler Weather Radar sites.

4.10. Post-Event Heat

When the derecho struck, the entire region impacted was in the midst of a building heat wave. Many of the offices had posted heat advisories and excessive heat warnings in the days leading up to June 29. The derecho did little to suppress the heat. Extremely hot temperatures continued for much of the week following the derecho. The situation was made more dangerous because millions of people were without power, some of whom had no easy access to air conditioning. **Table 2** shows power outages by state at 8 p.m. on July 5, 2012, and at their peak (source, FEMA).

Table 2: Power outage data by state provided by FEMA

State	Number of customers without Power on July 05, 2012	Number of customers without power at peak of outage
New Jersey	17,564	135,322
Washington, D.C.	1,000	68,567
Maryland	53,442	899,171
Virginia	89,104	1,076,051
Kentucky	1,000	52,616
Indiana	3,900	135,177
Ohio	139,080	915,366
West Virginia	226,483	643,284

There were 34 heat-related fatalities after the derecho in areas where the power was out (Appendix D). Most of the victims were elderly and could not easily get to air conditioning locations. Many residents in remote areas had no water and could not refrigerate medication.

Because of the power outages, WFO Pittsburgh, in conjunction with WFOs Charleston and Wilmington, initiated a plan to lower the heat advisory criteria in areas where there were significant outages. The three offices agreed to lower their heat advisory criteria to a heat index of 90 °F from 100 °F. WFO Northern Indiana also lowered its criteria. The WFOs used power outage maps to help refine where to lower the heat criteria. **Figure 22** shows a power outage map in WFO Pittsburgh's CWA and a corresponding map of where the heat advisory criteria was lowered.

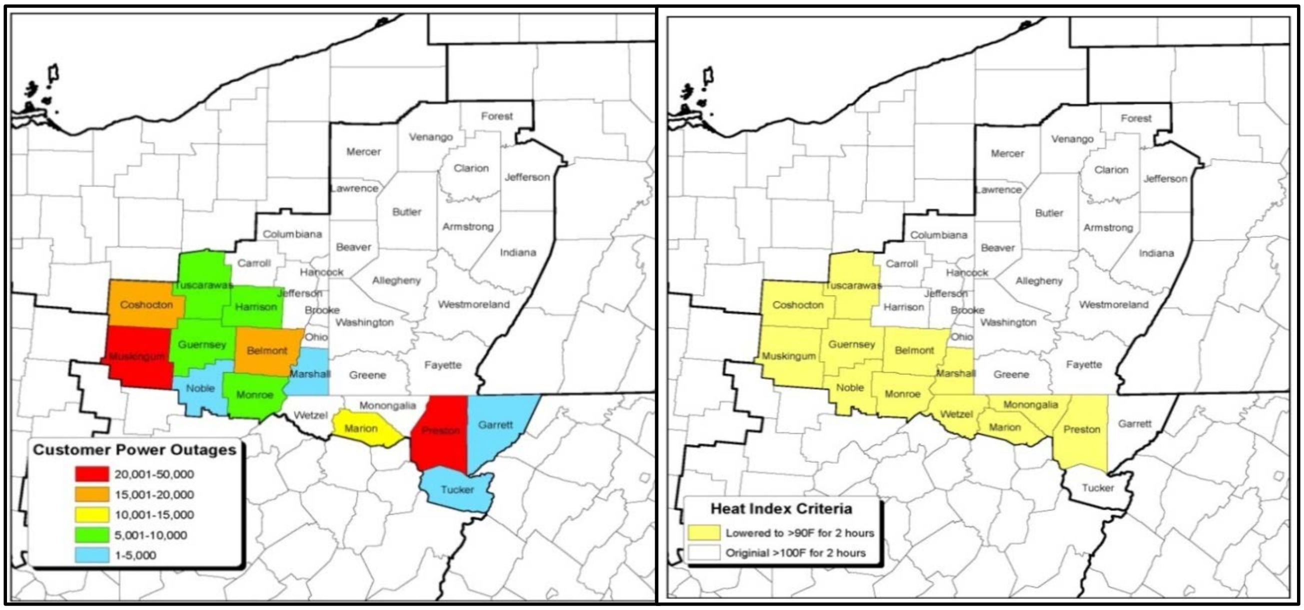

Figure 22: Power outages by county in the Pittsburgh CWA (Wetzel and Monongalia County data unavailable), left, and area where the WFO lowered heat advisory criteria, shaded region, right.

