Service Assessment

Tornadoes in Southern Alabama and Georgia on March 1, 2007

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

Cover Photograph:

EF4 tornado near Enterprise, Alabama, March 1, 2007 (photo courtesy of J. Barry Mott)

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November 2007

National Weather Service
John L. Hayes, Assistant Administrator

Preface

During the afternoon and evening of March 1, 2007, deadly tornadoes moved across southern Alabama and Georgia. In a 14-hour period beginning at 12:30 p.m. CST, 31 tornadoes occurred, resulting in 19 fatalities across the two states. Eleven of the tornadoes were classified as strong (EF2-EF3) on the new Enhanced Fujita Tornado Intensity Scale and two were classified as violent (EF4).

Due to the magnitude of this event, a service assessment team was formed to examine the warning and forecast services provided to key decision makers and the public. In keeping with the NOAA goals of developing hazard-resilient communities, the team was also tasked with trying to identify possible reasons for the large loss of life during this event, in light of the overall high quality of services provided by the National Weather Service.

The findings and recommendations from this assessment are offered with the goals of 1) improving the quality of warning and forecast products and services, and 2) enhancing the ability of the National Weather Service (NWS) to increase public education and awareness regarding issues associated with tornado safety. The ultimate goal is to help meet the NWS mission of saving lives and property and enhancing the national economy.

John L. Hayes
Assistant Administrator
for Weather Services

November 2007

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Service Assessment Team

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) activated an assessment team on March 2, 2007 to evaluate the NWS performance during the deadly tornado outbreak in southern Alabama and Georgia on March 1st. Team members visited damage areas and interviewed emergency managers, the media, and public in Alabama and Georgia and visited with staff from the Weather Forecast Offices (WFOs) located in Tallahassee, Florida; Peachtree City, Georgia; Birmingham, Alabama; and Mobile, Alabama. The team also reviewed products and services from the WFOs and the Storm Prediction Center (SPC). The following members were on the team:

Glenn Lussky	Team Leader, Meteorologist-in-Charge (MIC), WFO La Crosse, Wisconsin.
Michael Hudson	Chief Operating Officer (COO), NWS Central Region Headquarters, Kansas City, Missouri
Richard Okulski	Warning Coordination Meteorologist (WCM), WFO Memphis, Tennessee
James Ladue	Senior Instructor, Warning Decision Training Branch (WDTB), Norman, Oklahoma
Les Lemon	Research Associate Meteorologist, WDTB and Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), Norman, Oklahoma
Keli Tarp	NOAA Public Affairs Officer, Norman, Oklahoma
Greg Schlink	Operations Manager, Parsons Manufacturing, Roanoke, Illinois

Other valuable contributors include:

Ken Waters	Former Chief Scientist, NWS Pacific Region Headquarters, Honolulu, Hawaii
Wayne Presnell	NWS, Office of Climate, Water, and Weather Services, (OCWWS), Silver Spring, Maryland
Douglas Young	Chief, Performance Branch, OCWWS
Jim Hoke	Acting OCWWS Director
Dennis McCarthy	Former OCWWS Director

Acronyms

AWIPS	Advanced Weather Interactive Processing System
CIMMS	Cooperative Institute for Mesoscale Meteorological Studies
COO	Chief Operating Officer
CST	Central Standard Time
DPS	Department of Public Safety
EAS	Emergency Alert System
EF	Enhanced Fujita Tornado Scale
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FY	Fiscal Year
GFE	Graphical Forecast Editor
GIS	Geographic Information System
HWO	Hazardous Weather Outlook
IFPS	Interactive Forecast Preparation System
IEM	Iowa Environmental Mesonet
ISC	InterSite Collaboration
Knot	Nautical miles per hour
LSR	Local Storm Report
mb	Millibar
MIC	Meteorologist-in-Charge
mph	Miles per hour
NCF	AWIPS Network Control Facility
NDFD	National Digital Forecast Database
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory
NWR	NOAA Weather Radio All Hazards
NWS	National Weather Service
OCWWS	Office of Climate, Water and Weather Services
PDS	Particularly Dangerous Situation
SPC	Storm Prediction Center
SVS	Severe Weather Statement
UTC	Coordinated Universal Time
Warngen	Warning Generation Software
WCM	Warning Coordination Meteorologist
WDTB	Warning and Decision Training Branch
WFO	Weather Forecast Office
WSR-88D	Weather Surveillance Radar, 1988 Doppler
ZFP	Zone Forecast Product

Definitions

Best Practice - An activity or procedure that has produced outstanding results during a particular situation which could be used to improve effectiveness and/or efficiency 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 often lead to recommendations.

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 improve NWS operations and/or services, and it is achievable, the recommendation will likely become an action. Recommendations should be clear, specific, and measurable.

Service Assessment Report

1. Executive Summary

March 2007 roared in like a lion in southern Alabama and Georgia as strong tornadoes moved through the area, resulting in 19 fatalities on the 1st. The deadliest tornado (**see Appendix A**) occurred in Enterprise, Alabama, where eight high school students perished as a concrete wall collapsed onto them while they were seeking shelter in the hallway. Despite the fatalities, the team believes the high school followed proper tornado safety procedures. This tornado was rated an EF4 on the Enhanced Fujita (EF) Tornado Scale (**see Appendix B**). Another deadly tornado struck near the town of Newton, Georgia, killing six people in a mobile home park. This tornado was rated an EF2. Overall, there were 13 strong to violent tornadoes (EF2 or greater) and five tornadoes which produced fatalities in Alabama and Georgia during this event.

The NWS' mission is to help guard the Nation against loss of life and property from forces in the natural world. As such, the NWS must take part in building hazard-resilient communities by continually learning how to improve service to the Nation. As a result, the NWS formed a service assessment team to evaluate its performance during this event. This seven member team was tasked with documenting and evaluating the performance and overall effectiveness of NWS services and operational procedures for the event. In addition, the assessment team was tasked with examining 1) NWS operational and service aspects relating to how the Storm-Based Warnings approach would have affected any outcomes during this event; and 2) some of the societal impacts relating to this event, including tornado safety in residential homes, industrial plants, educational institutions, and other large facilities having the capacity to hold many people.

NWS offices performed well during the event. The offices' situational awareness was high; they provided information in a variety of ways to their critical customers, communicated well with decision makers and with each other, and correctly analyzed the severe weather threat. The Storm Prediction Center (SPC), along with local Weather Forecast Offices (WFOs), issued Tornado Watches, Warnings, and Outlooks well in advance of the event. Local WFOs highlighted the expected threats in their Hazardous Weather Outlooks (HWOs) and other forecast products as far out as four days before the event. The SPC had portions of the tornado outbreak area in the Day 4-8 Severe Weather Outlook starting on February 24th, six days before the outbreak. All four WFOs conducted pre-event conference calls with emergency management partners during the morning hours of March 1st (Best Practice from the May 4-10, 2003 Service Assessment). The Director of the Paulding County, Georgia Department of Public Safety (DPS) stated, "*Nobody was blind-sided by this system if they were paying attention to you [the NWS]*."

The lead time for all Tornado Watches issued by SPC during this event was 8.5 hours. All tornadoes producing fatalities were covered by Tornado Warnings. The average lead time for all Tornado Warnings issued by WFOs was 16 minutes, with a 20 minute average lead time for the tornadoes resulting in fatalities. From January 2007 through March 2007, the national average lead time for Tornado Warnings was 14 minutes.

During this event, the NWS issued short duration severe weather warnings based on county boundaries (County-Based Warnings). On October 1, 2007, the NWS began issuing Storm-Based Warnings. Storm-Based Warnings are polygons drawn by forecasters to define the specific geographic area imminently threatened by the severe weather. These polygons provide the public with more precise information about the location of severe weather and the direction it is expected to move.

