Service Assessment

Veterans Day Weekend Tornado Outbreak of November 9-11, 2002

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

Cover Photographs:

Left: Automobiles tossed into movie theater by an F4 tornado in Van Wert, Ohio, on November 10, 2002. (Courtesy of Paul Van Dyke)

Right: Aerial view of F2 tornado damage in Port Clinton, Ottawa County, Ohio, along Lake Erie. No one was in the two houses destroyed by the tornado. People were in the middle house left undamaged. (NOAA)

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March 2003

U.S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary

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

National Weather Service
John J. Kelly, Jr., Assistant Administrator

Preface

During the Veterans Day weekend of November 9-11, 2002, tornadoes struck 17 states from the Mississippi Valley to the Atlantic Coast and from the Gulf Coast to the Great Lakes. From Saturday afternoon, November 9, to the early morning hours of Monday, November 11, 2002, 76 tornadoes touched down. Twelve of these tornadoes killed 36 people in five states.

Due to the magnitude of this event, a service assessment team was formed to examine the warning and forecast services provided to emergency managers (EMs), government agencies, and the public. Service assessments provide a valuable contribution to ongoing efforts to improve the quality and timeliness of our products and services. Findings and recommendations from this assessment will improve techniques, products, services, and the information provided to the American public.

John J. Kelly, Jr.
Assistant Administrator
for Weather Services

March 2003

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Service Assessment Team

The service assessment team was activated on November 16, 2002. Team members visited damage areas and interviewed emergency managers, the media, and public in Ohio, Pennsylvania, Tennessee, Alabama, and Mississippi, and visited Weather Forecast Offices (WFOs) Northern Indiana; Cleveland, Ohio; Pittsburgh, Pennsylvania; Nashville, Tennessee; Morristown, Tennessee; Jackson, Mississippi; Birmingham, Alabama; and the Storm Prediction Center (SPC) in Norman, Oklahoma. Telephone interviews were conducted with WFO Memphis, Tennessee.

The team comprised the following individuals.

Larry Dunn	*Team Leader*, Meteorologist in Charge (MIC), WFO Salt Lake City, Utah
Buddy McIntyre	MIC, WFO San Angelo, Texas
Tyree Wilde	Warning Coordination Meteorologist (WCM), WFO Portland, Oregon
Rusty Kapela	WCM, WFO Milwaukee/Sullivan, Wisconsin
Rick Shanklin	WCM, WFO Paducah, Kentucky
Karl Jungbluth	Science and Operations Officer (SOO), WFO Des Moines, Iowa
Michael Vescio	SOO, WFO Fort Worth, Texas
Jeff Orrock	WCM, WFO Morehead City, North Carolina
Dan Cobb	SOO, WFO Caribou, Maine
Ron Trumbla	National Oceanic and Atmospheric Administration (NOAA) Public Affairs Specialist, National Weather Service (NWS) Southern Region Headquarters, Fort Worth, Texas
Pat Slattery	NOAA Public Affairs Specialist, NWS Central Region Headquarters, Kansas City, Missouri
Frank Lucia	Federal Communications Commission, Retired

Other valuable contributors include:

Darien Davis	NOAA, Forecast Systems Laboratory, Boulder, Colorado
Carl Bullock	NOAA, Forecast Systems Laboratory, Boulder, Colorado
William Lerner	NWS Headquarters, Office of Climate, Water, and Weather Services (OCWWS), Silver Spring, Maryland
Linda Kremkau	NWS Headquarters, OCWWS, Silver Spring, Maryland
Wayne Presnell	NWS Headquarters, OCWWS, Silver Spring, Maryland

Acronyms

AWIPS	Advanced Weather Interactive Processing System
CST	Central Standard Time
CWA	County Warning Area
EAS	Emergency Alert System
EM	Emergency Manager
EST	Eastern Standard Time
EWARN	Email Warning System
HMT	Hydrometeorological Technician
HP	Hewlett Packard
HWO	Hazardous Weather Outlook
IFPS	Interactive Forecast Preparation System
ITO	Information Technology Officer
LDAD	Local Data Acquisition and Dissemination System
LSR	Local Storm Report
MHz	Megahertz
MIC	Meteorologist in Charge
NAWAS	National Warning System
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory
NWR	NOAA Weather Radio
NWS	National Weather Service
OCWWS	Office of Climate, Water, and Weather Services
ORPG	Open Radar Product Generator
OST	Office of Science and Technology
PSDA	Post-Storm Data Acquisition
QRT	Quick Response Team
SDM	Station Duty Manual
SOO	Science and Operations Officer
SPC	Storm Prediction Center
SPS	Special Weather Statement
SRM	Storm Relative Motion
SVS	Severe Weather Statement
WCM	Warning Coordination Meteorologist
WDM	Warning Decision Making
WDSS	Warning Decision Support System
WES	Weather Event Simulator
WFO	Weather Forecast Office
ZFP	Zone Forecast Product

Service Assessment Report

Executive Summary

The second largest November tornado outbreak on record over the eastern United States occurred during the Veterans Day weekend of November 9-11, 2002. Seventy-six tornadoes were reported in seventeen states. Of the 76 tornadoes, almost one out of every six was a killer, resulting in 36 fatalities.

Tornadoes first developed in eastern Arkansas on Saturday afternoon, November 9. However, most of the storms occurred on Sunday, November 10, beginning in Indiana around midday and becoming widespread from Mississippi to Ohio through the afternoon and evening. There were 17 fatalities in Tennessee, 12 in Alabama, 5 in Ohio, and 1 each in Pennsylvania and Mississippi.

An assessment was made of the performance of the National Centers for Environmental Prediction's (NCEP) Storm Prediction Center (SPC) which is responsible for issuing severe weather outlooks and watches. The performance of the eight Weather Forecast Offices (WFOs) responsible for issuing warnings in the counties where the fatalities occurred was also assessed. The service assessment team found overwhelming approval of the National Weather Service (NWS) performance. The emergency management community and the public were well served by the outlooks, statements, watches, and warnings issued prior to and during the event.

- All 36 fatalities occurred within the boundaries of both watches and warnings.
- The eight WFOs with fatalities had an average lead time of 15.6 minutes for tornadoes occurring in their areas of responsibility.
- WFOs issued Hazardous Weather Outlooks (HWOs) and Special Weather Statements (SPSs) highlighting the severe weather threat for days leading up to the event.
- NWS preparedness efforts were validated as local officials, local businesses, and the public took life-saving actions based on outlooks, watches and warnings, minimizing the death toll.
- Timely warnings in Van Wert, Ohio, and Columbus, Mississippi, combined with quick action by law enforcement and citizens, resulted in moving more than 100 people out of buildings that were subsequently destroyed by tornadoes.
- Van Wert County, Ohio, EM Rick McCoy said of the interaction between the NWS and the local government and businesses, "*Excellent! If you want a textbook case of how things should go, this was one.*"

- Walker County, Alabama, EM Johnny Burnette said, "*I don't know anything they [WFO Birmingham] could have done better. I was very proud of them."*

The Veterans Day weekend tornado outbreak was the first major tornado outbreak since May 3, 1999, in Oklahoma and Kansas. The performance of WFO Norman, Oklahoma, on May 3 set a new level of service to its customers and partners for this type of event. It was the first major tornado outbreak where the various parts of the NWS' decade-long modernization were brought together to the benefit of the American public. The service assessment team found this new level of excellence demonstrated by WFO Norman in 1999 had become the operational standard during the November 9-11, 2002, tornado outbreak.

Service assessments are undertaken by the NWS to determine the level of service provided to its customers and partners. Best practices are identified for use throughout the country whenever feasible. Service lapses, if any, are noted so corrective action can be taken. Emergency managers, people in the media, and local residents were interviewed to obtain feedback on NWS performance. As noted above, the assessment team learned NWS customers and partners were very satisfied with the information received before and during the tornado outbreak. However, the service assessment team identified a number of internal issues where performance can be further enhanced.

Data contained in this report were compiled by the assessment team as of December 15, 2002. Final analyses may produce statistics that do not match those contained in this report.

Event Overview

The Veterans Day weekend tornado outbreak covered a very large area of the eastern United States and can be described as four distinct areas or episodes of tornadic activity. The fatalities associated with the event occurred over a 25-hour period.

The first of these four outbreaks took place during Saturday evening, November 9, through the early morning hours of Sunday, November 10. An isolated group of supercell thunderstorms formed in response to an upper-level disturbance and moved through western and central Tennessee. These storms produced 10 tornadoes and killed 4 people. Supercell thunderstorms are the most violent type of severe thunderstorm and produce large hail, damaging winds, and the majority of the tornadoes across the United States.

Twelve hours later, a second upper-level trough and associated surface-level cold front moved into the area bounded by the Great Lakes on the north and the lower Mississippi Valley on the south (*Figure 1*). The area ahead of this cold front was characterized by unseasonably warm, moist air and strong southerly surface winds. A very strong Pacific jet stream had spread eastward over the area. This created classic severe weather conditions where very unstable air combines with a strong change in wind direction with height to produce organized tornadic

supercell thunderstorms. The latter three areas of tornadic activity were associated with these atmospheric features.

By early Sunday afternoon, November 10, a supercell produced the first killer tornado of the day near the Ohio/Indiana border in Van Wert County, Ohio. A radar composite from mid-afternoon (*Figure 2*) shows three separate major tornado outbreaks unfolding simultaneously. The "northern outbreak" is over Ohio and later spread into western Pennsylvania. A "central outbreak" brought tornadoes to much of Tennessee during the afternoon and evening. The "southern outbreak" spread tornadoes over Mississippi, Alabama, and eventually into Georgia and South Carolina.

Just before 6 p.m. Central Standard Time (CST), Sunday, November 10, there were 15 different supercell thunderstorms in progress at the same time, each one containing a well-defined mesocyclone circulation capable of producing a tornado. *Figure 3* shows snapshots of these 15 storms taken from five different radars from Ohio to Alabama. The supercell thunderstorm tracks and the preliminary F2 or stronger tornado reports are shown in *Figure 4*. (See Appendix A, Fujita Tornado Intensity Scale.)

No F5 tornadoes occurred with this outbreak. One tornado was rated F4 in northwest Ohio. All other tornadoes were F3 intensity or less.

Twenty-four WFOs issued 250 tornado warnings, 400 severe thunderstorm warnings, and 15 flash flood warnings. The SPC issued 19 tornado and severe thunderstorm watches from Saturday evening, November 9, through early Monday morning, November 11. In addition to the 76 tornadoes, 250 damaging wind and 160 large hail reports were received.

Individual WFOs and the SPC highlighted the threat for severe weather and tornadoes prior to the event. At midnight CST, Sunday, November 10, the SPC issued a Day 1 Outlook with the following statement, "A SIGNIFICANT SEVERE WEATHER EPISODE INCLUDING A THREAT FOR A TORNADO OUTBREAK AND/OR WIDESPREAD WINDS ANTICIPATED SUNDAY."

The outlooks, watches, and particularly the warnings were timely and resulted in life-saving responses by EMs, law enforcement agencies, and the public. Two of the more dramatic actions, documented in greater detail later in this report, took place in Van Wert, Ohio, and Columbus, Mississippi.