There was a concern among EMs that many residents in the areas without power may not have received the impact-based heat products. However, the EMs felt lowering the heat criteria was the appropriate course of action because it provided a trigger for them to open cooling centers, send out state officials to check on vulnerable members of the population, and provide other necessary services to protect lives. The WFOs that lowered heat criteria were carrying an impact bullet in their heat statements to highlight the added concern for people without air conditioning. **Figure 23** shows an example from WFO Charleston. The heat abated on July 08, 2012, when a cold front moved southward across the region bringing cooler weather and some precipitation to the area.

Finding 11: Many of the people who died from the heat in the days after the derecho had no easy access to air conditioning.

Recommendation 11: NWS should develop a statement to include in the impacts portion of heat products emphasizing the dangers of staying in homes without air conditioning during prolonged heat waves.

Finding 12: WFOs Pittsburgh, Charleston, Wilmington, and Northern Indiana all lowered their heat advisory criteria in areas where the power was out after the derecho.

Recommendation 12: WFOs should be encouraged to reduce warning and advisory criteria when significant impacts to the population will occur at the lowered thresholds.

```
THE NATIONAL WEATHER SERVICE IN CHARLESTON HAS ISSUED A HEAT
ADVISORY...WHICH IS IN EFFECT FROM NOON TO 7 PM EDT WEDNESDAY.

* HEAT INDEX VALUES...IN THE UPPER 90S DUE TO TEMPERATURES IN
  THE LOWER TO MIDDLE 90S...AND DEWPOINTS IN THE MID 60S.

* TIMING...THIS AFTERNOON AND WEDNESDAY AFTERNOON.

* IMPACTS...HEALTH RELATED PROBLEMS...SUCH AS HEAT CRAMPS OR
   HEAT EXHAUSTION...BECOME MORE LIKELY IF PRECAUTIONS ARE NOT
   TAKEN. WITH PROLONGED EXPOSURE IN THIS ENVIRONMENT...A HEAT
   STROKE IS POSSIBLE. WITH WIDESPREAD POWER OUTAGES...AIR
   CONDITIONING MAY NOT BE ACCESSIBLE...ADDING TO THE IMPACTS.
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Figure 23: Example of impact-based heat advisory issued by WFO Charleston, WV

5. Societal Responses and Impacts

The team used a customized social scientific methodology to conduct this NWS assessment. The team was particularly interested in how the NWS contributes to hazard resiliency in the areas of decision support, operational procedures, collaboration, and communication. The resilience of a community, with respect to potential severe weather events, is determined by the degree to which a community has the necessary resources and is capable of organizing itself both prior to and during a severe weather event. Social scientists were included in this analysis of resiliency contribution because they study society and human behavior using the same techniques as the natural sciences. In this case, the assessment team undertook a social scientific analysis of the systemic networks and collaborations in the weather warning process and the efficacy of communication processes used to send and receive messages, especially during this severe weather event.

Social science methodologies used for this service assessment include pre-validated, triangulated methods of field interviews, descriptive survey analysis, focus group facilitation, analysis of existing data, and qualitative observations. These methods were used to study the behavior and actions of emergency planning professionals, including EMs, first responders, the media, government officials, and weather professionals. In addition, the same methods were used to study the public, to understand how they received warnings, and what actions they took. All of the data obtained from these methods were then analyzed using a systems approach to understand the social system that produces weather warnings and communicates them to the public with the expectation of a warned and protected community.

5.1. Public Opinion Survey

The team developed and conducted a public opinion survey to ascertain the public's response to NWS products and services associated with this derecho and the heat wave that followed. Highly impacted areas were selected for survey collection. High population venues, such as malls and regional and state fairs, were chosen within those areas because they drew a large, easily accessible sample group. Individuals at these locations were asked to participate in the survey. In some locations, the survey was publicized and respondents came to the surveyors.

Surveys collected at the onset of the storm were from the areas served by WFOs Northern Indiana and Wilmington, OH, (Group A). Surveys collected from the middle range of the storm track were from the areas served by WFOs Pittsburgh, PA and Sterling, VA (Group B). The remaining surveys were collected from the last phase of the storm track in the areas served by WFOs Charleston, WV and Blacksburg, VA (Group C). Each group had one social scientist to lead the survey process and worked with other team members who assisted in the survey collection. A descriptive analysis of the data is below.

Results are presented for each survey analysis group as well as for the overall data collection. The storm assessment took place a few weeks after the event and was of short duration considering the large geographic area covered by the derecho. A total of 105 surveys were collected during the storm assessment.

- Group A: 39 surveys were collected in Van Wert, OH, at a model railroad fair and in Franklin County, OH, at a county fair.