Storm Based Warnings were issued in a test mode during this event. A review of these test Storm-Based Warnings indicated the methodology reduced the warned area for the offices evaluated by an average of 58.4%, creating considerably less area (and fewer citizens) unnecessarily covered by Tornado Warnings. The review also showed small gaps (seams) between adjacent polygons, due largely to software inconsistencies. Some areas which the forecaster intended to place in a warning polygon were not included due to these seams. Since these were test warnings, there was no impact to the official warnings issued during this event. Advanced Weather Interactive Processing System (AWIPS) Operational Build 8.1, implemented before the release of this report, fixed this problem.

The safety actions of Enterprise High School during this event were a passionate topic of debate while the Team was conducting its interviews and gathering information. Some people indicated if the school had not been under Tornado Warnings for almost 3 hours (as a result, they sheltered in-place for nearly 3 hours), the school could have evacuated the buildings before the actual tornado hit. The Team was asked to evaluate if the Storm-Based Warnings approach could have improved public response by creating a shorter time that the high school was under a Tornado Warning. In most cases, Storm-Based Warnings will cause smaller areas to be under Tornado Warnings for shorter periods of time. However, in this case, three successive supercell thunderstorms moved over or near the Enterprise area during the 3 hour time period. As a result, the high school would have been under Tornado Warnings for approximately the same amount of time, even if the Storm-Based Warnings approach had been used. The Team believes that, given the ongoing danger from the successive supercell storms, the safety response of the school was the proper one and would have been the same whether County-Based or Storm-Based Warnings were used.

Overall, six recommendations have been made based on the team’s findings. These recommendations should address deficiencies, improve NWS performance, and enhance NWS weather safety outreach programs. On the next page are some of the major issues identified by the team. A summary of findings, recommendations and best practices can be found on pages 21-23 of this report.

Issues Identified

- Problems with the NWS warning generation software (WarnGen) limited the efficiency of warning operations. Similarly, issues related to reliability of GFE in backup mode were noted. There were some impacts on information flow to users and workload for some of the forecasters.

- Local Storm Report (LSR) software and use of LSR-based information was problematic.
    - The LSR software is not designed to distinguish multiple tornado reports from a single tornado track versus individual reports of multiple tornado events. This caused misleading information before and after the completion of the storm surveys.
    - Locations in the current LSR software are too coarse for the upcoming Storm-based warning methodology.
    - The team found some users were disseminating preliminary LSR information as final.

- Instant Message software enhanced the situational awareness of many key media and emergency management partners. It also provided the local offices with near real time severe weather damage reports from these partners. A standard Instant Message program across all of the NWS would provide a common forum for media interests whose listening or viewing areas cover multiple local office areas of responsibility.

- NOAA Weather Radio All Hazards (NWR) was an important part of dissemination, especially in the rural areas where the most damaging tornadoes hit. However, there were some concerns from rural customers about the lack of EAS alerts during the late evening/early morning when no one was on duty at the local radio stations serving their areas.

- The high school in Enterprise followed proper protocol in terms of maximizing student safety. The eight fatalities at the high school appear to have been due to structural failure of the roof and walls, which collapsed on the students. Previous events have shown that hardened safe rooms provide better shelter from tornadoes than other permanent structures, especially during EF3 or greater tornadoes, and may be a critical component of adequate tornado safety plans, especially in mobile home parks, homes with standard grade construction, and non-residential buildings in which many people normally gather (schools, office buildings, etc.).

2. Introduction

Strong tornadoes moved through southern Alabama and Georgia on March 1, 2007, resulting in 19 fatalities. The deadliest tornado, rated EF4 on the Enhanced Fujita (EF) Tornado Scale, occurred in Enterprise, Alabama, where eight high school students perished as a concrete wall collapsed onto them while they were seeking shelter in the hallway. Another deadly tornado struck near the town of Newton, Georgia, killing six people in a mobile home park. This tornado was rated an EF2. Overall, there were 13 strong to violent tornadoes (EF2 or greater) in Alabama and Georgia during this event with a total of 31 verified tornadoes. This event received substantial media attention, locally and nationally.

The offices evaluated (WFOs Birmingham and Mobile, Alabama; Peachtree City [Atlanta], Georgia; Tallahassee, Florida and the Storm Prediction Center) issued Tornado Watches, Warnings, and Outlooks well in advance of the event. Of those tornadoes causing fatalities, average lead times exceeded NWS national goals.

Between Sunday, February 25th and Tuesday, February 27th, the SPC and all WFOs impacted by this event began highlighting the potential threat for thunderstorms and/or severe weather on Thursday, March 1st. The threat for a potentially major severe weather outbreak became more evident by Wednesday, February 28th.

The SPC Day 1 Outlook on March 1st placed a very large portion of the southeastern U.S. under a High Risk for severe weather, including tornadoes. While the size and duration of the watches was unusual, they appear to have been well warranted, given the synoptic situation and ensuing results. The three watches they issued, including two PDS (Particularly Dangerous Situation) Tornado Watches, covered all 31 tornadoes during this event. The average watch lead time for all tornadoes during this event was 8.5 hours. The length of time from the first tornado touchdown until the last tornado lifted was 13 hours 37 minutes.

All of the deadly tornadoes had warnings preceding tornado touchdown. The WFOs had good situational awareness of the event as it unfolded and provided information in a variety of ways to their critical customers. The average warning lead time for all tornadoes during this event was 16 minutes, and the average lead time for the deadly tornadoes was 20 minutes.

Various impacts of tornadoes on society were considered during this Service Assessment. Of primary importance was what factors outside the tornadoes contributed to the fatalities during this event. Given the high quality early information from the SPC and WFOs, one would expect fewer fatalities. Ways the NWS can help mitigate loss of life in an effort to improve community resistance to weather hazards are also identified.

This is the first NWS service assessment following the national implementation of the EF Tornado Scale on February 1, 2007. This scale is an update to the Fujita Scale devised by Dr. Theodore Fujita in the early 1970s.

Overall, six recommendations and four Best Practices have been identified by the team. The recommendations address service deficiencies, improve NWS performance, and enhance NWS weather safety outreach programs.

3. Synoptic and Mesoscale Overview

Development of this outbreak of severe thunderstorms and tornadoes was clearly anticipated by the SPC and reflected in their Convective Outlooks issued in the days preceding the event. The Day 3 Convective Outlook, issued by the SPC at 2057 Universal Coordinated Time (UTC) on February 27th and valid for 1200 UTC March 1 through 1200 UTC March 2, stated, "*deep layer shear at 40 to 60 knots will be favorable for supercells…and would support wind damage and tornadoes. The greatest threat... appears most likely across portions of TN...MS and AL.*" Though the location was slightly off, the SPC had clearly identified the potential threat for tornadic development on March 1st.

On March 1st, the 1800 UTC 500 millibar (mb) analysis showed a negatively titled trough with a deep closed center over western Iowa (**Figure 1**). A 115 mph jet stream at this level extended from north central Texas across southeast Missouri and into central Illinois. At the 850 mb level, a 58 mph jet stream of warm, moist flow extended from the Louisiana Gulf coast across central Alabama into eastern Tennessee (**Figure 2)**. By 2100 UTC, surface dewpoints were in the low 60s and temperatures were in the mid to upper 60s over portions of Mississippi and Louisiana, and spreading into Alabama.