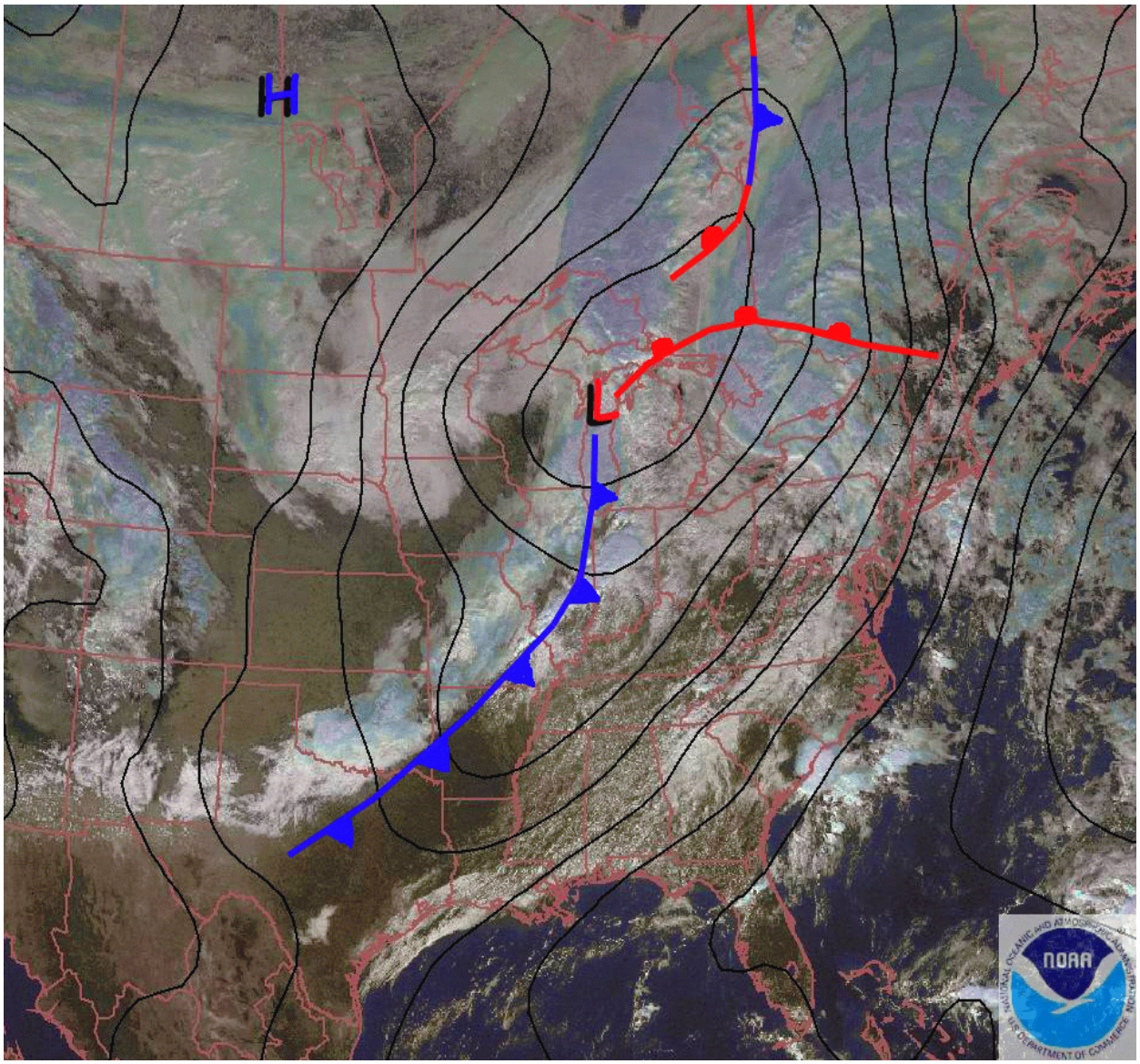


Figure 1: Visible satellite image at 11:30 a.m. CST, November 10, 2002, with contours of pressure, cold front, and warm front annotated. (NOAA)

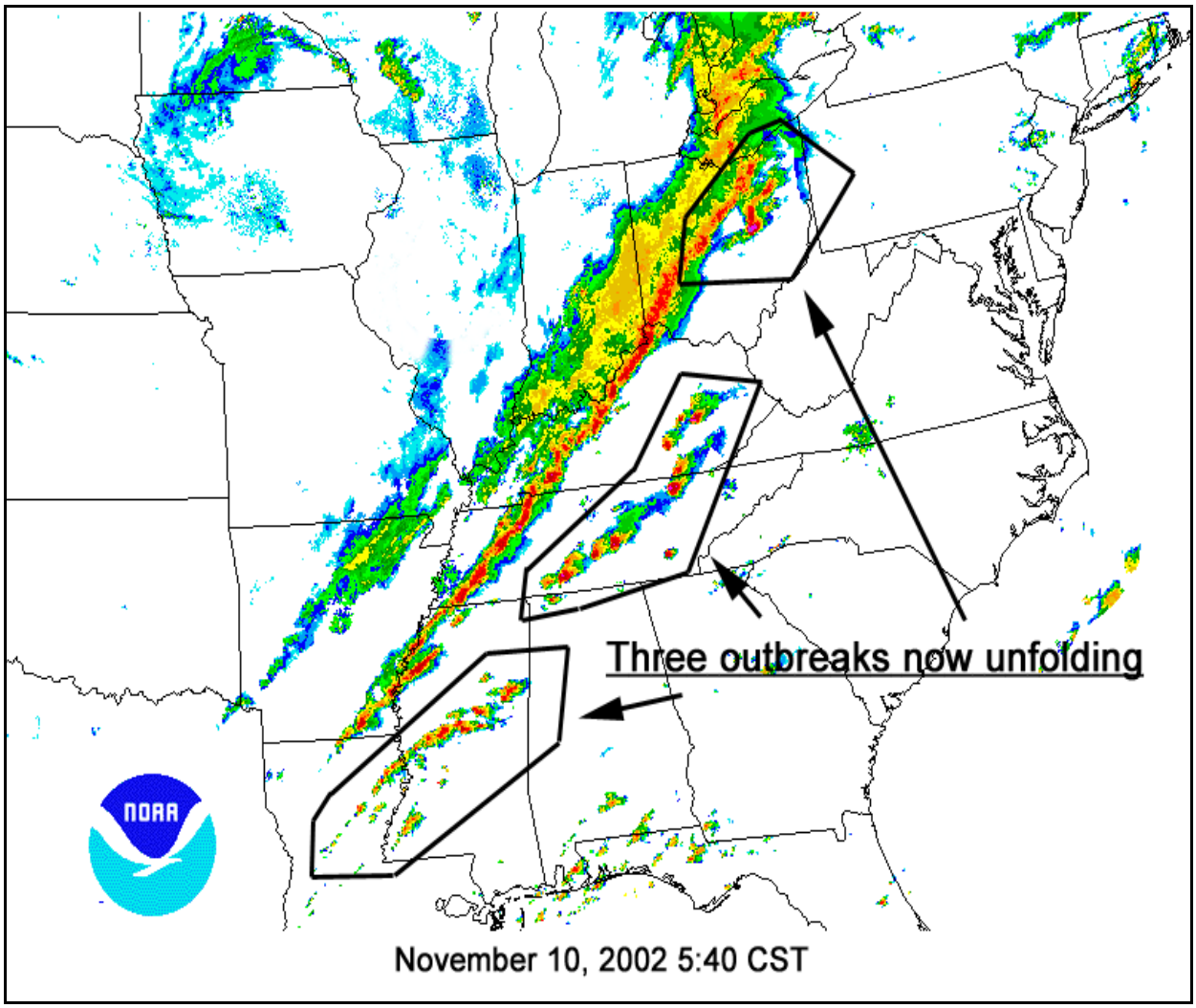


Figure 2: Radar composite base reflectivity at 6 p.m. CST, November 10, 2002, highlighting unfolding outbreaks. (Storm Prediction Center/NOAA)

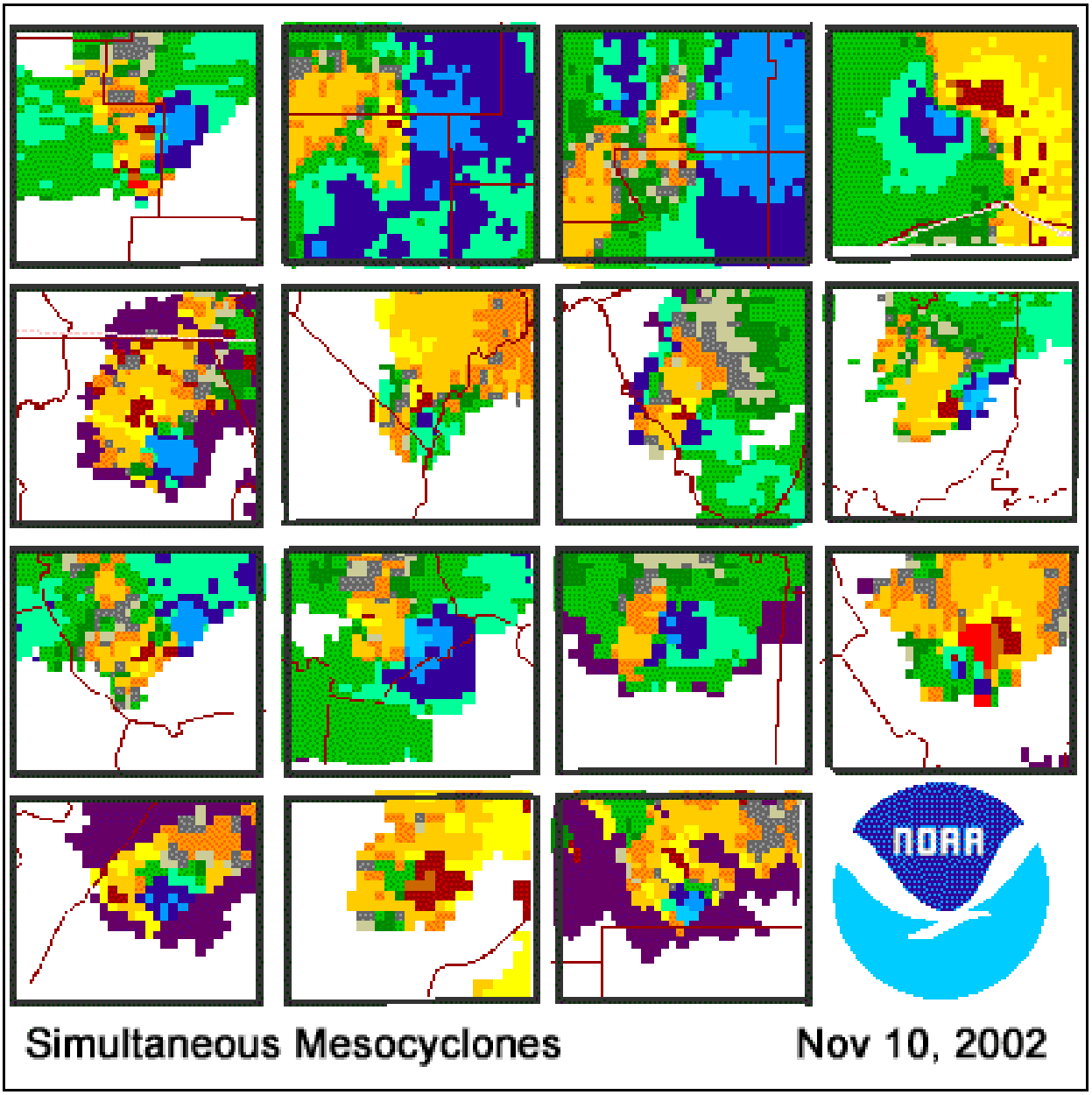


Figure 3: Snapshots of radar storm-relative velocity data showing simultaneous strong mesocyclones from 15 different supercell thunderstorms occurring about 6:20 p.m. CST, November 10, 2002. The images are from 5 different radars from Ohio to Alabama. (Storm Prediction Center/NOAA)