- Group B: 32 surveys were collected in St. Clairsville, OH, and near Sterling, VA, at two shopping malls.
- Group C: 34 surveys were collected in Virginia at two locations, in front of a Lowes and a Walmart, both in Christiansburg.

The goal of the survey was to assess:

- How impacted people received their severe weather warnings
- What they did when the warnings were received and/or the storm hit their areas
- The effectiveness of the warnings
- Perceptions about severe thunderstorm warnings

The data collected in the assessment provide some evidence of how people obtained weather warnings and how they reacted to the warnings and actual storm events on June 29, 2012. The responses are descriptive. They cannot be inferred to the general population and are not generalizable to the complete population impacted by the derecho. Instead, the results and interpretations serve as the context for the assessment of the warning processes that took place on June 29, 2012.

The following represent the descriptive results of the public opinion survey for the three groups.

Primary methods by which people receive weather warnings:

- **Group A**: Television, followed closely by NOAA Weather Radio
- **Group B**: Television
- **Group C**: Television, followed by local radio

Most effective ways to receive weather warnings:

- **Group A**: NOAA Weather Radio and television, followed by sirens
- **Group B**: Television
- **Group C**: Television, followed by cell phone alerts/apps and local radio

First and second most common responses to a thunderstorm warning:

- **Group A**: Take no action since it is either a false alarm or the usual type of storm. Seek secondary confirmation or tune in to media to hear it from a local source.
- **Group B**: Wait until respondent sees threatening clouds or rain before taking cover. Take no action since it is either a false alarm or the usual type of storm.
- **Group C**: Take no action since it is either a false alarm or the usual type of storm. Wait for a secondary source to confirm danger.

In the case of the Derecho storm on June 29, was there adequate warning?

- **Group A**: A majority said there was adequate warning.
- **Group B**: A majority said there was not adequate warning.
- **Group C**: A majority said there was not adequate warning.

Did the warnings help you understand what to do in the June 29 storm?

- **Group A**: A majority said the warnings did help them understand what to do.
- **Group B**: A majority said the warnings did not help them understand what to do.
- **Group C**: A majority said the warnings at least partially helped them understand what to do.

Did you take any precautions when you heard about this storm approaching and what were those precautions?

- **Group A**: A majority took immediate shelter.
- **Group B**: A majority did not take precautions. Those that did act stayed inside and away from windows.
- **Group C**: A majority took immediate shelter in their homes and basements. They stayed away from windows. They started gathering materials for a severe storm, including flashlights and candles. They moved portable outside items inside.

Would you do anything differently if faced with a similar severe weather warning in the future?

- **Group A**: A significant number said they would seek shelter immediately.
- **Group B**: Of those who did not take precautions, only seven would do things differently the next time. These seven would move things indoors, turn on the television sooner, and have a generator on hand.
- **Group C**: A significant number would seek shelter immediately, go to their basements, stay at home, move things inside, pay more attention to the warnings, and prepare more in advance.

Perceptions of the number of thunderstorm warnings issued: All three groups felt the number of warnings was just about right.

Impact of warnings and heat advisories: A significant majority in all three groups perceived the heat advisories and warnings to be helpful.

False Alarm Ratios:

- **Group A**: A majority said they were just as likely to take the same actions for a severe thunderstorm warning regardless of whether there have been false alarms.
- **Group B**: A significant majority said they were just as likely to take the same actions for a severe thunderstorm warning regardless of whether there have been false alarms.

- **Group C**: A majority said they were just as likely to take the same actions for a severe thunderstorm warning regardless of whether there have been false alarms.

To summarize, for these respondents:

- The primary means to receive warnings is television.
- Warnings do not typically trigger an immediate response.
- For this derecho, many felt they did not receive adequate warning.
- Many would react differently the next time a warning for this type of event is issued by taking more immediate shelter.

5.2. Impacts of Warning Language and Lead Time

If there is a single theme to this assessment from a societal perspective it is that impact-based messaging matters. The social impacts of severe weather events pose the greatest interruption to peoples' daily routines and they provide dramatic and vivid images, often captured by photographers and news media. Because of their visual impact, words that describe these same characteristics often indicate which messages become socially dominant in terms of public attention. For example, phrases such as "catastrophic winds" or "trees and power lines down" are analogous to photographs of a family standing in front of a home destroyed by a tornado. These descriptors are the characteristics that determine, in part, what is deemed "newsworthy" and what sometimes develops into trending topics across social media.