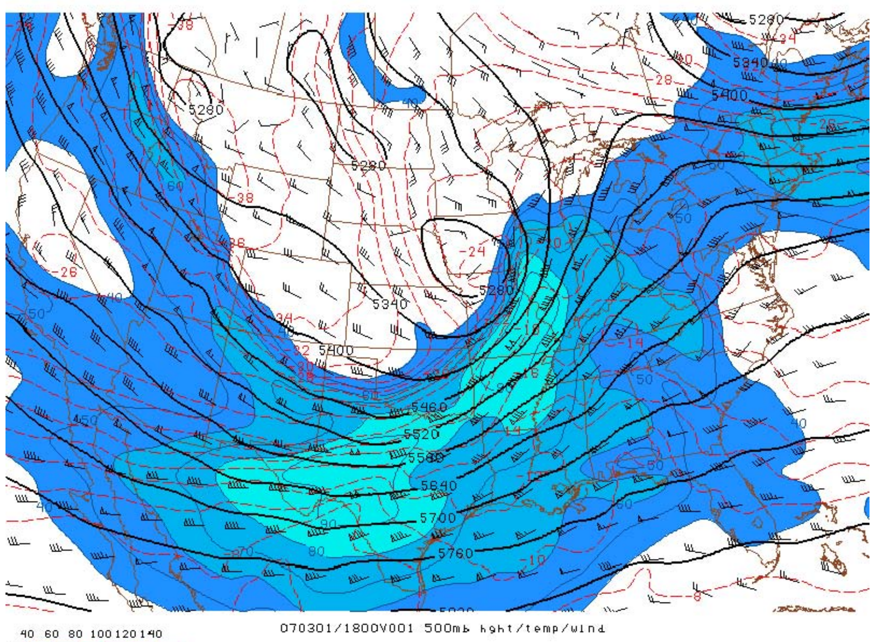


Figure. 1. 500 mb chart for 1800 UTC March 1, 2007, including heights (meters; solid black), temperature contours (ºC; dashed red), winds barbs (kts) and wind speed (shading).

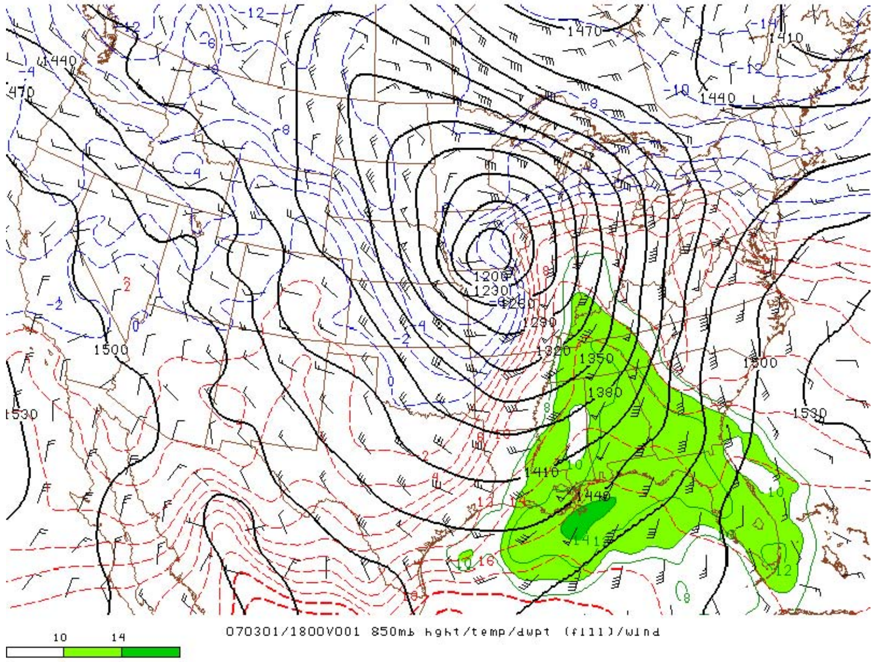


Figure 2. 850 mb chart for 1800 UTC March 1, 2007, including heights (meters; solid black), temperatures (ºC; dashed red and blue) and winds barbs (kts). Dewpoint temperatures > 10ºC are in light green; those > 14ºC are in dark green.

Excerpts from the March 1st Day 1 Outlook revealed that the SPC had accurately forecast the situation the morning prior to the event. The SPC stated: *"There is a high risk of severe thunderstorms across parts of eastern MS…much of AL…southern GA…and northern FL….*"

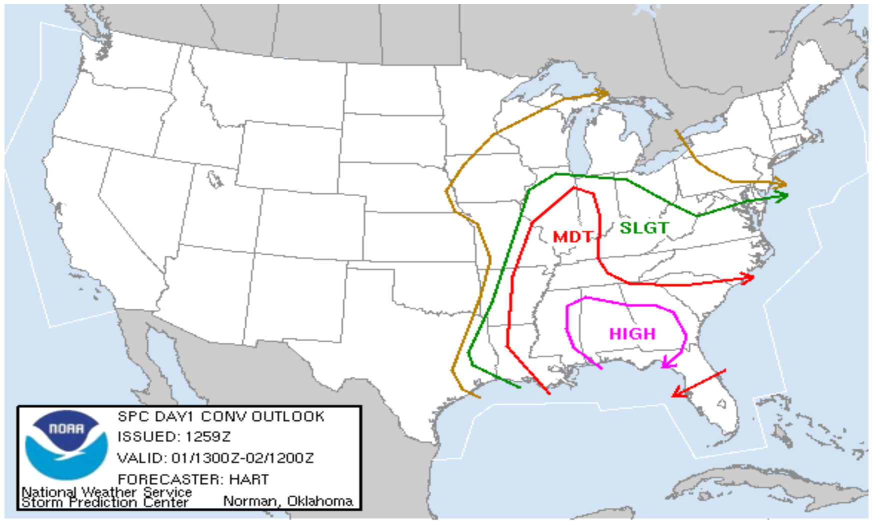
"…Major outbreak of tornadoes and severe thunderstorms possible across much of the central and southern United States today and tonight…"

"Very large and powerful upper trough is becoming negatively tilted this morning over the southern plains. This trough and associated 100+ knot mid-level jet max is forecast to rotate rapidly eastward today and into the Tennessee valley. Widespread extremely strong vertical shear profiles coupled with rapidly increasing low-level moisture and instability…indicate the threat of a large outbreak of tornadoes and severe thunderstorms this afternoon and tonight. Some of the tornadoes may be strong or violent."

"[The] Gulf Coast Region…will be very moist and unstable with MLCAPE values over 1000 J/kg expected. Very impressive vertical shear profiles are in place and will only strengthen through the day. This will result in very favorable conditions for tornadic supercells capable of strong/violent tornadoes…This activity will spread eastward across parts of AL/GA and into northern FL through the afternoon and evening."

At 1300 UTC March 1st, the SPC forecast placed all the locations where tornado fatalities occurred (Enterprise and Miller's Ferry, Alabama; and Americus, Reynolds, and Newton, Georgia; see **Appendix A**) within the high risk area for severe convection, with the estimated probability of tornadoes at 30% and that of EF4 or EF5 tornadoes at 10% (**Figure 3**).

Figure 3. March 1, 2007 1300 UTC Day 1 Convective Outlook



The EF-4 tornado that affected Enterprise, Alabama, strengthened rapidly just before it hit the city, due to a small scale low level boundary that enhanced the thunderstorm's circulation (**Figure 4).** The boundary separated small scale air masses with different characteristics.