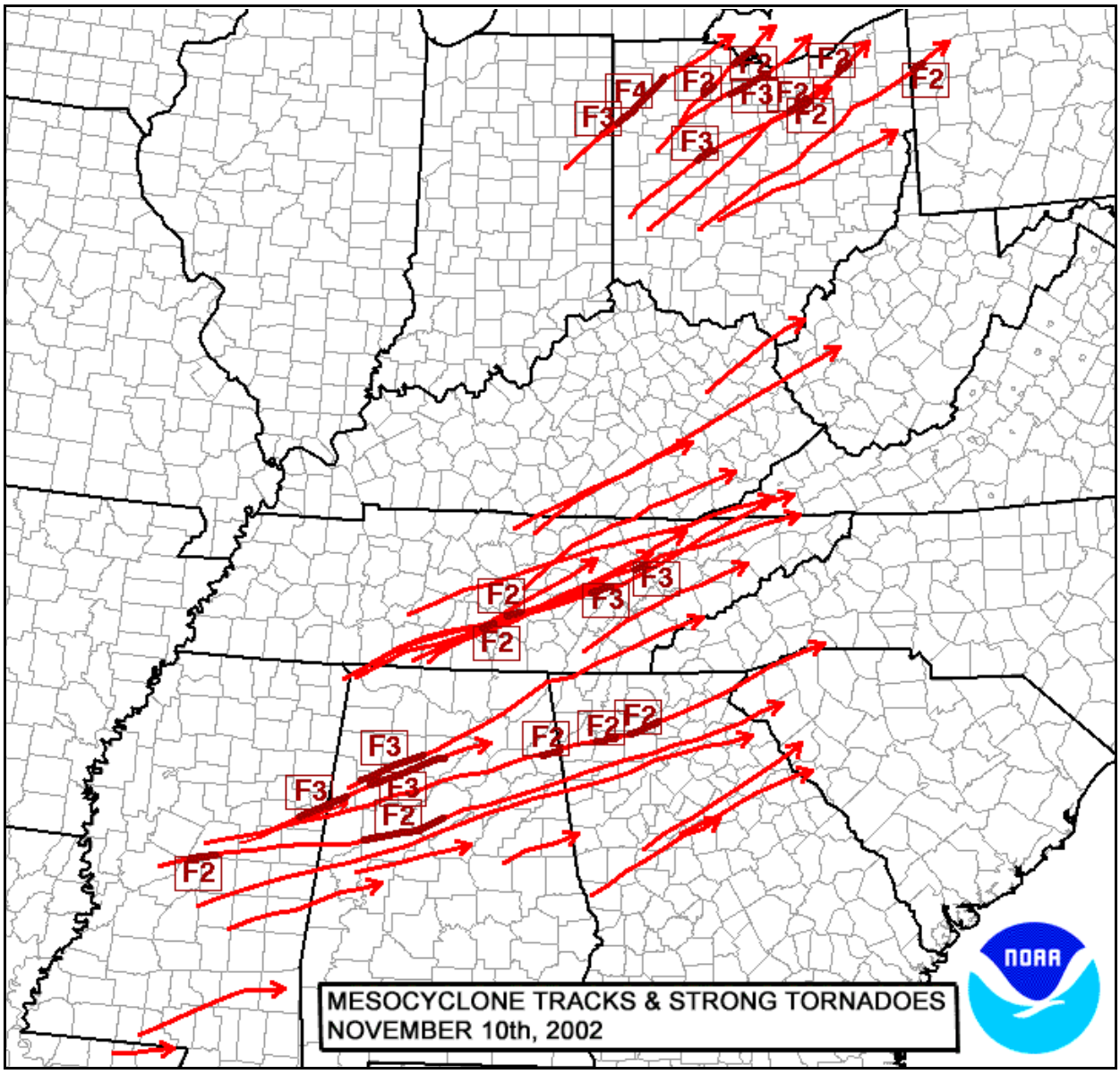


Figure 4: Tracks of supercell thunderstorms and preliminary reports of F2 or stronger tornadoes on Sunday afternoon, November 10, and early Monday morning, November 11, 2002. (Storm Prediction Center/NOAA)

In Van Wert, Ohio, a tornado warning issued 28 minutes before an F4 tornado struck the town prompted the manager of the Van Wert Cinema Complex to shut off the movies and direct 60 people into two bathrooms and an interior area of concrete block construction. The walls and roof of one of the theaters were destroyed by the tornado and three vehicles were thrown into the front rows of seats.

In Columbus, Mississippi, a tornado warning was issued 19 minutes before an F3 tornado struck Main Street. The warning was paged to a police officer who stopped at a church to relay the information. Sixty people moved from an activities building into interior hallways. The roof of the activities building collapsed after taking a direct hit from the tornado. There were no fatalities at either location.

The following sections describe the chronology of events at the SPC and the eight WFOs where killer tornadoes occurred. The WFO sections are ordered geographically from north to south. The quality of service provided and issues requiring remediation are discussed. Findings and recommendations, where appropriate, are included at the end of each section. A section "Advanced Weather Interactive Processing System (AWIPS) Issues" was added and is followed by "Best Practices." Preliminary event statistics from each WFO are provided in Appendix B.

Warning and Forecast Services

A. Storm Prediction Center (SPC)

Overview

NCEP's SPC issues products including tornado and severe thunderstorm watches, provides guidance to WFOs, and is a source of expertise concerning severe weather. WFOs have responsibility for issuing warnings.

During the Veterans Day weekend tornado outbreak, the SPC staff issued 19 tornado and severe thunderstorm watches from 6:20 p.m. CST, Saturday, November 9, through 4 a.m. CST, Monday, November 11. Eleven of the 12 killer tornadoes were covered by tornado watches. The 12th killer tornado, the F4 storm in northwest Ohio, was covered in a severe thunderstorm watch. The severe thunderstorm watch was not upgraded to a tornado watch. **(Finding 1)**

The SPC staff did a good job issuing outlooks, highlighting the potential for major severe weather and tornadoes across portions of the southern United States on Sunday afternoon, November 10. The Day 1 Outlook, issued at midnight CST, Sunday morning, indicated a *high risk* of severe weather over northern Mississippi and Alabama and much of Tennessee and Kentucky. A *moderate risk* was indicated northward into southern Ohio and western West Virginia. Northward toward the Great Lakes and eastward into Pennsylvania, the Carolinas, and Georgia, a *slight risk* was indicated. (See *Figure* 5 for SPC's Day 1 Convective Outlook.)

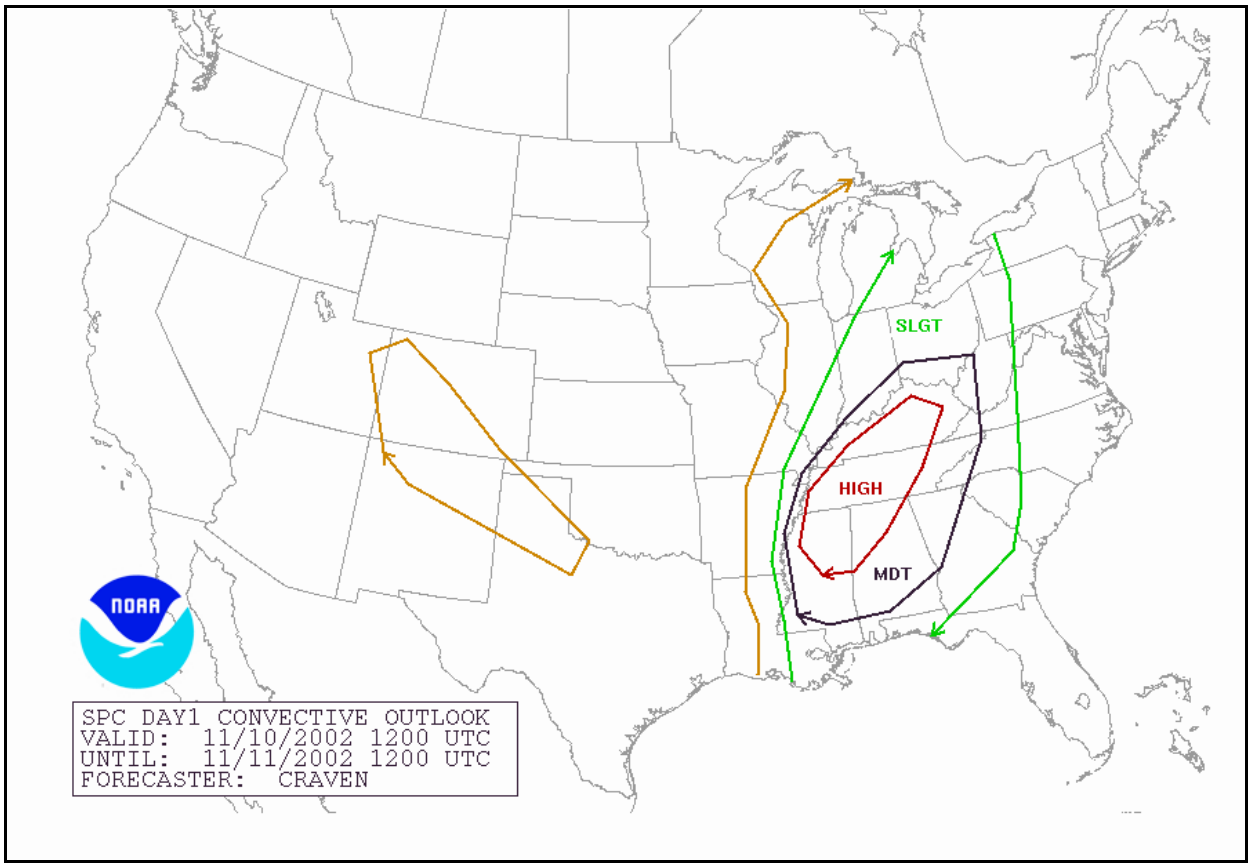


Figure 5: SPC Day 1 Convective Outlook for November 10-11, 2002. (Storm Prediction Center/ NOAA)

A high risk in an outlook is rare; this was only the second time in 2002 SPC issued a high risk outlook. The wording in the outlook specifically mentioned the threat for a tornado outbreak: "A SIGNIFICANT SEVERE WEATHER EPISODE INCLUDING A THREAT FOR A TORNADO OUTBREAK AND/OR WIDESPREAD WINDS ANTICIPATED SUNDAY." The SPC received an e-mail from citizen Jared Fisher of Florence, Mississippi, stating, *"...that Sunday morning when I woke up at 2 a.m. and saw you had put us under high risk, I knew it was going to be bad. So I went to church but made sure I was ready with my weather radio, flashlight, potential safe room in case of action, and a safety kit.... I just wanted to thank you...."*

In interviews with assessment team members, the high risk in the outlook was mentioned by WFO forecasters and EMs as being very important to their plans and preparations for the day. This outlook and subsequent mesoscale discussions, also issued by SPC, prompted WFOs to highlight the potential for severe weather and tornadoes in their HWOs and in numerous SPSs. Some forecasters even mentioned tornadoes in the Zone Forecast Product (ZFP), the primary product used by the NWS to issue general forecasts.

The tornado watches issued Saturday night, November 9, for western Tennessee had more than 2 hours lead time prior to the first reports of severe weather. During the major outbreak on Sunday afternoon and evening, November 10, five of the watches had less than an hour lead time. Tornado Watches 745 and 746 were created at the same time, but Watch 746 was not issued until 30 minutes later because the SPC operations area is configured for only one watch issuance at a time and only by a "lead certified" forecaster. A lead certified forecaster is defined as someone who has had the training and experience to be qualified to handle the duties of leading the shift, including issuance of severe weather watches. There was only one lead certified forecaster on duty at any given time during this event. Interviews with WFO forecasters indicated watch issuance with short lead time can be disruptive to warning operations. The SPC lead forecaster on duty Sunday, November 10, was one of the least experienced leads on the staff and had never been in this position during a major outbreak. **(Findings 2 and 3)**

Issues

FACT: The only F4 tornado in this outbreak occurred within the boundaries of Severe Thunderstorm Watch 744. This tornado resulted in four fatalities.