Including societal impacts in weather statements provides a context for the technical weather information—especially for non-NWS users. Impacts are the main reason non-meteorologically trained individuals express interest in and concern for weather phenomena. We have to communicate our science like non-meteorologists, simplifying the information in a way that the public would best understand it.

Even in the context of well-developed working relationships with key partners, including EMs and broadcast meteorologists, wording changes within severe weather statements not only convey specific content about likely impacts and their intensity, but also serve as a trigger that redirects attention. This enhanced language also raises the level of concern among different groups, including the public, and thus has the potential to result in more appropriate safety precautions before severe weather.

The team's public surveys indicate that even when people receive warnings, they are not always interpreted in ways that lead to life-saving actions. Survey results suggest the public needs specific, high-impact language and details of possible impacts before responding, much like the language contained in the warning in Appendix F.

People indicated had they known the intensity and severity of the winds, they would have taken protective actions, such as they might do for tornado warnings. While this survey could not be generalized to the entire population, the fact that this response was consistent throughout the surveys makes this a strong perception. This perception was reinforced by the media who, in some cases, used language to convey the similarities between this storm and tornadoes. Based on the positive feedback they received, media representatives believe this strong wording made a difference with their viewers. EMs indicated that more serious and detailed language would also be useful to them. They mentioned observed damage reports coupled with language similar to that used in tornado warnings are useful in determining the severity of an event such as this derecho.

Some people also felt that they had insufficient lead time for the derecho. While the NWS measures lead time by subtracting the ***warning issuance*** time from the time when the event began, the public measures lead time by subtracting the time they ***receive the warning*** from the time the event began at their location. Some people will get a warning as it is issued directly from the NWS (e.g., through NWR), but many will get the televised warning, which may be delayed. Others will get the warning through tornado sirens, phone apps, email alerts, word of mouth, or other means. The longer it takes to get the warning through dissemination channels, the shorter the perceived and experienced lead time is for an individual. In these cases, members of the public are likely unaware of any greater lead time the NWS may have provided.

5.3. NOAA Weather Radio All Hazards and Siren Systems

Results of the survey show respondents relied heavily on television reports for severe warnings. This result is consistent with field interviews conducted with the media and EMs who indicated a lack of reliance on other warning modalities such as NWR. As is mentioned in Section 4.9 of this report, several NWR transmitters stopped broadcasting due to power outages associated with the derecho. Nonetheless, having an NWR would have allowed many people who lost power and could no longer get warnings from television to receive the warnings more quickly in areas where transmitters remained operational.

Some EMs commented that of those who did own NWRs, many did not replace batteries regularly so they could not be used. Some communities have implemented a policy that helps mitigate this problem by distributing NWRs with batteries already included. Had there been more reliance on NWR, people with power outages might have heard these warnings. This fact proved to be especially important in the week following the derecho when numerous heat advisories and excessive heat warnings were issued by the NWS.

In spite of these issues, EMs reported that NWR continues to be an important communication tool in their communities. Many EMs are developing policies to distribute NWRs to key members of their emergency network. One example of a successful NWR policy is carried out in Woodburn, IN. The town's strategic plan ensures NWRs are delivered to people who serve as network connectors, such as EMs, school and hospital officials, and other key decision makers that have access to large populations. This approach has been a more successful strategy than simply distributing radios throughout the general population.

One challenge across all CWAs is reaching partners and members of the public who live in rural or remote locations. During the derecho event, for example, West Virginia experienced significant and long-lived power outages. In fact, one of the few networks still available for communication after the event was the 800 MHz network, which extended across the state; however, the NWS was not a part of this network.

Finding 13: As a result of extensive power outages across West Virginia, the 800 MHz network was one of the few networks available for communication in the days after the derecho; however, the NWS was not a part of this network.

Recommendation 13: WFOs should become part of the 800 MHz networks in their areas as a means of emergency communication.