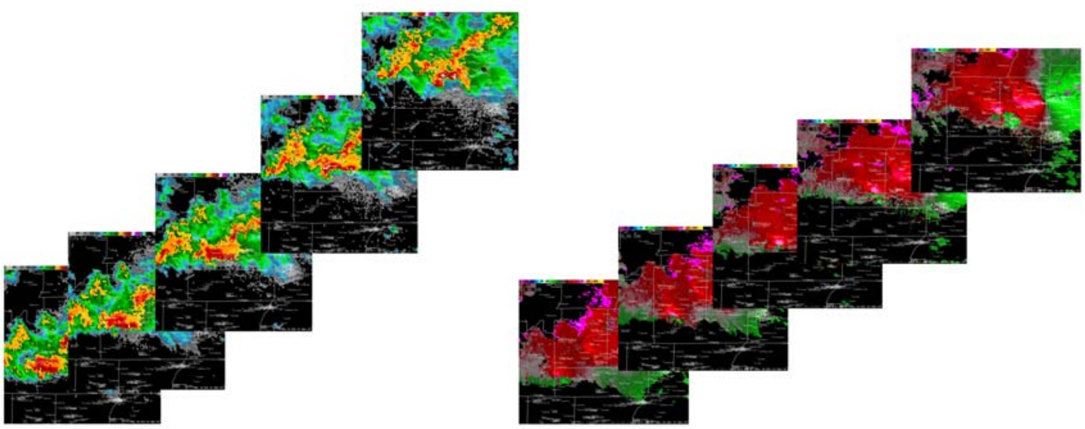


Figure 4. Successive Fort Rucker (KEOX) WSR-88D reflectivity (left) and velocity (right) images for March 1, 2007. Time increases from bottom left to top right. Matching reflectivity and velocity images are from 1840 UTC to 1920 UTC at 10 minute intervals.

4. Warning and Forecast Services

All four local WFOs and the SPC provided excellent service and skill in outlooks given at least two days in advance. Specific synoptic and mesoscale features of the outbreak were not evident prior to February 27th; thus, the more strongly worded outlooks were found from February 27th through March 1st.

The SPC first highlighted the potential for severe weather in the southeastern U.S. in their Day 3 outlook issued on February 27th. Much of the Southeast was highlighted in "Slight Risk," with enhanced probabilities across much of Alabama, Mississippi and Tennessee. Much of this area was upgraded to a "Moderate Risk" in the SPC Day 2 outlook issued on February 28th and to a "High Risk" on the morning of March 1st (**Figures 5 and 6**).

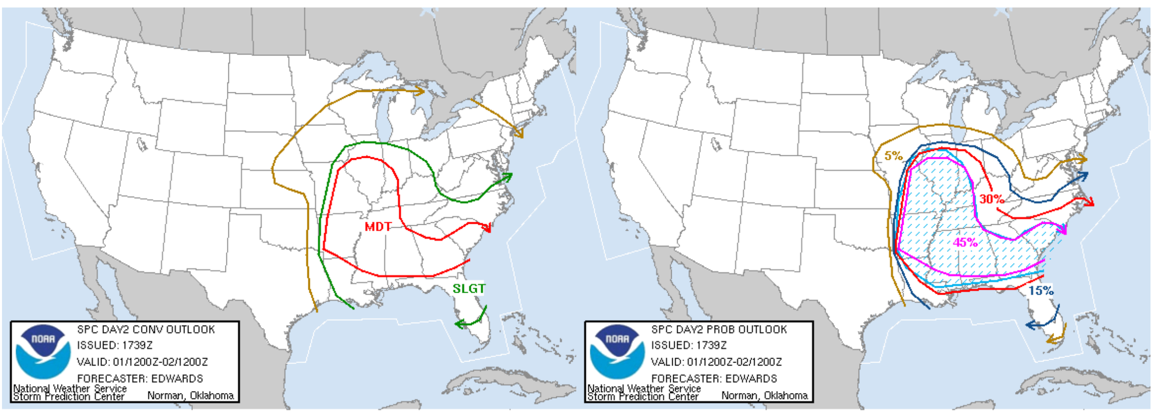


Figure 5. Day 2 outlooks issued 1739Z February 28, 2007

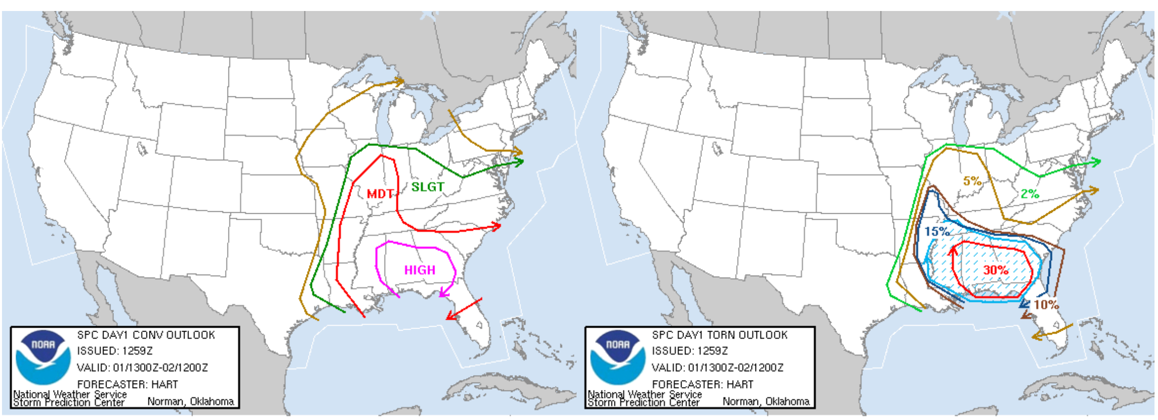


Figure 6. Day 1 outlooks issued 1259Z March 1, 2007

Tornado Watch #44 was issued at 1330 UTC March 1st, valid until 0000 UTC March 2nd. This watch, which included Miller's Ferry, Alabama, covered all of Mississippi, two-thirds of Alabama, most of Tennessee and a part of Louisiana. Tornado Watch #46 was issued at 1645 UTC March 1st, valid until 0300 UTC March 2nd, for the remainder of eastern Alabama, the Florida Panhandle, and much of Georgia, including Enterprise, Alabama as well as Americus, Reynolds and Newton, Georgia.

Both of these watches were “Particularly Dangerous Situation”, or PDS Tornado Watches, stressing the threat for multiple strong to violent tornadoes. Tornado Watch #50 was issued at 0250 UTC March 2nd, valid until 1100 UTC March 2nd, for much of Georgia, eastern Alabama, and the Florida Panhandle. The average watch lead time for all tornadoes during this event was 8.5 hours.

Local WFOs also highlighted the expected threats well in their Hazardous Weather Outlooks (HWOs) and other forecast products. All four WFOs conducted pre-event conference calls with emergency management partners during the morning hours on March 1st (**Best Practice from the May 4-10, 2003 Service Assessment)**. The Director of the Paulding County, Georgia, Department of Public Safety (DPS) stated, “*Nobody was blind-sided by this system if they were paying attention to you [the NWS].*”

During this event, the four WFOs issued 114 Tornado Warnings (for a total of 165 counties) and 65 Severe Thunderstorm Warnings. The 31 tornadoes during the event impacted 45 counties. All four WFOs were able to maintain a high level of warning service by sectorizing their warning operations.

Best Practice 1: All offices used sectorized warning operations to manage warning issuance during this event. Sectorized operations have proven to be a valuable mode of operations during widespread severe weather events.

Event tornado statistics are shown in the table below. Overall, the WFO statistics for this event compare favorably to the national goals for FY07. All tornadoes that produced fatalities were preceded by Tornado Warnings, with an average lead time of 20 minutes.

	3/1/07 Event	FY07 National Goal
Probability of Detection (POD)	0.87	0.76
False Alarm Ratio (FAR)	0.76	0.75
Average Lead Time (all tornadoes)	16 min	13 min
Average Lead Time (deadly tornadoes)	20 min	13 min

Table 1. Tornado verification statistics for this event compared to National goals.