FACT: The SPC Station Duty Manual (SDM) states, *"If a severe thunderstorm watch is in effect and it appears that a tornado threat has developed within a sufficiently large portion of the severe thunderstorm watch and is expected to last for more than an hour or so, the severe thunderstorm watch should be replaced with a tornado watch."*

FINDING 1: Severe Thunderstorm Watch 744 was not upgraded to a tornado watch per policy in the SPC SDM. **The SPC lead forecaster on duty believed upgrading to a tornado watch after 1 p.m. CST, Sunday, November 10, would have an adverse impact on WFO warning operations.**

RECOMMENDATION 1: The Office of Climate, Water, and Weather Services (OCWWS), SPC, and the Regions should review policy on issuing or upgrading weather watches for WFOs already in warning operations.

FACT: Listed below are lead times for initial watches (watch issuance time to time of first severe weather event) issued for WFOs where there were tornado fatalities:

Watch #	Lead Time to 1st Severe Weather	Lead Time to First Tornado	Lead Time to 1st Killer Tornado
740	+2:29	+3:50	+3:50
741	+1:30	+1:30	+2:00
744	+0:46	+0:50	+1:50
746	-0:02	+1:30	+4:40
748	+0:50	+2:37	+3:40
749	+0:25	+0:25	+1:00
750	-0:04	-0:04	+1:09

FACT: SPC created Tornado Watches 745 and 746 at the same time. Watch 745 was coordinated with the WFOs and issued. Watch 746 was issued after the first report of severe weather and after WFO Nashville was already issuing warnings. The SPC lead forecaster stated Watch 746 was created 30 minutes before it was issued.

FACT: Watches are coordinated and issued only by SPC personnel who are "lead certified."

FACT: The SPC operations area is configured for only one person to coordinate and issue watches.

FACT: Additional SPC staff were not called in to work this event. Staff were not held over from one shift to another. Only one lead certified forecaster was on duty at any given time during this event.

FACT: Interviews with WFO forecasters at the eight offices where fatalities occurred indicated in a number of situations the SPC watches were issued with short lead time and were disruptive to warning operations.

FINDING 2: The SPC had difficulty meeting its goal, stated in the SPC SDM, of issuing tornado watches with 1 to 2 hours of lead time. The assessment team concluded this difficulty is related to not enough people on duty at the time, having only one lead certified forecaster on duty, and an operations area configured for only one person to issue watches.

RECOMMENDATION 2a: The SPC should modify its SDM to provide guidance when extra staff should be brought in to handle the workload associated with a major outbreak by September 1, 2003.

RECOMMENDATION 2b: The SPC should reconfigure its operations area to handle simultaneous multiple watch issuances by multiple forecasters by September 1, 2003.

RECOMMENDATION 2c: The SPC should reexamine its policy of allowing only lead forecasters to be certified to issue watches. Any changes should be completed by September 1, 2003.

FACT: The SPC lead forecaster on duty Sunday, November 10, was one of the least experienced leads on staff. This event was his first major severe weather outbreak as the lead.

FINDING 3: The SPC lead forecaster's inexperience resulted in inefficient time management and issuance of some watches with limited lead time.

RECOMMENDATION 3: The SPC should modify its training program to include Weather Event Simulator (WES)-like simulations of major severe weather outbreaks.

B. WFO Northern Indiana

Overview

Tornadoes struck the Northern Indiana WFO county warning area (CWA) Sunday afternoon, November 10. The WFO began alerting the public and EMs to the threat of severe thunderstorms with the HWO issued Friday morning, November 8. This was done again in the HWO issued Saturday morning, November 9, and again at 5:40 a.m. Eastern Standard Time (EST) on Sunday, November 10. The anticipated type of severe weather was straight line winds from a squall line. This was reflected in the issuance of a severe thunderstorm watch by the SPC for the area at 1:44 p.m. EST, Sunday, November 10.

Four tornadoes occurred in the WFO Northern Indiana CWA on Sunday afternoon, November 10. Three of these tornadoes were covered by tornado warnings. The first tornado, an F1, in Blackford County at 2:30 p.m. EST was not in a warning. The same thunderstorm that spawned the Blackford County tornado later spawned a long-track tornado that went through Van Wert County, Ohio, and later into Putnam, Paulding, and Henry Counties in Ohio. The average lead time for counties hit by tornadoes was 15 minutes.

All fatalities were associated with the long-track tornado. This tornado reached F4 intensity as it moved through the town of Van Wert, Ohio, where two fatalities occurred, and was rated at F3 intensity in Putnam County where the other two fatalities occurred. The tornado warning for Van Wert County was issued 12 minutes before the tornado touched down and 28 minutes before the tornado entered the town of Van Wert. The warning included the statement, "THIS STORM HAS A HISTORY OF TORNADOES." A follow-up Severe Weather Statement (SVS), issued at 3:21 p.m. EST, Sunday, November 10, provided spotter

reports of two tornadoes and the statement, "THESE TORNADOES WILL MOVE TOWARD DOWNTOWN VAN WERT. PEOPLE IN VAN WERT SHOULD TAKE COVER NOW!" The F4 tornado struck the movie theater in downtown Van Wert at 3:30 p.m. EST.

At 3:32 p.m. EST, Sunday, November 10, another tornado warning was issued for areas downstream from Van Wert County in Defiance, Paulding, and Putnam Counties. This warning provided lead times of 33, 13, and 25 minutes, respectively. It included the statement, "...EXTREMELY DANGEROUS AND LIFE THREATENING SITUATION."

Outreach and community preparedness activities by the Northern Indiana WFO have been very effective. In particular, Van Wert County, which became a StormReady community in January 2002, offers an example of how lives can be saved when a WFO, local government, and businesses work together.

The Van Wert County EM used state funds to purchase a commercial radio receiver system known as "Informer" to relay emergency information to schools, radio stations, nursing homes, hospitals, all government facilities, and many local businesses (including the local cinema complex).

On Sunday afternoon, November 10, the Northern Indiana WFO issued a tornado warning for Van Wert County at 3:02 p.m. EST. The Van Wert County EM received the warning over NOAA Weather Radio (NWR), immediately activated the warning sirens, and disseminated the tornado warning over the "Informer" system. The manager of the local cinema complex heard the warning over his "Informer" receiver approximately 28 minutes prior to the F4 tornado hitting the theater. The manager stopped all movies in the cinema complex, told the patrons a tornado warning was in effect for Van Wert County, and led them into the restrooms and an interior hallway. At the time, 60 people were in the cinema. A few minutes later the tornado swept through the theater, tore the roof off a portion of the cineplex, and deposited debris, including automobiles, in the front rows of seats. Due to the advance warning from WFO Northern Indiana, the decisiveness of the Van Wert EM, and the effort of the cinema manager, no fatalities occurred.

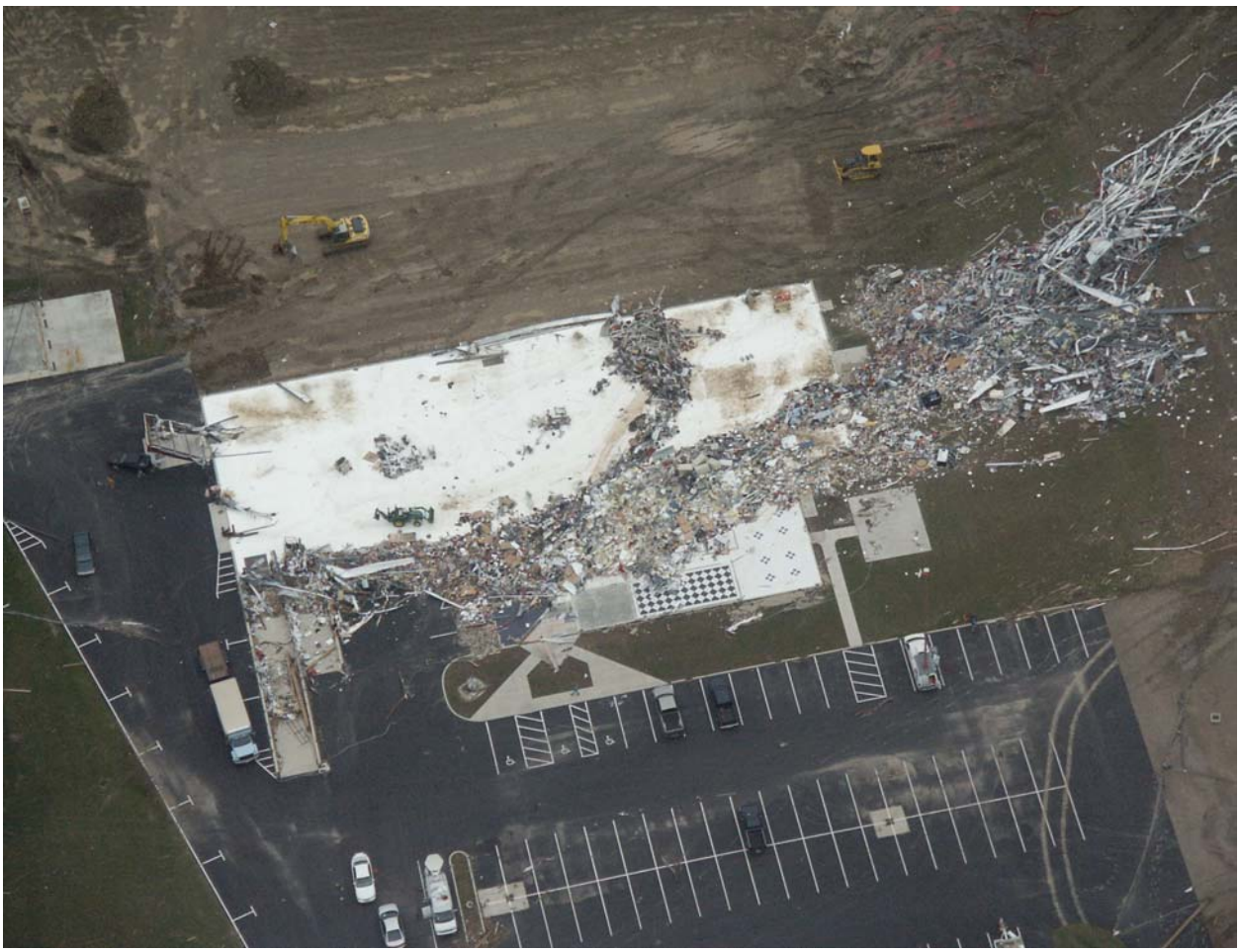
According to Van Wert County EM Rick McCoy, *"The coordination between the NWS and emergency management is excellent and it definitely saved lives."* When asked how the coordination between all the agencies went during the event, McCoy said, *"Excellent! If you want a textbook case of how things should go, this was one."*

All media interviewed by the assessment team (three Ft. Wayne, Indiana, television stations and the Van Wert radio station) reported excellent service by the Northern Indiana WFO. They were unanimous in complimenting the timeliness and accuracy of the tornado warnings.

The WFO was well prepared for this event. Additional staff were called in prior to the event and the lead forecaster delegated duties accordingly, resulting in efficient, effective

warning and routine operations. Supporting SVSs were issued for each of the tornado warnings, with most warnings having more than one follow-up SVS. Five Local Storm Reports (LSRs) were released while tornadoes were still in progress. Throughout the event, staff made frequent updates to information posted on the WFO's Internet home page. This timely information was used by EMs, the media, and the public.