Tornado warning sirens are, for many people, a main way to receive severe weather warnings. As the derecho illustrated, when there is a widespread power outage, warning sirens may be the only means people have to receive notice of impending severe weather. This reality was the case for many communities in West Virginia and Ohio who experienced a second round of severe weather 24 hours after the derecho, when power had already been lost across most of the area. Many members of the public expressed confusion about which weather events trigger a siren and indicated that sirens would not have made a difference to them in this event because they did not know what the sounding of a siren meant. This was the case in the *NWS Central Region Service Assessment Joplin, MO Tornado – May 22, 2011*. This team fully supports Recommendation 4 from the Joplin Assessment: *"The NWS should collaborate with partners throughout the weather enterprise to provide a better coordinated weather message. Guidance should be developed to assist partners in the development of local warning system and siren strategies that work in conjunction with NWS warnings rather than independent of them."*

5.4. Summary

A historic derecho impacted the Ohio Valley and Mid-Atlantic states on June 29, 2012. The event originated in northeast Illinois as a small cluster of thunderstorms. The derecho became organized over northeast Indiana during the afternoon and raced southeastward across Ohio and West Virginia at 60 mph. The derecho remained intact crossing the Appalachians, a climatological rarity, and caused widespread damage in the Washington, D.C., metropolitan area during the late evening. The derecho moved offshore shortly after midnight on June 30, 2012. In its wake, 13 people were killed and several million customers were left without power, many for several days. Tony Cavalier, Chief Meteorologist from WSAZ-TV Huntington-Charleston, WV, was quoted as saying, *"The derecho was one of the top two impacting events in my 25 year career."*

This derecho was not forecast until the day of the event. Summertime derechos are often difficult to forecast because they respond to smaller-scale forcing mechanisms. Despite the extreme instability available for thunderstorms in the region affected by the derecho, the NCEP operational models were not indicating any disturbances that would help initiate and organize thunderstorms. This delayed the onset of decision support services and the use of enhanced wording in forecasts and hazardous weather outlooks.

On the day of the event, some of the CAMs that more closely simulate thunderstorms were developing an MCS over the area impacted. This allowed the SPC and WFOs to reflect the seriousness of the threat in their product suite. Much of the high-resolution, CAMs data are experimental and not available in the Day 2 forecast time period. Fully supported, ensemble, high-resolution model data extending further out in time are needed to improve the lead time in forecasting these extreme wind storms. Without these data, many of these derecho events will continue to have forecast lead times of 24 hours or less.

Numerous interviews with the public, media, and EMs revealed that despite accurate severe thunderstorm warnings and enhanced wording used by most of the WFOs, nearly everyone surveyed was surprised by the intensity of the winds during this event. NWS should move toward an impact-based severe thunderstorm warning so partners and the public receiving warnings have a better understanding of the storm's severity.

The heat was a significant concern after this derecho, especially because of the widespread power outages. A heat wave that was building in the days leading up to the derecho continued for about a week after the event. More people died because of the heat in the days following the storm than from the derecho itself: 34 versus 13. Several WFOs lowered their heat advisory criteria in the areas hit hard by power outages by as much as 10 ^{o}F. NWS heat products should include an impact statement emphatically expressing the dangers of remaining in homes without air conditioning during prolonged heat waves.

Appendix A: Acronyms

ASOS	Automated Surface Observing System
AWOS	Automated Weather Observing System
AWIPS	Advanced Weather Interactive Processing System
CAM	Convection-allowing model
CAP	Common Alerting Protocol
CAPE	Convective Available Potential Energy
CG	Cloud to Ground
COMET®	Cooperative Program for Operational Meteorology, Education and Training
CWA	County Warning Area
EAS	Emergency Alert System
EMC	Environmental Modeling Center
J/Kg	Joules per Kilogram
EF	Enhanced Fujita (Scale)
FEMA	Federal Emergency Management Agency
GFS	Global Forecast Systems
hr	hour
IBW	Impact Based Warnings
IPAWS	Integrated Public Alert and Warning System
HRRR	High Resolution Rapid Refresh
KFWA	Fort Wayne Indiana Airport ASOS
KIAD	Washington Dulles International Airport ASOS
KIWX	Northern Indiana WSR-88D Doppler Radar
KLWX	Sterling, VA, WSR-88D Doppler Radar
km	kilometer
kt	knot, nautical mile per hour
LSR	Local Storm Report
mb	millibar
MCS	Mesoscale Convective System
MHz	Megahertz
MIC	Meteorologist in Charge
mph	miles per hour
NCEP	National Centers for Environmental Prediction
NLDN	National Lightning Data Network
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio All Hazards
NWS	National Weather Service
NWSH	National Weather Service Headquarters
OCWWS	Office of Climate, Water, and Weather Services
RAP	Rapid Refresh
SPC	Storm Prediction Center
SPS	Special Weather Statement
WarnGen	AWIPS-based warning generation software
WCM	Warning Coordination Meteorologist

WCN	Watch County Notification
WEA	Wireless Emergency Alerts
WFO	Weather Forecast Office
WSR-88D	Weather Surveillance Radar, 1988 Doppler

Appendix B: Findings, Recommendations, & Best Practices

Definitions

Best Practice – An activity or procedure that has produced outstanding results during a particular situation that could be used to improve effectiveness and/or efficiently throughout the organization in similar situations. No action is required.