4a. Operational Software

WFOs Birmingham and Peachtree City noted that whenever the potential exists that a neighboring office could require backup support associated with a severe weather event, they test the backup processes prior to the event. This testing includes the severe weather warning generation software (WarnGen) and the Graphical Forecast Editor (GFE) software. WarnGen generates severe weather warnings for dissemination by NWS offices, and GFE produces the graphical forecast products and digital forecast database used by NWS customers and partners.

The WFOs noted that issues with backup software were common, leading to the inclusion of pre-event testing as part of their standard operating procedure. In this instance, no offices had to go to backup operations, but the pre-event testing revealed some potential problems with the WarnGen and GFE software, should they have been required in backup operations.

WFO Birmingham noted that WarnGen requires frequent backup localization and testing to ensure it is ready for use in a backup situation. This feedback was similar to comments made by WFO Peachtree City. The WFOs also expressed concerns that GFE is not reliable in backup mode. Specifically, they indicated it takes too long to ready GFE for use in backup mode, it is not consistently reliable when it does come up and, with no intersite collaboration (ISC) grids available when GFE backup commences in backup mode, all neighboring WFOs must be contacted to send their grids to the backup office. These issues were noted as hindering the efficient use of GFE backup in a real-time mode.

In their pre-event testing, WFO Peachtree City identified some problems using backup WarnGen; these were corrected after running a localization procedure. However, the WFO was unable to resolve issues related to GFE backup capability with WFO Huntsville, Alabama. The GFE problems were elevated to the Advanced Weather Interactive Processing System (AWIPS) Network Control Facility (NCF) and Southern Region Headquarters; they were resolved at 1500 UTC on March 1st. At WFO Birmingham, all testing of WarnGen and GFE was performed during the afternoon of February 28th.

Fact: Reliability is low and inefficiencies are high relating to backup processes associated with WarnGen and GFE software.

Fact: Improvements to backup procedures for GFE are planned for AWIPS build 8.3. Testing will begin by December 2007.

Finding 1: WFOs involved in this event were frustrated and concerned by the lack of reliability and high levels of attention required to minimize any potential problems using the WarnGen or GFE software in backup mode.

Recommendation 1a: The NWS should take steps to simplify service backup procedures in GFE. Technology in support of service responsibility transfer between offices needs to be more expeditious and dependable to maximize the capability of backup offices to issue updated hazardous weather products when needed.

Recommendation 1b: The NWS should modify the WarnGen localization process to 1) enable a single localization to update both the local site's templates and those of backup sites, and 2) provide an automated daily process which checks for outdated localizations and informs the local IT administrator to correct the situation.

WFO Birmingham noted the WarnGen requirement to cancel or expire a warning via a Severe Weather Statement (SVS) within the last 10 minutes of the warning was sometimes a major limiting factor regarding the information they were able to provide in real time. This was especially true when the warning forecaster was unsure whether they would allow the warning to expire or extend it.

Fact: WarnGen will only allow an expiration statement to be issued if a warning is within 10 minutes of its expiration time.

Fact: An improvement for the 10 minute window problem is planned for AWIPS build 8.2.

Finding 2: WFO Birmingham forecasters had opportunities to provide additional real-time information on warnings that were within 10 minutes of expiration. Because the forecasters did not know if they wanted the warning to expire, they could not provide the information due to this WarnGen limitation.

Recommendation 2: WarnGen should be modified to allow continuation statements up to the time a warning expires; forecasters could select Continuation and Expire options as appropriate within this 10-minute time window to expiration.

4b. Local Storm Report Program

WFOs disseminate reports of severe weather they receive from trained severe weather spotters. They issue Local Storm Reports (LSR) as quickly as possible with limited quality control. The LSR product is headlined as preliminary since there is no time during a fast moving event like a tornado outbreak to validate the reports. These reports are valuable to other WFOs, users and partners; this is especially true for the media, since they can further disseminate and inform their audiences. It is very important these reports be as accurate and timely as possible.

During a large event like this tornado outbreak, WFOs issue numerous LSRs. It can be difficult to keep track of all the reports, the validity of each report, duplicate reports, the location of each report, and for which storm the report is associated (to be used later in verification). Internal and external collection software can plot near real-time Tornado Warnings and preliminary tornado events reports using Geographic Information System (GIS) coordinates listed in warning and local storm report products.

Fact: Some entries in preliminary Local Storm Reports (LSR) were inaccurate due to confusion between the event and spotter location and whether or not the report was for straight line wind damage or a tornado.

Fact: No mechanism exists in the LSR software to notify users of corrections to or removal of erroneous information in preliminary reports.

Fact: The error of event location placement will have a larger impact in Storm-Based Warnings than on county-based warnings due to the more precise warning area of Storm-Based Warnings. Most tornado event tracks will be surveyed by local WFO teams, however; errors are introduced by location estimations in the LSR software and by survey teams not using equipment designed to measure precise locations. Errors may also be introduced by use of non-standard latitude/longitude datum sources.

Finding 3: Overall, the team found three areas for improvement within the LSR program.

1. WFOs often update preliminary LSRs based on damage surveys and provide followup reports which include more accurate information on event type, location and time. The current LSR product format does not allow internal and external parsing software to differentiate between initial event reports, retransmitted reports in summary LSRs, or event reports corrected based on updated information.

2. The current LSR software is designed for county based warnings and, as a result, the locations are too coarse for Storm-Based Warnings.

3. *Preliminary* reports of tornadoes (sent out via LSRs) are sometimes later determined to be straight line wind damage, but the some media partners will indicate the preliminary report as a confirmed tornado.

Recommendation 3a: The NWS should develop materials clarifying the difference between preliminary and final storm report information and indicate that one tornado could be associated with multiple tornado reports. All NWS offices should be provided this information.

Recommendation 3b: NWS should issue guidance on how to address unconfirmed tornado reports in preliminary LSRs. The next update of NWSI 10-517, Multi-Purpose Weather Products Specification, should have an example of how to enter unconfirmed tornado reports in the LSR product.

Recommendation 3c: The NWS should develop LSR software that is compatible with Storm-Based Warnings and provides more explicit information regarding updated reports.

4c. Storm-Based Warnings

The NWS officially transitioned Tornado, Flash Flood, Special Marine, and Severe Thunderstorm Warnings from a county-based to storm-based methodology on October 1, 2007. Storm-Based Warnings are more geographically specific, providing the public with more precise information about the location of severe weather and the direction it is expected to move. The local WFOs in the area of impact utilized the storm-based methodology during this event.

A preliminary analysis of office performance in the context of Storm-Based Warnings was conducted. The calculation of Storm-Based Warning accuracy, false alarm ratio, and lead time was not possible due to multiple tornado event reports along the same track.

Fact: An evaluation of test Storm-Based Warnings during this event indicated a reduction of the warning coverage area by an average of 58.4% (**Figure 7**).