One Internet customer on optonline.net sent a Veterans Day e-mail saying: *"I just wanted to thank the personnel at the Northern Indiana office in Syracuse, Indiana, for their life-saving work yesterday. Your timely and accurate warnings made sure a lot of people are alive today."*



Aerial view of Kams Manufacturing destroyed by F4 tornado in Van Wert County, Ohio, just northwest of town of Van Wert, November 10, 2002. (NOAA)

C. WFO Cleveland, Ohio

Overview

The Cleveland WFO was not expecting severe weather in the days leading up to the event. However, the SPC Outlook early Sunday morning, November 10, extended the slight risk northward over WFO Cleveland's CWA, and the WFO's 6:12 a.m. EST HWO included the possibility of severe thunderstorms for the afternoon. Damaging winds were expected to be the most probable type of severe weather.

Thirteen tornadoes occurred in the WFO Cleveland CWA Sunday afternoon and evening, November 10. Eleven of the 13 were covered by tornado warnings. Average lead time for the counties hit by tornadoes was 17 minutes.

Despite the large number of tornadoes, there was only one fatality. This fatality was associated with an F3 tornado near the town of Tiffin in Seneca County. The tornado warning for Seneca County was issued 12 minutes prior to touchdown southwest of Tiffin and 22 minutes before the fatality northwest of Tiffin near the end of the tornado track at 5:25 p.m. EST.

In addition to conventional warning dissemination, WFO Cleveland enters abbreviated messages with type, location, and timing for each warning into a paging system. This information reaches EMs, media, and spotters who sign up for the service through a commercial paging system. The WFO follows up with a telephone call to each county to confirm receipt of each warning.

The SKYWARN spotter network maintained by WFO Cleveland consists of 5,000 members, 1,500-2,000 of these are amateur radio operators. The radio network is divided into six districts, each with a "captain" who collects and disseminates information within the district. Radio contact with the WFO is through the captains. This network uses a 6-meter radio system heard across the entire CWA. The radio traffic is closely monitored by the media and EMs. Monthly meetings are held to maintain and coordinate activities of this large radio network. Although damage reports flowed well over the radio network and met the needs of EMs and media with access to this network, no SVSs or LSRs were issued during the event.

The WFO allowed one forecaster to leave at the end of the day shift and held over one forecaster. The forecaster was later called back. During the height of the event, the staff consisted of four meteorologists and one Hydrometeorological Technician (HMT). Warnings were issued every 3 to10 minutes for over a 2-hour period for a total of 45 tornado and severe thunderstorm warnings.

Because the local Emergency Alert System (EAS) committee was not satisfied with the older synthesized voice on NWR, WFO Cleveland manually recorded all warnings. With the implementation of the concatenated voice associated with the Voice Improvement Project, warnings were to be automated. The WFO had planned to automate their warnings on Friday,

November 8, but decided to postpone the work rather than make a major change just before a weekend with the possibility of thunderstorms. Thus, the HMT on duty was completely dedicated to getting the warnings on NWR. **(Finding 4)**

Issues

FACT: No SVSs or LSRs were issued during the event.

FACT: Interviews with EMs and the media indicated satisfaction with the information flowing to and from the WFO during the event via the amateur radio network.

FACT: With no SVSs or LSRs issued during the event, customers without access to the radio network or located outside the media market were not getting ground truth storm reports.

FACT: The workload during the event was as follows: Two forecasters were working the radar, issuing warnings, entering messages for paging, and doing follow-up coordination calls to each county warned. One forecaster handled incoming phone calls and assisted in the dissemination of warnings. One forecaster, who arrived midway through the event, maintained the routine product flow. The HMT kept warnings flowing on NWR via manual recording.

FINDING 4: The Cleveland WFO did not have enough staff on duty to handle the workload during the event, including issuance of SVSs and LSRs.

RECOMMENDATION 4a: WFO Cleveland should automate the placement of warnings on NWR.

RECOMMENDATION 4b: WFO Cleveland should determine the feasibility of either automating warning information into the paging system or looking at alternative paging methods, such as EWARN (Email Warning System) used in Western Region. If feasible, implement the change.

RECOMMENDATION 4c: Regions should ensure all WFOs' Severe Weather Operations Plans identify realistic staffing levels necessary to handle the workload during a severe weather outbreak.

RECOMMENDATION 4d: Regions should work with WFO management to ensure issuance of SVSs per Directive 10-511 and LSRs per Directive 10-517 are included in Severe Weather Operations Plans and emphasized in station drills.

Aerial view of F3 tornado damage to homes near Republic in Seneca County, Ohio, on November 10, 2002. (NOAA)

D. WFO Pittsburgh, Pennsylvania

Overview

The Pittsburgh WFO began discussion of severe weather in the 2 a.m. EST, Sunday, November 10, Area Forecast Discussion released 1 hour after the SPC Outlook placed its CWA into a slight risk area. The 6:40 a.m. EST HWO headlined, "SLIGHT RISK OF SEVERE THUNDERSTORMS ACROSS THE AREA TODAY." The primary severe weather expected was damaging straight line winds. The first inclusion of tornadoes in a product was the tornado warning issued for Coshocton County, Ohio, at 6:28 p.m. EST, followed by a tornado watch issued by the SPC at 6:44 p.m. EST.

One tornado occurred in the WFO Pittsburgh CWA on Sunday evening, November 10, in the town of Clark, Mercer County, Pennsylvania. This F2 tornado occurred while a severe thunderstorm warning was in effect. A tornado warning was issued 2 minutes after touchdown, while the tornado was still on the ground. One fatality occurred in Clark—an 81-year-old man was found covered by rubble in the basement of his home. The severe thunderstorm warning for Mercer County preceded the tornado touchdown by 6 minutes and the fatality by 8 minutes. The tornado warning provided no lead time for the tornado.

Less than 30 minutes before the severe thunderstorm warning was issued for Mercer County and with radar showing a well-developed supercell thunderstorm just upstream, county officials who called the WFO were told by a forecaster severe weather was not expected in the near term. This call was not logged at the WFO and the forecaster did not discuss it with the rest of the forecast staff. In a meeting with the service assessment team, Mercer County officials and the public expressed dissatisfaction with NWS performance during this event. **(Finding 5)**

WFO Pittsburgh was unaware the thunderstorm that produced the Mercer County tornado had previously produced a tornado two counties upstream in Stark County, Ohio, which is in WFO Cleveland's CWA. Although reports of damage and rotation from Stark County were received by WFO Cleveland, they did not issue any SVSs or LSRs with this information during the event.

Media interviews from both Pittsburgh, Pennsylvania, and Youngstown, Ohio (four TV stations; one radio station), indicate satisfaction with the performance of the Pittsburgh WFO during this event and with their severe weather program. Paul Wetzel of Youngstown's WKBN-TV stated, *"In general, this office has a very good severe weather program; in fact, probably the best I've ever worked with."*

Staff on duty at 4 p.m. EST, Sunday, November 10, correctly anticipated the severe weather potential, including some threat of tornadoes. Sufficient staff were held over, called in, or brought in early for their shift to handle the event. At the height of the event, staffing

consisted of six meteorologists and one HMT. Despite adequate staffing, no SVSs or LSRs were issued during the event. **(Refer to Recommendation 4d.)**

Issues

FACT: Logs, based on transcripts of telephone recordings from the Mercer County 911 system, indicate the EM called WFO Pittsburgh at 7:21 p.m. EST, Sunday, November 10, to ask about the severity of the storm approaching Mercer County from Trumbull County, Ohio. He was told, *"This storm won't hold together and nothing serious would be expected in Mercer County until about 9 p.m. when a storm currently in Columbus, Ohio, would come into Pennsylvania."*

FACT: Radar data from KPBZ at 7:19 p.m. EST, Sunday, November 10, show a supercell thunderstorm with a well developed mesocyclone over Trumbull and Mahoning Counties in Ohio. This thunderstorm later produced the deadly tornado in Mercer County, Pennsylvania.

FACT: The WFO issued a severe thunderstorm warning for Mercer County at 7:48 p.m. EST and a tornado warning for Mercer County at 7:56 p.m. EST, Sunday, November 10.

FACT: Service assessment team interviews with all forecasters working the event could find no one recalling the phone call with the Mercer County EM, and there was no record of the call in the WFO's logs. Subsequent interviews revealed a forecaster on duty took the call but did not log it or discuss it with any of the forecasters.

FACT: At a meeting among the Mercer County EM, county staff, the public, the service assessment team, and a member of WFO Pittsburgh's management team, dissatisfaction with NWS performance was voiced based on the belief they were mislead about the severe weather threat by the 7:21 p.m. EST phone call.

FINDING 5: Although the service assessment team found WFO Pittsburgh had good intra-office communication, a single instance of poor communication led to the dissemination of incorrect information to a customer at a critical time during a severe weather event.

RECOMMENDATION 5a: WFO Pittsburgh management should ensure all employees read the La Plata, Maryland, Tornado Outbreak of April 28, 2002, Service Assessment Report, paying particular attention to the narrative on intra-office communication and Finding/Recommendation 4.

RECOMMENDATION 5b: WFO Pittsburgh management should certify all employees have reviewed information contained in the Warning Decision Making (WDM) Workshop training module entitled, "Learning from History: Warning Decision Making Implications from Significant Events."

E. WFO Memphis, Tennessee

Overview

Severe weather and tornadoes occurred in eastern Arkansas and western Tennessee on Saturday evening, November 9, and spread into the northern portion of middle Tennessee just after midnight on Sunday, November 10. The Memphis WFO first began emphasizing severe weather for Saturday evening in the Saturday morning zone forecast released at 4:22 a.m. CST. The statement, "SOME THUNDERSTORMS MAY CONTAIN DAMAGING WINDS," was included with the forecast. The HWO issued at 4:40 a.m. CST also highlighted the severe weather potential. This product included the statement, "IF THE STORMS DEVELOP, DAMAGING WINDS ARE POSSIBLE.... AN ISOLATED TORNADO WOULD ALSO BE POSSIBLE." Products issued throughout the day continued to mention the severe weather threat.

Six tornadoes occurred in the WFO Memphis CWA on Saturday evening, November 9. All six tornadoes were covered by tornado warnings. Average lead time for the counties hit by tornadoes was 10 minutes.

There were two fatalities in the WFO Memphis CWA. Both were associated with an F2 tornado in Carroll County, 2 miles northwest of Cedar Grove, Tennessee. A tornado warning for Carroll County was issued 3 minutes before touchdown and 14 minutes before the fatalities occurred at 10:37 p.m. CST, Saturday, November 9. The pathcast portion of the warning, which lists communities in the path of the storm, specifically mentioned the tornado would affect the Cedar Grove area. A tornado watch for the area was issued by SPC at 6:26 p.m. CST.

Interviews with three Memphis TV stations and the Carroll County EM indicated satisfaction with WFO Memphis' performance during this event, and all noted they had a good working relationship with the WFO. The TV meteorologists reported they interrupt programming when the NWS issues tornado warnings, and their policy is to go "wall-to-wall" with coverage if the tornado warning includes the Memphis metropolitan area. All of the media interviewed cited the need for real-time storm report information to lend credibility to their broadcasts and to allow them to remain on the air during severe weather episodes.

Staffing during this event consisted of three meteorologists and one HMT. Tornado warnings were issued for 29 counties and severe thunderstorm warnings were issued for 6 counties. Follow-up SVSs were issued for less than half of the warnings. **(See Recommendation 4d.)**

F. WFO Nashville, Tennessee

Overview

WFO Nashville was the only WFO having two distinct severe weather episodes. Severe weather moved through the northwest corner of WFO Nashville's CWA just after midnight on Sunday, November 10, as storms in western Tennessee propagated into the area. Severe weather began again in mid-afternoon as part of the larger outbreak of severe weather. WFO Nashville began focusing on the possibility of severe weather Saturday morning, November 9. The HWO issued at 5:35 a.m. CST, Saturday, November 9, mentioned the potential of severe thunderstorms with damaging winds. That evening, at 10:08 p.m. CST, the ZFP for Montgomery County (site of the fatalities) was updated to include: "A FEW THUNDERSTORMS POSSIBLY SEVERE."