Fact – A statement that describes something important learned from the assessment for which no action is necessary. Facts are not numbered, but may begin to justify the need for a recommendation.

Finding – A statement that describes something important learned from the assessment for which an action may be necessary. Findings are numbered in ascending order and are associated with a specific recommendation or action.

Recommendation – A specific course of action, which should improve NWS operations and services, based on an associated finding. Not all recommendations may be achievable but they are important to document. If the affected office(s) and OCWWS determine a recommendation will likely improve NWS operations and services, and it is achievable, the recommendation will likely become an action. Recommendations should be clear, specific, and measurable.

Findings and Recommendations

Finding 1: SPC creates a seven-member ensemble of convection-allowing models to help with the Day 1 Convective Outlook, but some of the members are experimental and others are sometimes superseded by higher priority model runs at NCEP. There is currently no ensemble of convection-allowing model data to help with the Day 2 Convective Outlook, which could help provide additional lead time for events such as this derecho.

Recommendation 1a: The NWS should invest in infrastructure that would provide the computational resources to operationally run the convection-allowing models, and network resources that would allow delivery of the model output to forecasters.

Recommendation 1b: The Environmental Modeling Center (EMC) should work with SPC to develop a fully supported ensemble of high-resolution, convection-allowing models that cover the Day 2 Convective Outlook time period. EMC should then make these data available to WFOs.

Finding 2: Some forecasters at the impacted WFOs were using the convection-allowing models on the day of the event, particularly the experimental HRRR; however, the use and understanding of these models varied.

Recommendation 2: WFOs should add to their required training for forecasters the Cooperative Program for Operational Meteorology, Education and Training (COMET®) module, "Effective Use of High Resolution Models." WFO managers should provide sufficient time for their forecasters to complete the training.

Finding 3: WFOs Northern Indiana and Sterling, VA, locally extended Severe Thunderstorm watches issued by the SPC for counties downstream (east) of the derecho via the WCN; however, there was limited lead time between the issuance of the WCN and the issuance of warnings for the new counties in the watch.

Recommendation 3: SPC and the WFOs should collaborate more closely during these kinds of events. Either SPC should issue watches or WFOs should extend them locally at least 1 hour before warnings are necessary in situations such as this derecho, where it is apparent additional watches will be required downstream.

Finding 4: Many WFOs had some difficulty keeping up with the rapid forward progress of the derecho, which was approximately 60 mph. This resulted in minimal lead time near the western fringes of several warning polygons issued for this event. Two warning techniques were employed at the WFOs: an overlapping and non-overlapping polygon methodology.

Recommendation 4: The Warning Decision Training Branch (WDTB) should develop a computer-based training module that defines and demonstrates the optimal warning polygon methodology for rapidly moving MCSs such as this derecho. WFO training plans should be updated to include this module for FY 13, and NWS mangers should provide time for warning forecasters to complete the training.

Finding 5: The current severe thunderstorm warning format used by the AWIPS software program, WarnGen, results in considerable redundant text in the warning location portion, leading to long NWR broadcast cycles during MCS events such as this derecho.

Recommendation 5: NWS Headquarters should develop a new warning format that eliminates redundant text in the location portion of severe thunderstorm warnings.

Finding 6: WarnGen is currently configured to allow a maximum of 20 vertices for warning polygon generation. This limit forced WFO Sterling to exclude the western shore of the Chesapeake Bay from its warning.

Recommendation 6: The minimum number of vertices allowed in warnings along irregular coastlines needs to be determined. NWS Headquarters should then make the necessary adjustments to WarnGen software.

Finding 7: Despite the use of enhanced wording in many of the warnings, nearly everyone interviewed was surprised by the intensity of the winds with this derecho. As a result, most people surveyed did not take any special precautions as the storms moved through their area.

Recommendation 7: To promote a better public response, the NWS should experiment with new approaches for highlighting impact-based wording in severe thunderstorm warnings, especially during unusual events. NWS should collaborate closely with social scientists to develop wording clearly defining impacts of a storms based on its severity.

Finding 8: Starting June 28, 2012, the day prior to the derecho, NWS began triggering 90-character Wireless Emergency Alert (WEA) messages for a predefined set of NWS warning types. Tornado warnings trigger WEA, but severe thunderstorm warnings currently do not.