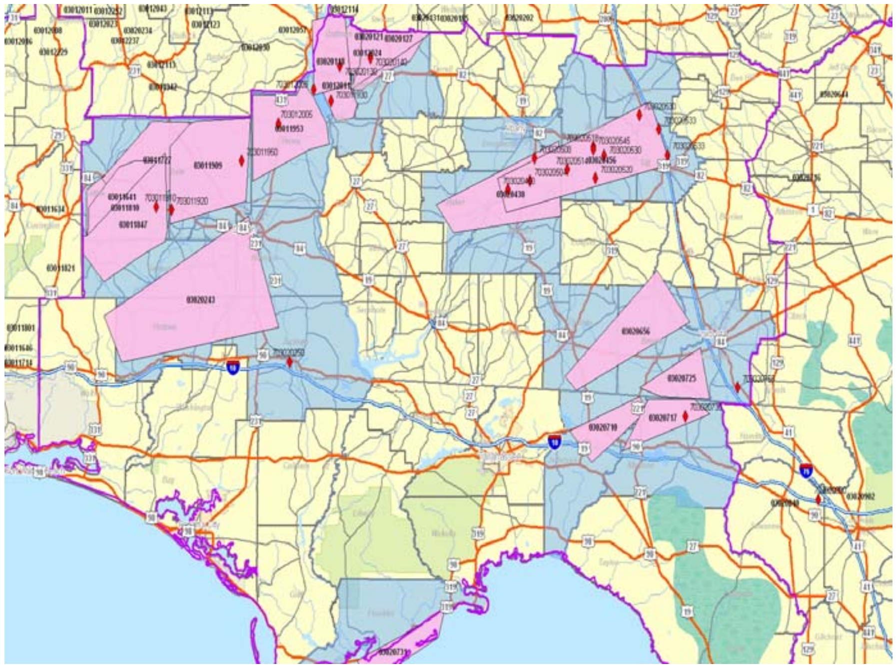


Figure 7. Storm-based Warnings areal coverage (pink shade) for Tornado Warnings compared to county warning areal coverage for Tornado Warnings (blue shade) March 1, 2007. The red triangles indicate approximate location of confirmed tornadoes.

Fact: There were small gaps (seams) between adjacent polygons, due largely to software inconsistencies. Some areas which the forecaster intended to place in a warning polygon were not included due to these seams.

Fact: There was no impact to the official warnings issued during this event since the Storm-Based Warnings were issued in a test mode.

Fact: Advanced Weather Interactive Processing System (AWIPS) Operational Build 8.1, implemented before the release of this report, fixed this problem.

The city of Enterprise, Alabama was struck by an EF4 tornado at approximately 1:10 p.m. CST. This tornado claimed nine lives, eight of which were at the high school. By all reports, the school and all the students followed appropriate safety measures prior to and during the event.

Fact: WFO Tallahassee issued four Tornado Warnings for portions of Coffee County, Alabama. The first warning was issued at 1641 UTC and the last warning expired at 1930 UTC. Three of these four warnings specifically mentioned Enterprise in the text of the warning as being included in the warning (i.e., "*This includes the city of Enterprise.*") Tornado Warnings were in effect continuously for all or portions of Coffee County for 2 hours 49 minutes.

Fact: Some of the Tornado Warnings for Coffee County (and other counties) were issued for one-hour time periods. NWS Directive 10-511, WFO Severe Weather Products Specifications, states that the valid time for a Tornado Warning should be 15 to 45 minutes.

Fact: As the NWS moves to Storm-Based Warnings identified by polygons, the tendency to issue Tornado Warnings longer than 45 minutes for geopolitical reasons will no longer exist.

Interviews with staff and students at Enterprise High School indicated they sheltered in-place for over 2½ hours, as Tornado Warnings were in effect for the entire time. As a result, alternatives to sheltering in-place were not invoked. In this case, because there were successive rotating storms that moved over the same area (3 in about 2½ hours), it is unlikely that shorter warnings would have altered the need to shelter in place for such a long time. In other cases, however, it could.

Fact: The Storm-Based Warning concept will reduce (but not eliminate) the chances of a location being under severe weather warnings for periods longer than 1 hour. The NWS began using Storm-Based Warnings October 1, 2007.

4d. Digital Services

Many technological advances and scientific breakthroughs have allowed NWS weather forecasts and warnings to become much more specific and accurate. In association with these advances, the production and dissemination of routine NWS forecasts must keep pace with the need for better and more detailed information in this digital age. The Interactive Forecast Preparation System (IFPS) in the NWS provides not only for preparation of familiar text and voiced products, but also creates digital data from which these products are prepared. These digital forecasts are put into the National Digital Forecast Database (NDFD).

A major component of the NDFD and evolving services consists of gridded forecasts of sensible weather elements (e.g., wind, probability of precipitation, temperature, etc.). The NDFD contains much more data than the NWS was previously able to provide, at time scales as small as hourly and space scales of a few kilometers. The database is made available for users to create a wide variety of products and information to meet their needs. Since other routine forecast products are derived from the NDFD, the database is the primary information source that must be maintained, relative to the other products that are derived directly from the database.

Fact: A Zone Forecast Product (ZFP) from one of the WFOs issued at 3:02 a.m. EST on March 1st contained updated forecast information mentioning the potential for severe weather. However, the NDFD grids were not updated coincidental with this ZFP issuance and, as of 6 a.m. EST on March 1st, the NDFD grids had not been updated for over 12 hours.

Fact: NWS Instruction 10-503, *WFO Public Forecast Products Specification*, will be updated with guidance and instruction on required updates to the NDFD. The goal is to ensure that updated NDFD grids are sent coincidental with forecast updates that require the issuance of an updated ZFP.

5. Communication

Instant and efficient communications are necessary to keep the public informed of quickly changing weather, especially during severe weather operations. Information from the NWS is often relayed by a broadcast media outlet. It is in the mutual interest of both the NWS and media to accurately and quickly disseminate this type of information.

All four offices involved in this assessment made effective use of IEMChat to communicate in real-time with key media and Emergency Management partners. IEMChat is an internet-based collaboration tool that facilitates the real-time communication of operational meteorologists. It is managed and hosted by the Iowa Environmental Mesonet (IEM) and available to WFOs throughout the NWS.

Instant messaging provides a quick mechanism to route severe weather information to broadcast outlets and, similarly, reports from broadcast outlets back to the NWS. All WFOs noted IEMChat was a great asset for communicating with their partners. The communication passed information quickly to partners and had a positive impact on the warning decision-making process at the WFOs.

Input from media partners indicated similar thoughts. These include the following statements from interviews conducted by the assessment team:

"The chat program is the greatest thing. I was reading verbatim from it at times and passing the information along in real time. I passed along storm reports. It's the greatest thing that ever happened for the public, us and you guys. It's a win-win for all."

- Rich Thomas, Chief Meteorologist, WSFA-TV, Montgomery, Alabama

"Chat is by far the most valuable tool we have here. Even before warnings came out we knew they would. That was huge. Every office needs to use it. It's the best thing that ever happened as far as being able to pull everything in one place."

- Greg Dee, Chief Meteorologist, WDHN-TV, Dothan, Alabama

Best Practice 2: All four offices utilized IEM Chat effectively and all feedback from the partners on this type of collaboration and communication was positive.

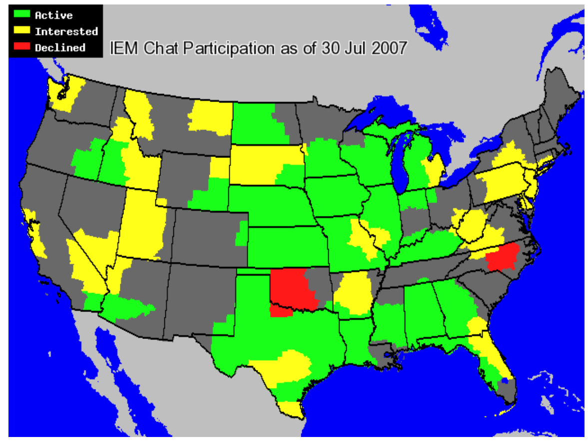


Figure 8. All WFOs who are participating in the IEM Chat program (as of 7/30/07; see https://iemchat.com/). Some offices may be using other similar programs for real-time chat capabilities. Green areas are those offices which are currently using IEM as a real-time chat program, yellow indicates those interested in IEM, and red shows those which have declined to use the IEM chat program, but may be using other chat programs.