Four tornadoes occurred just after midnight CST, Sunday, November 10. Three of the four occurred within tornado warnings. One F0 tornado with a very short path length of 1/10 mile was not within a warning. An F1 tornado in Montgomery County, Tennessee, resulted in two fatalities at 1 a.m. CST, Sunday, November 10. A tornado warning was in effect for 49 minutes before touchdown. A tornado watch for the area was issued by SPC at 11 p.m. CST, Saturday, November 9. As noted in WFO Nashville's logs, during the coordination call for the tornado watch, the SPC forecaster also mentioned Tennessee would be "ground zero" for a severe outbreak on Sunday, November 10.

The potential for severe weather later Sunday was strongly emphasized by WFO Nashville. In addition to including the potential for severe weather in the HWO issued Sunday morning, November 10, the 4 a.m. CST ZFP included enhanced wording: "SOME STORMS MAY BE SEVERE WITH ISOLATED TORNADOES."

Five tornadoes occurred Sunday evening, November 10. Two of these tornadoes (F2 and F3) were preceded by tornado warnings; one F2 tornado occurred within a severe thunderstorm warning with no lead time, and two tornadoes (F1 and F2) were not within warnings. The average lead time for all nine tornadoes was 13 minutes. A tornado watch was issued by the SPC at 3:05 p.m. CST, Sunday, November 10, a few minutes after the first report of severe weather (hail and wind reports) from WFO Nashville's CWA, but more than 3.5 hours before the first tornado in Bedford County, Tennessee, at 6:42 p.m. CST, Sunday, November 10.

Between 5:30 and 8:30 p.m. CST, Sunday, November 10, a series of five supercell thunderstorms, each with a deep, well defined mesocyclone circulation moved over a nearly identical track through Bedford and Coffee Counties, Tennessee. These powerful storms were moving at 50 mph and passed over the same ground at 30- to 90-minute intervals. Each storm produced strong winds and large hail. According to aerial surveys, one F2 tornado touched down in Bedford County and another F2 tornado occurred in Coffee County. Eyewitness and media reports from these two counties include reports of tornadoes at widely varying times ranging from 5:45 to 7:45 p.m. CST, Sunday, November 10. The times of tornado occurrence

used in this report are based on comparisons of Doppler radar data with 911 logs from Bedford and Coffee Counties.

A tornado warning was issued at 5:15 p.m. CST, Sunday, November 10, for the first supercell tracking across Coffee County. Another warning followed for the second supercell valid from 6 to 6:30 p.m. CST. Neither of these two storms produced tornadoes at this time. The second warning was allowed to expire with an SVS containing the following wording: "THE TORNADO WARNING FOR NORTHERN COFFEE...WARREN AND NORTHERN GILES...WILL BE ALLOWED TO EXPIRE AT 6:30 P.M. STILL...ADDITIONAL STORMS MAY STRENGTHEN AND POSE AN EXTENDED TORNADIC THREAT THIS EVENING TO THESE COUNTIES...."

The third supercell produced an F2 tornado in Bedford County at 6:42 p.m. CST, Sunday, November 10. Another F2 tornado from the same supercell began in Coffee County at 6:52 p.m. CST. Two fatalities occurred in Coffee County at 7:05 p.m. CST. Neither tornado was covered in a tornado warning. A severe thunderstorm warning was issued for Coffee County at 7:01 p.m. CST, while the tornado was still on the ground.

The fourth and fifth supercell thunderstorms did not produce tornadoes as they moved through Bedford and Coffee Counties. The fifth supercell thunderstorm produced another deadly F3 tornado in Cumberland County at 9:43 p.m. CST, Sunday, November 10. A tornado warning for Cumberland County was issued at 9:31 p.m. CST with the pathcast in the warning stating, "THE TORNADO IS EXPECTED TO BE NEAR CROSSVILLE AT 9:45 P.M. CST." Four fatalities occurred near Crossville at 9:45 p.m. CST, 14 minutes after the issuance of the warning.

WFO Nashville issued 22 tornado warnings and 23 severe thunderstorm warnings, covering 86 counties. Only 11 SVSs were issued. **(See Recommendation 4d.)**

Two operational problems at WFO Nashville were identified by the service assessment team during this event. First, after warning operations were sectorized on Sunday afternoon, November 10, an erroneous warning was issued and never corrected. This warning was for Van Buren County and was issued with coding for Coffee County. The warning also stated storms were stationary but in fact were moving at 50 mph. Second, no warning was issued for the third supercell (the third in a series of five supercells mentioned above) as it moved over Bedford County and produced a tornado. This supercell then moved into Coffee County. A severe thunderstorm warning was issued for Coffee County after a tornado was on the ground. Since tornado warnings had been in effect for Coffee County previously (Coffee County was under tornado warnings from 5:15 until 6:30 p.m. CST), local officials and the media interviewed perceived the public was warned for the tornado which began in Coffee County at 6:52 p.m. CST. The service assessment team concluded these operational problems might not have occurred if additional staff had been working this event with someone in the role of warning coordinator. **(Finding 6)**

WFO Nashville developed a Web page entitled "Middle Tennessee SKYWARN." The server is operated by the SKYWARN network and is located outside of the WFO. This Web page contains a variety of meteorological information, including model output, satellite pictures, and radar imagery. All watches, warnings, advisories, and outlooks are moved to this Web site as soon as they are issued. Warnings result in automatic update of the graphical display for anyone using the Web page, and an audio voice alarms and says what type of warning has been issued. SKYWARN spotters and EMs use the page extensively, and it now receives more than 7,000 visitors each month. Linda Brooks, the Assistant Director of the Cumberland County Emergency Management Agency, told the assessment team, *"We use it all the time. It's faster than NAWAS [National Warning System]."*

Interviews with the Coffee County EM and the public indicate satisfaction with the WFO's performance during this event. The EM said, *"The warnings were out there...they were hitting it right on the head."* Captain Rodney Banks, Coffee County Sheriff Department, noted in a letter to WFO Nashville, *"...97 homes were damaged or destroyed and two lives taken and 17 people were taken to hospitals; however, adequate notice was given by the National Weather Service and by all local radio and television stations."* Also, the Cumberland County EM was satisfied with NWS performance. He noted precautionary measures, such as alerting schools, churches, nursing homes, and businesses, are done when a tornado watch is issued, and on Sunday, November 10, these actions took place many hours before the first of two tornadoes moved through the county.

Interviews with Nashville TV stations also indicated satisfaction with the WFO's performance during the event and in general praised the overall warning program since the installation of the Next Generation Radar. Davis Nolan of WKRN-TV stated, *"The warnings were coming out before the fact."* All members of the media noted the importance of receiving timely reports of damage in order to lend credibility to their severe weather broadcasts and allow the weathercasters to remain on the air during severe weather episodes. One TV weathercaster indicated there could have been more ground truth reports in SVSs coming from the WFO during the event.

Issues

FACT: On Sunday afternoon, November 10, two staff members were dismissed at the shift change from day to evening, leaving three meteorologists, one HMT, and the Information Technology Officer (ITO) to work a major severe weather outbreak in progress.

FACT: At approximately 5:30 p.m. CST, Sunday, November 10, a decision was made to divide severe weather responsibilities with one forecaster to handle the pre-frontal storms over the eastern and southern portion of the CWA and another forecaster to track the storms associated with the squall line over the northwest portion of the CWA.

FACT: Numerous storms were located over the southern and eastern portion of the CWA, including a series of five supercells tracking across Bedford and Coffee Counties between

5:30 and 8:30 p.m. CST, Sunday, November 10. These five storms were moving at 50 mph and all were characterized by well-defined, deep mesocyclones, and hook appendages in the reflectivity data.

FACT: At 6:18 p.m. CST, Sunday, November 10, a severe thunderstorm warning was issued for Coffee County valid until 6:45 p.m. CST, but the text of the warning stated, "...DOPPLER RADAR INDICATED A SEVERE THUNDERSTORM NEAR CENTRAL VAN BUREN COUNTY...OR NEAR SPENCER. THE STORM WAS NEARLY STATIONARY." Storms were moving at 50 mph on this day and Van Buren County is two counties downstream (east) of Coffee County. This erroneous warning was never corrected.

FACT: No warning was issued for the third supercell (in the series of five) as it moved over Bedford County and produced a tornado. A severe thunderstorm warning was issued after the storm moved into central Coffee County and produced another tornado.

FINDING 6: Between 6:15 and 7 p.m. CST, Sunday, November 10, an erroneous warning was issued for Coffee County and never corrected. Also, no warning was issued for the third supercell (in a series of five) as it moved over Bedford County producing a tornado. A severe thunderstorm warning was issued for this third supercell after it moved into Coffee County and produced another tornado. With three forecasters, an HMT, and the ITO, additional staffing, including a warning coordinator, may have mitigated these problems.

RECOMMENDATION 6a: WFO Nashville should revisit the station's Severe Weather Operations Plan and define realistic staffing levels necessary to handle various degrees of severe weather activity. Roles should be defined, including that of a warning coordinator, when numerous warnings are anticipated.

RECOMMENDATION 6b: The MIC should certify the staff is familiar with the revised operations plan through drills, simulations using the WES, and the WDM Workshop training module entitled, "Learning from History: Warning Decision Making Implications from Significant Events."

G. WFO Morristown, Tennessee

Overview

The Morristown WFO began alerting the public and EMs to the threat of severe weather and tornadoes in the HWO issued at 5 a.m. EST, Saturday, November 9. It stated, "STRAIGHT LINE WINDS WILL BE THE MAJOR THREAT BUT ISOLATED TORNADOES CANNOT BE RULED OUT." Additional HWOs were issued at 7:05 a.m. and again at 12:15 p.m. EST all indicating "moderate to high risk" of severe weather. An SPS issued at 5:20 a.m. EST, Sunday,

November 10, contained the following headline: "SIGNIFICANT SEVERE WEATHER EPISODE INCLUDING THREAT FOR TORNADO OUTBREAK AND/OR WIDESPREAD DAMAGING WINDS EXPECTED LATE THIS AFTERNOON THROUGH LATE EVENING." This statement was updated and reissued at 2:05 p.m. EST.

Six tornadoes occurred in the WFO Morristown CWA on Sunday evening, November 10. All six tornadoes were covered by tornado warnings. The average lead time for counties hit by a tornado was 21 minutes.

An F3 tornado struck the communities of Mossy Grove and Petros/Joyner in Morgan County, Tennessee, resulting in seven fatalities. A tornado warning was issued for this area at 8:12 p.m. EST, Sunday, November 10, 19 minutes before the tornado touched down on the slopes of Lone Mountain and 23-26 minutes before the fatalities occurred. The warning included the statement, "THIS IS A DANGEROUS STORM; TAKE COVER IMMEDIATELY!"

The Morgan County EM told the assessment team the tornado warning had so much lead time he was able to travel from home to the Emergency Operations Center before the storm hit the area. He stated, *"I have heard reports most of the people got the warnings...some people that were out went home to prepare for the storms,"* and, *"From what the NWS told us, we knew it was going to track through Mossy Grove and Petros. It was precise."* Eyewitnesses reported at least three of the seven people killed knew of the tornado warning. One 73-year-old woman opted not to seek shelter after her grandson called to tell her of the warning, and two other people were killed in their vehicle after the warning prompted them to abandon their trailer home for better shelter.

WFO Morristown anticipated the magnitude of the severe weather outbreak and was adequately staffed. At the height of the event, staffing consisted of five meteorologists and two HMTs, including a warning coordinator. Also, warning operations were sectorized. WFO Morristown issued 33 tornado warnings and 18 severe thunderstorm warnings, covering 93 counties. A follow-up SVS was issued for every warning.