Recommendation 8a: The NWS should implement agency-wide the threat tags used at the bottom of Central Region warnings. NWS should then leverage those tags to trigger WEA for extreme severe thunderstorm events such as this derecho.

Recommendation 8b: Future NWS warning tools should allow WFO forecasters to natively control which warnings trigger WEA as well as the content of the WEA message.

Finding 9: Nearly all conversations with members of the media highlighted the usefulness of Facebook and Twitter in reaching the public and in receiving observations and damage reports throughout the viewing area.

Recommendation 9: NWS should expand the use of social media for reaching the public and receiving observations and damage reports during high impact events. NWS should consider a virtual volunteer program to support social media operations similar to the SKYWARN program.

Finding 10: EMs felt that information regarding the derecho was not covered in-depth during spotter training and that providing this information along with impacts would enable them to better plan for these events.

Recommendation 10: WFO WCMs in areas susceptible to derechos should supplement their spotter training program with information on derecho science, identification, and impacts.

Finding 11: Many of the people who died from the heat in the days after the derecho had no easy access to air conditioning.

Recommendation 11: NWS should develop a statement to include in the impacts portion of heat products emphasizing the dangers of staying in homes without air conditioning during prolonged heat waves.

Finding 12: WFOs Pittsburgh, Charleston, Wilmington, and Northern Indiana all lowered their heat advisory criteria in areas where the power was out after the derecho.

Recommendation 12: WFOs should be encouraged to reduce warning and advisory criteria when significant impacts to the population will occur at the lowered thresholds.

Finding 13: As a result of extensive power outages across West Virginia, the 800 MHz network was one of the few networks available for communication in the days after the derecho; however, the NWS was not a part of this network.

Recommendation 13: WFOs should become part of the 800 MHz networks in their areas as a means of emergency communication.

Best Practices

Best Practice: WFO Wilmington staffed for the derecho well ahead of time, defining clear roles and responsibilities and selecting a Warning Coordinator.

Best Practice: WFO Northern Indiana issued exceptionally timely and frequent LSRs during and immediately after the derecho moved through its forecast area.

Best Practice: WFOs Indianapolis and Jackson issued graphical Nowcasts during this event, providing useful short-term information on the derecho for decision makers and the general public.

Best Practice: WFO Sterling issued two high-impact SPSs to provide advance warning of the derecho that struck the region during the evening of June 29. Likewise, WFO Cleveland issued several SPS up to 2 hours ahead of the derecho to give advance notice of its arrival.

Best Practice: WFOs Northern Indiana and Wilmington aggressively used NWSChat during the derecho event.

Appendix C: Direct Fatalities from the Derecho

Gender	Age	Location	Circumstance
Male	2	Pittsgrove Township, NJ	Large tree fell on tent
Male	7	Pittsgrove Township, NJ	Large tree fell on tent
Male	Unknown	Atlantic City, NJ	Boat capsized in high winds, drowned
Female	66	Hamilton Township, NJ	Tree fell on trailer home
Female	Unknown	Scottsville, VA	Killed near car by falling tree
Male	Unknown	Albemarle County, VA	Killed on porch by falling tree
Female	90	Springfield, VA	Tree fell on house while sleeping in upstairs bedroom
Male	Unknown	Burke, VA	Killed exiting vehicle by falling tree
Male	25	Harwood, MD	Tree fell on car
Male	Unknown	Calvert County, MD	Boat capsized on Chesapeake Bay, drowned
Female	71	Silver Spring, MD	Tree fell on house while sleeping in upstairs bedroom
Male	54	Boones Mill, VA	Firefighter killed by falling tree while assisting motorist
Female	70	Muskingum County, OH	Barn collapsed

Appendix D: Heat-Related Fatalities in Areas Affected by the Derecho

Gender	Age	Date	Location
Unknown	Unknown	6/30/12	Richmond City, VA
Unknown	Unknown	7/1/12	Loudon County, VA
Male	57	7/1/12	Bedford, VA
Unknown	Unknown	7/2/12	Greene County, VA
Male	72	7/1/12	Newark, OH
Female	84	7/2/12	Heath, OH
Female	85	7/2/12	Heath, OH
Male	45-64	7/2/12	Montgomery County, MD
Male	65+	7/2/12	Wicomico County, VA
Male	65+	7/2/12	Baltimore City, MD
Male	65+	7/2/12	Baltimore City, MD
Unknown	Unknown	7/3/12	Fairfax County, VA
Female	Unknown	7/4/12	Muskingum County, OH
Male	65+	7/5/12	Baltimore City, MD
Male	65+	7/5/12	Baltimore City, MD
Male	65+	7/5/12	Montgomery County, MD
Male	65+	7/5/12	Baltimore City, MD
Male	65+	7/6/12	Baltimore County, MD
Male	65+	7/6/12	Baltimore City, MD
Female	84	7/6/12	Elkhart, IN
Male	45	7/7/12	Elkhart, IN
Male	Unknown	7/7/12	Muskingum County, OH
Male	65+	7/7/12	Harford County, MD
Male	65+	7/8/12	Baltimore City, MD
Female	65+	7/8/12	Wicomico County, MD
Male	Unknown	7/9/12	Muskingum County, OH
Male	65+	7/9/12	St. Mary’s County, MD
Male	65+	7/9/12	Prince George’s County, MD
Male	45-64	7/9/12	Baltimore City, MD
Female	65+	7/9/12	Baltimore County, MD
Male	45-64	7/9/12	Prince George’s County, MD

There were two other heat-related deaths in Virginia and one in the District of Columbia, but no further details are available.