Fact: Each of the WFOs noted that, while monitoring the chat room and communicating regularly takes precious personnel resources, this capability is often important and effective enough to ensure it is a part of the communication process and is considered in the event staffing assessment process.

Fact: While all WFOs stated there was clear value collaborating with their media partners in real-time during critical weather events, some also noted it was also a resource that needed to be "managed." Constant monitoring of the chat room was not realistic and not all communication within the chat room by partners is always pertinent to the mission.

Finding 4: Instant Message software enhanced the situational awareness of many key media and emergency management partners. It also provided the local offices with near real-time severe weather damage reports from these partners. A standard Instant Message program across all of the NWS would provide a common forum for media interests whose listening or viewing areas cover multiple local office areas of responsibility.

Recommendation 4: The NWS should explore the feasibility of providing or supporting standard Instant Messaging software for all WFOs and National Centers.

Information flow to partners and users after an event of this magnitude can be challenging. The office workload is increased dramatically in responding to requests for information. It is imperative the NWS issue accurate information related to the event as quickly as possible. This informs everyone affected and allows for more efficient post-event activities. Currently, there is no consistent method among WFOs to format post-event information.

Best Practice 3: WFOs Birmingham and Peachtree City provided routine updates to the ongoing surveys as they occurred the following day, both via Public Information Statements (PNS) and via their web news stories. They noted that providing regular PNSs to regularly inform the public of post-event review progress following the event helped reduce phone calls.

Best Practice 4: After the event, WFO Birmingham assembled talking points within the staff to help provide consistent media information. These are typically developed within two hours of the end of the event by station management and/or the Lead Forecaster on duty and shared with the staff.

6. Dissemination (NOAA Weather Radio All Hazards)

NOAA Weather Radio All Hazards (NWR) is a nationwide network of radio stations broadcasting continuous weather information directly from a nearby National Weather Service office. NWR broadcasts NWS warnings, watches, forecasts and other hazard information 24 hours a day. The NWR network is a critical part of the warning process, as it provides direct input to the Federal Communication Commission's (FCC) Emergency Alert System (EAS). As a result, weaknesses in transmitting warnings broadcast via NWR over the EAS will have an impact on the citizens served in that area.

Fact: Radio stations in rural areas of Georgia do not automatically activate severe weather alerts via the EAS if no one is on duty. The stations rely on a satellite feed, which does not automatically capture NWS weather watch and warning information.

Finding 5: A Georgia Emergency Management Agency official stated that the lack of EAS alerts (during the late evening/early morning when no one is on duty) on the local radio stations had a negative impact on the situational awareness of the residents of Americus, Georgia.

Recommendation 5: The NWS should encourage the FCC to explore ways to improve EAS alert activation in rural areas where local radio stations broadcast via satellite during times when no one is on duty.

7. Using Hardened Safe Rooms as Tornado Shelters

The Service Assessment Team was tasked with evaluating issues related to public response and other societal impacts related to tornado safety as they pertained to this event. Why did 19 fatalities occur when the public received considerable advance warning via outlooks and every tornado that produced fatalities was warned with an average lead time of 20 minutes?

The team considered issues relating to the concept of NOAA "creating hazard-resilient communities," particularly from the perspective of minimizing loss of life. The following sections address topics related to this issue.

It is well known that manufactured homes are extremely dangerous places to be when a tornado strikes. In this event, eight of the nineteen fatalities occurred in manufactured homes. Seven of those fatalities occurred with tornadoes rated EF2; one with an EF4. A month earlier, a tornado outbreak in central Florida caused 21 fatalities, all of which occurred in manufactured homes.

Fact: Past research has shown that the risk of fatality from a tornado for those inside a manufactured home is 15 to 20 times greater than for those in permanent structures (National Severe Storms Laboratory [NSSL]).

Fact: Though only 7% of U.S. residents live in manufactured homes, around 50% of tornado fatalities occur in manufactured homes (NSSL).

Research and tornado fatality statistics show permanent structures are safer places of refuge during a tornado than mobile homes. However, even permanent structures are at risk in tornadoes rated EF3 or higher. Violent tornadoes can remove permanent homes from their foundations, especially those structures where “standard grade” construction techniques are used. Standard grade construction techniques use materials and methods typical for federal or state codes, i.e., the minimum requirements.

Fact: Some of the permanent structures (i.e., two-story homes) impacted by the tornadoes were completely removed from their foundations.

Fact: In this event, most of the homes removed from their foundations exhibited “standard-grade” construction techniques.

Fact: All eleven fatalities in permanent structures during this event occurred with tornadoes rated EF3 or greater.

The team supports the idea that hardened safe rooms used for tornado shelters are essential for adequate tornado safety in residential areas (See FEMA publication *Residential Safe Rooms: Background and Research)*. A hardened safe room is lined and topped with concrete and has no windows. The rooms are designed to withstand severe sustained winds and wind gusts.

In permanent structures, a hardened safe room is a small, specially designed room, intended to provide a place of refuge from extreme winds only for the people who live in the house. For manufactured homes, this type of interior safe room is not practical, as mobile homes often move off their foundation and roll over during extreme winds. In a manufactured home community, a necessary component for tornado safety is a hardened safe room which can be easily accessed, in a timely manner, by all the residents in the community.

The portion of this event that received significant attention from the media was the EF4 tornado which hit a high school in Enterprise, Alabama. Eight fatalities, all students, occurred at the high school. There was considerable local debate regarding whether the school should have let the children out before or during the event, and even whether they should have had school on a day where there was a high risk of tornadoes. Dismissing students and faculty while a Tornado Warning was in effect for the area could have been just as (or more) dangerous.

The potential impact of a strong to violent tornado on human life is amplified any time it strikes a large facility which houses many people (such as a school or industrial complex). Many existing schools (and other facilities) do not have optimum locations for the safety of those who spend considerable time in the buildings. The safest locations at many of these facilities are the hallways.

Direct hits to large facilities have occurred in the past, with no loss of life (i.e., Parsons Manufacturing in Roanoke, Ill. on 7/13/04). Parsons had built special hardened safe rooms, in which all their employees were located at the time of the tornado. The tornado safety success story at the Parson's Manufacturing Company emphasizes the reality that it is possible to protect lives in large facilities, even in the face of strong to violent tornadoes and extreme destruction. Providing adequate hardened safe areas (rooms) is a very realistic way to enable survival of many people, even in a violent tornado.

Fact: In July 2004, an F4 tornado struck the Parsons Manufacturing Company near Peoria, Ill., leaving behind a mangled pile of manufacturing equipment, employee vehicles and building material; however, none of the 150 people in the building was killed or seriously injured. Parsons had built special hardened safe rooms, in which all their employees were located at the time of the tornado.

Finding 6a: This event further demonstrates the risk of seeking shelter in manufactured homes and homes with "standard grade" construction during a tornado. Tornado survival for those in these type homes depends not only on the warning decision being made along with communication and receipt of the warning, but also having an adequate hardened safe room for use as a place of safety, either in the home itself or within a reasonable distance from the home.

Finding 6b: The high school in Enterprise followed proper procedures in terms of maximizing student safety. The eight fatalities at the high school appear to have been due to structural failure of the roof and walls, which collapsed on the students. Previous events, such as the violent tornado which hit the Parsons Plant (where everyone evacuated into a hardened safe room and no one was killed) have shown that hardened safe rooms provide better shelter from tornadoes than other permanent structures, especially during tornadoes rated EF3 or greater.