Interviews with weathercasters from three Knoxville television stations indicated satisfaction with the WFO's performance during the event and with the overall outreach program. Todd Howell from WBIR-TV stated, *"The SVSs were the most important information. They contained confirmation and heightened awareness."*

Remnants of house struck by an F3 tornado in Mossy Grove, Tennessee, on November 10, 2002. (NOAA)

Vehicles and homes destroyed by an F3 tornado in Mossy Grove, Tennessee, on November 10, 2002. (NOAA)

H. WFO Jackson, Mississippi

Overview

The Jackson WFO first alerted the public and EMs to the potential for severe weather on Sunday, November 10, in the HWO issued on Thursday afternoon, November 7. Subsequent HWOs continued to describe the threat of severe weather for Sunday. An SPS was issued early on Sunday morning, November 10, and enhanced wording in the ZFP included the threat of severe storms with damaging winds. Updated HWO and SPS products were issued at 10:30 a.m. CST on Sunday, November 10, both with the following language: "ISOLATED TORNADOES ARE ALSO POSSIBLE BY LATE AFTERNOON.... DEVELOPMENT WILL BE GREATEST DURING THE EVENING INTO TONIGHT." This information was briefed to all county warning points via NAWAS during the late morning. A tornado watch was issued by the SPC at 4:30 p.m. CST.

Ten tornadoes occurred in the WFO Jackson CWA on Sunday evening, November 10. Nine of the ten tornadoes occurred within tornado warnings and one tornado occurred within a severe thunderstorm warning. The average lead time for counties hit by tornadoes was 11 minutes.

Three different tornadoes moved through Lowndes County, Mississippi, between 7 and 8 p.m. CST, Sunday, November 10. The third tornado (F1) resulted in a fatality near Crawford, Mississippi, at 7:46 p.m. CST, 11 minutes after a tornado warning for Lowndes County was issued. A 54-year-old man left his home to warn neighbors of the approaching tornado and was returning home when his trailer flipped over pinning him to the ground. The tornado warning preceding this fatality stated, "DO NOT WAIT UNTIL YOU SEE OR HEAR THE TORNADO–IT MAY BE TOO LATE. TAKE COVER NOW!"

The strongest tornado (F3) in Mississippi during this event struck the city of Columbus at approximately 7:20 p.m. CST, Sunday, November 10, destroying dozens of homes and businesses and a church. At 7:01 p.m. CST, a tornado warning was issued for Lowndes County stating, "THE TORNADO IS EXPECTED TO...BE NEAR COLUMBUS...NEW HOPE AT 7:20 P.M. CST," while a 7:16 p.m. CST SVS again stated, "NEAR COLUMBUS AT 7:20 P.M. CST."

At a church in Columbus, about 60 people were moved from an activities building into interior hallways after a Columbus police officer stopped to tell them about the tornado warning. The police officer received the warning through a page sent out by the emergency management office after the warning was received. The roof of the activities building collapsed just minutes later. There were no fatalities in Columbus.

The primary media outlets serving the citizens of Columbus and Lowndes Counties are WCBI-TV and WMBC Radio in Columbus. Both suffered power outages when the F3 tornado ripped through the center of town. At the primary EAS station, WMBC's backup generator

allowed the station to resume broadcasting. The television station was unable to continue operations. Both stations managed to broadcast the tornado warning prior to losing power.

WCBI-TV Chief Meteorologist Brian Owens said, *"We were knocked off the air and couldn't get back on with our backup generator. However, we received the initial NWS warning and managed to get it out before we went off the air. The warnings were timely."*

WMBC News Director Jodi Smith concurred, *"We were also knocked off the air, but our backup generator kicked in. We received and passed on the tornado warnings in a timely fashion. The EAS worked well. We find it is very dependable."*

Civilians Alan King and Willie Williams were among those who scrambled for cover before the powerful F3 tornado ripped through their Columbus neighborhood. *"I knew it was coming,"* King said, *"There was plenty of warning. I would say we probably had 15 or 20 minutes before it hit." "We had plenty of time because we had been warned,"* Williams added. *"I'd say 10 or 15 or 20 minutes before the tornado reached this area–we knew it was headed this way. I went into my house, laid down in the bathroom and started praying–and I was answered."*

WFO Jackson was staffed adequately. At the height of the event, nine people were present at the WFO (four meteorologists, one HMT, the Meteorologist in Charge [MIC], the Service Hydrologist, an Electronics Technician, and one person from the National Severe Storms Laboratory [NSSL]). Warning operations were divided into three sectors and there was a warning coordinator. A total of 24 tornado warnings and 22 severe thunderstorm warnings were issued, covering 69 counties. Thirty-six SVSs were issued during the event.

WFO Jackson has an online submission program allowing spotters to fill out a Web form to quickly submit a storm report. The reports arrive as formatted text products in AWIPS via the Local Data Acquisition and Dissemination System (LDAD), sounding an alarm on the AWIPS console. After quality control by WFO staff, the reports are sent out as LSRs. WFO Jackson issued eight LSRs for this event.

A demonstration project with NSSL is in progress at WFO Jackson where a system known as Warning Decision Support System-II (WDSS-II) is being tested in real-time operations. This system is the next generation of the system (WDSS) described in the Service Assessment of the Oklahoma/Southern Kansas Tornado Outbreak of May 3, 1999. A scientist from NSSL was present at the WFO during the November 10 event.

Some of the key features of WDSS-II useful during this event include:

- *Availability of High Resolution 8-bit Storm Relative Motion (SRM) products.* The storm motion can be quickly tailored to an individual storm.

- *Dynamic Cross Sections* allow meteorologists to "fly" through storms and quickly discern their three-dimensional structure.

- *Azimuthal Shear* allows the forecaster to analyze "cyclonic/anticyclonic shear triplet" signatures of true mesocyclones versus other shear features.

- *Rotation Tracks Products* show tracks of rotational velocity allowing forecasters to more easily discern the movement of mesocyclones.

- *Multiple Radar Algorithms* such as MR-VIL which use data from multiple overlapping radars to update storm parameters every minute as opposed to the 5-minute volume scan updates from a single radar currently available in AWIPS.

Issue

FINDING 7: WFO Jackson benefitted from new experimental radar products produced by WDSS-II during the November 10 event.

RECOMMENDATION 7: The Office of Science and Technology (OST) should meet with the developers of WDSS-II, itemize the capabilities of the system, and identify those capabilities beneficial to NWS operations. These capabilities should be prioritized for inclusion in future AWIPS and future Open Radar Product Generator (ORPG) builds.

I. WFO Birmingham, Alabama

Overview

On Wednesday, November 6, WFO Birmingham issued a Public Information Statement reminding Alabama residents the secondary season for tornadoes in Alabama is November and early December. On each of the next three days, WFO Birmingham issued a HWO discussing the possibility of severe weather on Sunday, November 10. After SPC's Day 1 Outlook increased the potential to high risk over Alabama at midnight, Sunday, November 10, the WFO's HWO elevated the potential for severe weather to high. The WFO also issued an SPS early on Sunday, November 10, alerting users to the potential for damaging winds and isolated tornadoes. Another SPS was issued at 1 p.m. CST. A tornado watch was issued by the SPC at 4:30 p.m. CST.

At 7:10 a.m. CST, Sunday, November 10, the WFO provided a heads-up briefing on the severe weather potential to Alabama EMs and Highway Patrol via NAWAS and an 800 Megahertz (MHz) radio system run by the state of Alabama. A page was sent to EMs at 8:53 a.m. CST. An update on the severe weather threat was provided via the 800 MHz system at 1:03 p.m. and via NAWAS at 2:15 p.m. CST. Spotters were activated at 3:25 p.m. CST. The Blount County EM, who was out of town for the Veteran's Day weekend, said he made plans to

return home by Sunday afternoon after getting the WFO's briefing on the 800 MHz system early Sunday morning, November 10. The Winston County EM did the same thing after getting the page initiated by the WFO.

Ten tornadoes occurred in the WFO Birmingham CWA on Sunday evening, November 10. All ten tornadoes occurred within tornado warnings. The average lead time for counties hit by tornadoes was 18 minutes.

Three different tornadoes resulted in 12 fatalities in Alabama. The first killer tornado struck Fayette, Walker, and Winston Counties. It formed over Fayette County with F3 intensity at 6:52 p.m. CST, Sunday, November 10, 23 minutes after a tornado warning was issued. There were no deaths in Fayette County. Walker County was warned at 7 p.m. CST. The pathcast portion of this tornado warning included the towns of Carbon Hill and Poplar Springs. A follow-up SVS was issued at 7:11 p.m. CST, with the headline: "TORNADO EMERGENCY." The tornado made a direct hit on Carbon Hill, but caused no fatalities. However, three people were killed in Walker County in the community of Rose Hill, located between Carbon Hill and Poplar Springs, from 7:24 to 7:26 p.m. CST. A tornado warning was issued for Winston County at 7:07 p.m. CST. The tornado entered the county and caused a fatality near Arley at 7:45 p.m. CST. This tornado was on the ground for 44 miles.

Later that evening, Fayette and Walker Counties were struck with a second killer tornado. At 8:15 p.m. CST, another F3 tornado formed in Fayette County, 21 minutes after a tornado warning was issued. Again, there were no fatalities in Fayette County. As the tornado approached Walker County, a tornado warning was issued at 8:24 p.m. CST. The tornado tracked across Alabama for 73 miles, resulting in seven fatalities in the Saragoosa area of Walker County at 8:45 p.m. CST.

The third deadly tornado (F2) occurred in Cherokee County at 11:25 p.m. CST, Sunday, November 10, 15 minutes after a tornado warning was issued. This tornado resulted in one fatality.

On average, tornado warnings were issued 22 minutes before tornado impact at the locations of the 12 fatalities. In at least three instances, relatives of the deceased stated the people killed knew of the warnings but declined to seek shelter.

The WFO was well prepared for the event. Planning began the previous evening and called for staggering the arrival of additional people so fresh staff would be able to assist operations. Extra people arrived at 4, 6, 8, and 9 p.m. CST, reaching a maximum of nine individuals, including the Science and Operations Officer (SOO) and MIC. A total of 45 tornado warnings and 13 severe thunderstorm warnings for 78 counties were issued. Thirty-three follow-up SVSs were issued.

Without exception, EMs who were interviewed praised the performance of WFO Birmingham during the event. The primary communication link between WFO Birmingham and

Alabama EMs is the 800 MHz statewide radio system. Through this 800 MHz system, WFO Birmingham can brief individual or all Alabama EMs. EMs can use the system to inform WFO Birmingham of damage or ask questions. Teresa Willcutt, Director of the Fayette County Emergency Management Agency, stated, *"I felt like I was one-on-one with the NWS that night,"* because of briefings on 800 MHz.

Art Faulkner, 911 coordinator for the state of Alabama Emergency Management Agency stated, *"I don't know anything they [WFO Birmingham] could have done better. I was very proud of them."* Johnny Burnette, director of the Walker County Emergency Management Agency, stated, *"The warnings saved a lot of lives. The National Weather Service did a great job. There could have been many more fatalities."*

Three of the four major television stations in Birmingham provided "wall-to-wall" weather coverage for the time there were tornado warnings in their viewing areas. Station meteorologists praised the timeliness of the warnings issued by WFO Birmingham, the WFO's effective use of instant messaging computer software, and the use of strong language noting a tornado emergency. Some also expressed appreciation of the WFO's Web site tracking maps showing radar imagery and county warnings on a split screen and the early morning high risk outlook by the SPC.

Through instant messaging, WFO Birmingham's meteorologists notified the media when they began preparation of tornado warnings allowing station meteorologists to inform their viewers with up-to-the-minute NWS warnings prior to their official dissemination. This provided additional warning lead time for viewers to take precautions. Instant messaging also provided an avenue for reports to flow from media outlets to the NWS. People often call radio or television stations with reports which could be lost and never reach the NWS.