Appendix E: ASOS/AWOS Peak Wind Gusts > 57 mph

Location	Peak Wind Gust (mph)
Fort Wayne Airport, IN	91
Atlantic City, NJ	87
Dayton, OH	82
Ohio State Airport, Columbus, OH	82
Roanoke, VA	81
Charleston, WV	78
Wapakoneta, OH	74
Columbus Airport, OH	72
Washington Dulles, VA	71
Ronald Reagan Airport, District of Columbia	70
Lancaster Airport, OH	69
Baltimore Washington International Airport, MD	69
Zanesville, OH	68
Beckley, WV	68
Wilmington Airport, OH	67
Millville, NJ	67
Rickenbacker Airport, OH	66
Clarksburg, WV	66
Delaware, OH	64
Ohio University, Athens, OH	64
Elkins, WV	64
Franklin, VA	64
Middleton, OH	63
Winchester, VA	61
Indianapolis, IN	60
Lunken Airport, OH	59
Huntington, WV	59
Lewisburg, WV	58
Baltimore City, MD	58

Note: An Acu-rite anemometer 11 miles north-northwest of Cambridge, OH, measured an unofficial peak wind gust of 106 mph.

Appendix F: Sample Impact-based Warning

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WUUS53 KICT 150114
SVRICT
KSC009-053-105-167-150200-
/O.NEW.KICT.SV.W.0051.120415T0114Z-120415T0200Z/

BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WARNING
NATIONAL WEATHER SERVICE WICHITA KS
814 PM CDT SAT APR 14 2012

THE NATIONAL WEATHER SERVICE IN WICHITA HAS ISSUED A

* SEVERE THUNDERSTORM WARNING FOR...
  NORTH CENTRAL BARTON COUNTY IN CENTRAL KANSAS...
  NORTHWESTERN ELLSWORTH COUNTY IN CENTRAL KANSAS...
  WESTERN LINCOLN COUNTY IN CENTRAL KANSAS...
  EASTERN RUSSELL COUNTY IN CENTRAL KANSAS...

* UNTIL 900 PM CDT

* AT 812 PM CDT...A SEVERE THUNDERSTORM WAS LOCATED 6 MILES NORTH OF
  SUSANK...AND MOVING NORTHEAST AT 65 MPH.

  HAZARD...GOLF BALL SIZE HAIL AND 70 MPH WIND GUSTS.

  SOURCE...RADAR INDICATED.

  IMPACT...DAMAGE TO VEHICLES...ROOFS AND WINDOWS. TREE BRANCHES UP
           TO THREE INCHES IN DIAMETER BROKEN. POSSIBLE MINOR DAMAGE
           TO SHINGLE ROOFS AND METAL OUTBUILDINGS.

* LOCATIONS IMPACTED INCLUDE...
  LINCOLN...BUNKER HILL...DORRANCE...WILSON...LUCAS...SYLVAN GROVE...
  WILSON LAKE AND ASH GROVE.

THIS INCLUDES INTERSTATE 70 BETWEEN MILE MARKERS 208 AND 211.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

FOR YOUR PROTECTION MOVE TO AN INTERIOR ROOM ON THE LOWEST FLOOR OF A
BUILDING.

&&

LAT...LON 3905 9812 3862 9865 3874 9888 3914 9859
      3914 9850 3922 9849 3922 9823
TIME...MOT...LOC 0114Z 211DEG 55KT 3875 9871

HAIL...1.75IN
WIND...70 MPH
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Appendix G: References

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