Recommendation 6: The NWS should promote the benefits of using hardened safe rooms as tornado shelters. Hardened safe rooms can be especially beneficial for manufactured home communities, residences with standard grade construction, and for non-residential buildings in which many people often gather (schools, office buildings, etc.)

8. Summary

Strong tornadoes rated EF2, EF3, and EF4 moved through southern areas of Alabama and Georgia on March 1, 2007. These tornadoes killed 19 people, including 8 in a high school in Enterprise, Alabama.

Evaluation of services and products during this event showed that, though some technological challenges existed, the overall NWS performance for its users and partners was excellent. Severe Weather Outlooks, Tornado Watches, and Tornado Warnings were issued well in advance and disseminated in a timely manner, allowing for proper planning and decision-making by partners and the public.

The Team found that Storm-Based Warnings during this event would have reduced the area which was unnecessarily warned by 58%. However, the Team also found that Storm-Based Warnings would not have alleviated the time spent sheltering in place at Enterprise High School, since Enterprise was in the path of all 3 supercells that moved through Coffee County during the 2½-hour period.

This report also examined some reasons for the high number of fatalities during this event. The Team supports the idea that hardened safe rooms used as tornado shelters are critical to adequate tornado safety plans, especially in mobile home parks, homes with standard grade construction, and non-residential buildings in which many people often gather (schools, office buildings etc.)

The report offers six recommendations highlighting 1) technological improvements which would positively impact the level of information and service provided by NWS offices; and 2) enhancements to the NWS public safety and education programs.

Findings and Recommendations

Finding 1: WFOs involved in this event were frustrated and concerned by the lack of reliability and high levels of attention required to minimize any potential problems using the WarnGen or GFE software in backup mode.

Recommendation 1a: The NWS should take steps to simplify service backup procedures in GFE. Technology in support of service responsibility transfer between offices needs to be more expeditious and dependable, to maximize the capability of backup offices to issue updated hazardous weather products when needed.

Recommendation 1b: The NWS should modify the WarnGen localization process to 1) enable a single localization to update both the local site's templates and those of backup sites, and 2) provide an automated daily process which checks for outdated localizations and informs the local IT administrator to correct the situation.

Finding 2: WFO Birmingham forecasters had opportunities to provide additional real-time information on warnings that were within 10 minutes of expiration. Because the forecasters did not know if they wanted the warning to expire, they could not provide the information due to this WarnGen limitation.

Recommendation 2: WarnGen should be modified to allow continuation statements up to the time a warning expires; forecasters could select Continuation and Expire options as appropriate within this 10-minute time window to expiration.

Finding 3: Overall, the team found three areas for improvement within the LSR program.

1. WFOs often update preliminary LSRs based on damage surveys and provide followup reports which include more accurate information on event type, location and time. The current LSR product format does not allow internal and external parsing software to differentiate between initial event reports, retransmitted reports in summary LSRs, or event reports corrected based on updated information.

2. The current LSR software is designed for county based warnings and as a result, the locations are too coarse for Storm-Based Warnings.

3. *Preliminary* reports of tornadoes (sent out via LSRs) are sometimes later determined to be straight line wind damage, but the some media partners will indicate the preliminary report as a confirmed tornado.

Recommendation 3a: The NWS should develop materials clarifying the difference between preliminary and final storm report information and indicate that one tornado could be associated with multiple tornado reports. All NWS offices should be provided this information.

Recommendation 3b: NWS should issue guidance on how to address unconfirmed tornado reports in preliminary LSRs.

Recommendation 3c: The NWS should develop LSR software which is compatible with Storm-Based Warnings and provides more explicit information regarding updated reports.

Finding 4: Instant Message software enhanced the situational awareness of many key media and emergency management partners. It also provided the local offices with near real-time severe weather damage reports from these partners. A standard Instant Message program across all of the NWS would provide a common forum for media interests whose listening or viewing areas cover multiple local office areas of responsibility.

Recommendation 4: The NWS should explore the feasibility of providing or supporting standard Instant Messaging software for all WFOs and National Centers.

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Recommendation 5: The NWS should encourage the FCC to explore ways to improve EAS alert activation in rural areas where local radio stations broadcast via satellite during times when no one is on duty.

Finding 6a: This event further demonstrates the risk of seeking shelter in manufactured homes and homes with "standard grade" construction during a tornado. Tornado survival for those in these type homes depends not only on the warning decision being made along with communication and receipt of the warning, but also having an adequate hardened safe room for use as a place of safety, either in the home itself or within a reasonable distance from the home.

Finding 6b: The high school in Enterprise followed proper procedures in terms of maximizing student safety. The eight fatalities at the high school appear to have been due to structural failure of the roof and walls, which collapsed on the students. Previous events, such as the violent tornado which hit the Parsons Plant, where everyone evacuated into a hardened safe room and no one was killed, have shown that hardened safe rooms provide better shelter from tornadoes than other permanent structures, especially during tornadoes rated EF3 or greater.

Recommendation 6: The NWS should promote the benefits of using hardened safe rooms as tornado shelters. Hardened safe rooms can be especially beneficial for manufactured home communities, residences with standard grade construction, and for non-residential buildings in which many people often gather (schools, office buildings, etc.)

Best Practices

1. All offices used sectorized warning operations to manage warning issuance during this event. Sectorized operations have proven to be a valuable mode of operations during widespread severe weather events.

2. All four offices utilized IEM Chat effectively and all feedback from the partners on this type of collaboration and communication was positive.

3. WFOs Birmingham and Peachtree City provided routine updates to the ongoing surveys as they occurred the following day, both via Public Information Statements (PNS) and via their web news stories. They noted that providing regular PNSs to inform the public on post-event review progress following the event helped reduce phone calls.

4. After the event, WFO Birmingham assembled talking points within the staff to help provide consistent media information. These are typically developed within two hours of the end of the event by station management and/or the Lead Forecaster on duty and shared with the staff.

Appendix A

Statistics for the Tornadoes Producing Fatalities

Time	Location	County	WFO	Path Length (miles)	EF rating	Deaths	Injuries	Lead Time (min)	Other Info
1824-1833	Millers Ferry, Alabama	Wilcox	Mobile	15.6	4	1	2	6	Fatality in mobile home
1908-1918	Enterprise, Alabama	Coffee	Tallahassee	7	4	9	50	18	8 fatalities in school
2230-2241	Reynolds, Georgia	Taylor	Atlanta	7	2	1	0	36	Fatality in mobile home
0200-0240	Americus, Georgia	Sumter	Atlanta	38	3	2	0	29	Fatalities in duplex
0444-0517	Newton, Georgia	Baker	Tallahassee	30	2	6	0	12	All fatalities in mobile homes

Appendix B

Enhanced Fujita (EF) Tornado Scale

FUJITA SCALE			DERIVED EF SCALE		**OPERATIONAL EF SCALE**	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)	**EF Number**	**3 Second Gust (mph)**
0	40-72	45-78	0	65-85	**0**	**65-85**
1	73-112	79-117	1	86-109	**1**	**86-110**
2	113-157	118-161	2	110-137	**2**	**111-135**
3	158-207	162-209	3	138-167	**3**	**136-165**
4	208-260	210-261	4	168-199	**4**	**166-200**
5	261-318	262-317	5	200-234	**5**	**Over 200**

The Enhanced F-scale (also known as the EF scale) is a set of wind estimates (not measurements) based on damage. It uses three-second gusts estimated at the point of damage based on a judgment of different levels of damage. Levels of damage are judged based on 28 damage indicators (not shown here). These estimates vary with height and exposure. The 3 second gust is not the same wind as in standard surface observations. Standard measurements are taken by weather stations in open exposures, using a directly measured “one minute mile" speed.