Birmingham's ABC 33/40 chief meteorologist James Spann commented, *"This is the greatest thing that ever happened between the private sector and the National Weather Service. The greatest ever."* ABC colleague Mark Prater agreed, *"We started using the text messaging system which vaulted us to a whole new level of coverage and getting the word out because we were linked to the National Weather Service office."*

WAIT-TV meteorologist Ben Smith said, *"We get instant messaging immediately. We've got damage here. We've got confirmation there. We see that immediately and get it to the public within seconds. That's the greatest idea I've seen since I've been doing weather."*

WVTN-TV (Birmingham) chief meteorologist Jerry Tracey added, *"You have the latest on what has happened in terms of damage. You also get some great insights on what they're (WFO meteorologists) thinking if a storm looks suspicious–but is not at warning status yet. And I think lives were saved!"*

"In the past, we relied on listening to spotters on HAM radio and calling them occasionally. This [instant messaging] has been the biggest thing to happen in our relationship

with the NWS," said FOX 6 Meteorologist David Neal. *"Somebody will say 'we're watching X storm'–and that gives me an unbelievable jump to get everyone prepared for another warning for this county or that one."*

Instant messaging also provided WFO Birmingham with a quick method to inform the media of damage. When the first damage reports were received at the WFO, the communicator quickly sent the message, "TORNADO EMERGENCY...TORNADO REPORTED WITH THE STORM MOVING OUT OF FAYETTE." A few minutes later the WFO Birmingham communicator sent the message, "...EXPECTING A LONG TRACK WITH THIS TORNADO."

"I'll never forget that," Birmingham's ABC 33/40 chief meteorologist James Spann said. *"Tornado Emergency for Walker County! ...in bold print coming from the Weather Service office. That's better than 15 tornado warnings."*

Carbon Hill Elementary School, Carbon Hill, Alabama, after being struck by an F3 tornado on November 10, 2002. (NOAA)

Destroyed house from an F3 tornado in Winston County, Alabama, on Smith Lake, about 5 miles southwest of Arley. This was from the path of the Carbon Hill tornado that crossed three Alabama counties—Fayette, Walker, and Winston—on November 10, 2002. (NOAA)

Remnants of F3 tornado damage to truck in Walker County, Alabama, on November 10, 2002. (NOAA)

J. Advanced Weather Interactive Processing System (AWIPS) Issues Common to all Eight WFOs

The service assessment team found issues related to capabilities of the AWIPS common to all WFOs visited. The recent augmentation of two of the five older Hewlett Packard (HP) workstations at each WFO with PC-based LINUX workstations represents a significant upgrade to the AWIPS hardware suite and provides much greater processing power. However, these two new workstations, which are now the fastest AWIPS computers in the WFO, were underutilized for interrogation of radar data and not used at all for warning preparation. One reason is a primary use of these fast workstations is for the Interactive Forecast Preparation System (IFPS). Another reason is WFOs have not configured their LINUX workstations to be used for warning generation. **(Finding 8)**

The recent addition of full resolution radar reflectivity and velocity data to AWIPS is another significant upgrade to severe weather forecast and warning capabilities. However, this upgrade did not include a full resolution version of the SRM, which is one of the most common AWIPS products used when examining potentially tornadic thunderstorms. Another AWIPS capability used in severe weather operations is the combination of reflectivity and velocity data on a single display allowing the forecaster to toggle or fade back and forth between the two data sets. The new full resolution reflectivity and velocity data cannot be combined without image degradation on older HP workstations, and the team found no one at any WFO visited knew there was no image degradation when these data were combined on LINUX workstations. **(Finding 9)**

FACT: The two LINUX workstations at each WFO are the highest performance workstations in each forecast office.

FACT: The LINUX workstations are being used primarily for the IFPS and saw limited use for interrogation of radar data during this tornado outbreak, and were not used to run WARNGEN to generate warnings.

FINDING 8: Most WFOs are not using their AWIPS hardware to its best potential during severe weather and do not have their hardware configured to allow WARNGEN to run from LINUX workstations.

RECOMMENDATION 8a: Regions should ensure WFOs' Severe Weather Operations Plans are updated to prioritize the use of the LINUX workstations for data display and interpretation during severe weather events.

RECOMMENDATION 8b: OST and the Regional AWIPS program managers should provide each WFO with instructions to ensure all workstations are configured to run WARNGEN, including LINUX workstations.

FACT: Few forecasters used the 8-bit full resolution reflectivity and velocity data that became available after the installation of the ORPG and AWIPS Build 5.2.1.

FACT: There is no 8-bit SRM product in AWIPS.

FACT: The image combine feature on AWIPS results in a degraded image when 8-bit reflectivity and velocity data are combined on an HP workstation, but there is no degradation on the LINUX workstations.

FACT: The knowledge that 8-bit reflectivity and velocity radar data can be combined without degradation on the LINUX workstations is not widespread within the WFOs.

FINDING 9: Without 8-bit SRM and the knowledge that 8-bit reflectivity and velocity data can be combined without degradation, very few forecasters are using this new data set to diagnose storm structure and make decisions about warning for severe weather and tornadoes.

RECOMMENDATION 9a: A full resolution (8-bit) SRM product should be created for display in AWIPS as part of a future build. This should be done in a manner similar to the capability demonstrated in the WDSS-II system so relative motion can be viewed for individual storms. OST should identify the future AWIPS build where this capability will be added.

RECOMMENDATION 9b: Regional Scientific Services Divisions should provide WFOs information and guidance on the use of the LINUX workstations for display of 8-bit combined radar imagery.

RECOMMENDATION 9c: The WDM Workshop should incorporate guidance on optimal use of LINUX workstations during severe weather episodes.

RECOMMENDATION 9d: The NWS goal of upgrading AWIPS hardware, as stated in the OST Science and Technology Infusion Plan, should be given high priority to reduce the contention between use of the LINUX workstations for IFPS and warning operations.

Best Practices

Communications to Customers and Partners

1. WFO Birmingham, Alabama, meteorologists used instant messaging to notify the media when they began preparation of tornado warnings. This allowed TV station meteorologists to provide viewers with up-to-the-minute NWS warnings.

2. WFO Birmingham, Alabama, used the Alabama 800 MHz statewide radio system to brief EMs and receive storm reports from them.

3. WFO Birmingham, Alabama, developed a Web page with a split screen display of radar imagery and county warnings.

4. WFO Northern Indiana staff made frequent updates to storm information and damage reports posted on the WFO's Internet home page.

5. WFO Nashville, Tennessee, developed a Web page entitled the "Middle Tennessee SKYWARN" which has all county warnings issued by the Nashville WFO. The Web page refreshes automatically every 10 seconds with a series of banners and audio voice alarms alerting customers and partners when new products are issued.

6. WFO Jackson has an online submission program allowing spotters to fill out a Web form to quickly submit a storm report. The reports arrive as formatted text products in AWIPS via the LDAD, sounding an alarm on the AWIPS console. After quality control by WFO staff, the reports are sent out as LSRs.

Value of Post-Storm Data Acquisition (PSDA) and Quick Response Team (QRT)

Using PSDA and a QRT, experts were deployed in the days immediately following the event to assist local WFOs with damage surveys and assignment of tornado intensity. Because of this, the service assessment team was able to focus on the quality of service provided and customers and partners' response rather than devote resources to assigning tornado intensity.

Appendix A

Fujita Tornado Intensity Scale[1]

The Fujita Tornado Intensity Scale is a scale of wind damage intensity which wind *speeds* are inferred from an analysis of wind *damage*.

Tornadoes are rated using the Fujita Tornado Intensity Scale or F-scale, named after Dr. T. Theodore Fujita, former professor of Meteorology, University of Chicago. The F-scale is a subjective visual interpretation used by the NWS to rate the worst building damage anywhere along the path from 0 to 5, with 5 being the most destructive. Empirically-derived wind speed ranges are also associated with the F-scale. An accurate F-scale rating is important for historical, statistical, and climatological reasons and allows the public to get a sense of the storm's destructive force.

Category	Definition and Effect
F0	**Gale tornado (40-72 mph): Light damage.** Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage sign boards.
F1	**Moderate tornado (73-112 mph): Moderate damage.** The lower limit is the beginning of hurricane wind speed; peel surface off roofs; mobile home pushed off foundations or overturned; moving autos pushed off the roads.
F2	**Significant tornado (113-157 mph): Considerable damage.** Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
F3	**Severe tornado (158-206 mph): Severe damage.** Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown.
F4	**Devastating tornado (207-260 mph): Devastating damage.** Well-constructed houses leveled; structure with weak foundation blown off some distance; cars thrown and large missiles generated.
F5	**Incredible tornado (261-318 mph): Incredible damage.** Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 100 yards; trees debarked; steel-reinforced structures badly damaged; incredible phenomena will occur.

[1] From *J. Atmos. Sci.*, August 1981, p. 1517-1519.

Appendix B

Event Statistics

November 9-11, 2002

WFO Northern Indiana (IWX)

November 10, 2002

# Tornadoes	4
# Tornado Warnings	8
Average Lead Time for Tornado Warnings	15 minutes
# Severe Thunderstorm Warnings	7
Fatalities	4
Injuries	26
Homes Destroyed	65
Homes Damaged	78
Damage Costs	$60M

WFO Cleveland, Ohio (CLE)

# Tornadoes	13
# Tornado Warnings	26
Average Lead Time for Tornado Warnings	16.9 minutes
# Severe Thunderstorm Warnings	19
Fatalities	1
Injuries	16
Homes Destroyed	63
Homes Damaged	388
Damage Costs	$20M

WFO Pittsburgh, Pennsylvania (PBZ)

November 10, 2002, 6 p.m. - Midnight (L)

# Tornadoes	1
# Tornado Warnings	2
Average Lead Time for Tornado Warnings	0 minutes
# Severe Thunderstorm Warnings	25
Fatalities	1
Injuries	19
Homes Destroyed	15
Homes Damaged	42
Damage Costs	Unknown

WFO Memphis, Tennessee (MEG)

November 9-10, 2002, 9 p.m. - 9 p.m.

# Tornadoes	6
# Tornado Warnings	33
Average Lead Time for Tornado Warnings	10.1 minutes
# Severe Thunderstorm Warnings	46
Fatalities	2
Injuries	7
Homes Destroyed	54
Homes Damaged	668
Damage Costs	$15M

WFO Nashville, Tennessee (BNA)

November 10, 2002

# Tornadoes	9
# Tornado Warnings	38
Average Lead Time for Tornado Warnings	19.9 minutes
# Severe Thunderstorm Warnings	48
Fatalities	8
Injuries	46
Homes Destroyed	84
Homes Damaged	473
Damage Costs	Unknown

WFO Knoxville/Tri-Cities, Tennessee (MRX)

November 10-11, 2002, 5 p.m. - 2 a.m.

# Tornadoes	6
# Tornado Warnings	51
Average Lead Time for Tornado Warnings	21 minutes
# Severe Thunderstorm Warnings	42
Fatalities	7
Injuries	28
Homes Destroyed	45
Homes Damaged	115
Damage Costs	Unknown

WFO Jackson, Mississippi (JAN)

November 10-11, 2002, 3 p.m. - 2 a.m.

# Tornadoes	10
# Tornado Warnings	37
Average Lead Time for Tornado Warnings	10.7 minutes
# Severe Thunderstorm Warnings	32
Fatalities	1
Injuries	60
Homes Destroyed	122
Homes Damaged	340
Damage Costs	$60+M

WFO Birmingham, Alabama (BMX)

November 10, 2002

# Tornadoes	11
# Tornado Warnings	45
Average Lead Time for Tornado Warnings	15.7 minutes
# Severe Thunderstorm Warnings	13
Fatalities	12
Injuries	100
Homes Destroyed	384
Homes Damaged	608
Damage Costs	Unknown