Service Assessment

May 2013 Oklahoma Tornadoes and Flash Flooding

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

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March 2014

National Weather Service
Louis W. Uccellini, Assistant Administrator for Weather Services

Preface

A series of tornadoes and associated weather hazards impacted the metropolitan area of Oklahoma City, OK, on May 19, 20, and 31, 2013, resulting in 47 direct fatalities, hundreds of injuries, and billions of dollars in property damage. This event presents a unique learning opportunity with regard to forecast and warning operations, post-storm data acquisition, dissemination services, interactions with the media, public response, and safety awareness information.

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

Louis W. Uccellini
Assistant Administrator
for Weather Services

March 2014

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Service Assessment Team

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Executive Summary

From May 19 to May 31, 2013, a series of devastating weather events affected the area in and around Oklahoma City. Although this report focuses on three specific days, May 19, 20, and 31, the entire period was characterized by an active weather pattern and multiple tornadoes across several National Weather Service (NWS) Weather Forecast Offices' (WFO) areas of responsibility. The historic flash flooding that occurred in Oklahoma City on May 31 is also of note. This flash flooding caused more fatalities than the tornadoes on that day. In all, there were 47 direct weather fatalities in the WFO Norman County Warning Area during these 13 days in May.

NWS formed a Service Assessment Team to evaluate NWS performance and to undertake a detailed social science review to examine the effectiveness of messaging and the behavior of the public in each severe weather event. The team concentrated its efforts primarily on counties and cities affected by the strongest tornadoes during this period. NWS also conducted a complete review of the operations of WFO Norman and the Storm Prediction Center. After the events on May 20 and May 31, NWS Southern Region Operational Services Division conducted a Rapid Evaluation of Service Activities and Performance (RESAP). Several of the RESAP findings were incorporated into this report.

During the events assessed in this report, WFO Norman performed well above the NWS's 2013 goals for national tornado and flash flood under the Government Performance Requirements Act. From May 19 to May 31, WFO Norman issued 55 tornado warnings and hundreds of statements and social media posts, with overall tornado accuracy (Probability of Detection) of 0.87, False Alarm Rate of 0.54, and an average lead time of nearly 21 minutes. The flash flooding performance was also above NWS goals, with a Probability of Detection of 0.91, False Alarm Rate of 0.50, and a lead time of 84 minutes.

Despite the WFO's excellent performance and the Storm Prediction Center's accurate long-term outlooks, the last event on May 31 created anxiety among some in the public. When considering the public response to each of these three tornado events and the flash flooding event, the team needed to look at the overall timeline. Public response to the warnings on May 31 was definitely affected by the events on May 19 and 20. The flash flooding on May 31 caused more fatalities than the tornadoes that day, yet the public was largely unaware of the threat, in spite of several NWS products and extensive outreach efforts, webinars, and social media posts. Much of the information contained in Section 4 of this report discusses the public's response and suggests that performance metrics such as Probability of Detection and lead time do not tell the entire story. Messages concerning event severity and safety actions from the weather enterprise were not consistent. In some cases, these messages directly contradicted each other. Many of the people receiving these differing messages were unsure how to respond.

A significant section of this report concentrates on the use of social media. NWS is steadily increasing its visibility on social media sites such as Facebook and Twitter. Direct feedback from state and local partners, media, and the public reinforced the lifesaving nature of this information dissemination method. WFO Norman is one of the leaders in social media presence among WFOs. This information flow directly led to lives saved. Other WFOs are encouraged to emulate this level of effort, based on this service assessment's findings and recommendations.

The team submitted 26 findings to address NWS performance, outreach, and safety programs. In addition, the team identified seven best practices. The appendices support this report with the following resources:

- Appendix A: Acronyms
- Appendix B: Findings, Recommendations & Best Practices
- Appendix C: Direct Tornado and Flash Flood Fatalities
- Appendix D: List of Interviewed Subjects for Public Response Research
- Appendix E: References

Service Assessment Report

1. Introduction

1.1. NWS Mission

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

1.2. Purpose of Assessment Report

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

This document presents findings and recommendations related to NWS performance during the central Oklahoma tornadoes of May 19 and 20, and the tornadoes and flooding on May 31, 2013. This outbreak of severe weather resulted in 47 direct fatalities and caused billions of dollars in damage to central Oklahoma.

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

- Timeliness, quality, accuracy, and usefulness of NWS forecasts and warnings
- Internal and external coordination and collaboration
- Forecasting and warning procedures at Weather Forecast Office (WFO) Norman, OK
- Social science-related issues and public response

1.3. Methodology

The NWS formed an assessment team on July 2, 2013, consisting of two employees from WFOs and one each from the NWS Central Region Headquarters office, NWS Headquarters (NWSH), EM community, and the National Transportation Safety Board. The 6-member team completed the following:

- Performed onsite evaluations, July 14-19, 2013
- Conducted interviews with staff from WFO Norman and the Storm Prediction Center (SPC), which shared primary responsibility for providing watches, warnings, forecasts, and decision support for EMs, media, and the general public for this event
- Interviewed members of the media, EM community, and the public to assess services provided by the NWS
- Collected data from WFO Norman, the SPC, and other NWS offices to obtain a complete record of the event and to determine if any facts, findings, recommendations, or best practices pertained to these offices
- Evaluated products and services provided by WFO Norman and the SPC
- Developed and agreed upon significant findings and recommendations to improve NWS products and services

Social science consultants performed on-scene evaluations July 21–25, 2013, and provided their conclusions to the assessment team. The consultants used a qualitative method approach to study the public response. Interviews were conducted with EMs, media personnel, and the public from the impacted areas. (See Appendix D for a list of people interviewed for the public response assessment.) The social scientists used pre-validated questions to guide the interviews.

The team used a customized social science methodology to assess the public's response. The team was particularly interested in how the NWS contributes to hazard resiliency in the areas of decision support, operational procedures, collaboration, and communication. The resilience of a community, with respect to potential severe weather events, is determined by the degree to which it has obtained necessary resources and its ability to organize itself prior to and during a severe weather event. Social scientists were included in this analysis of resiliency evaluation because they use the same techniques as the natural sciences to study society and human behavior. In this case, the assessment team analyzed the systemic networks and collaborations in the weather warning process and the efficacy of communication processes used to send and receive messages, especially during each of the three severe weather events.

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

After a series of internal reviews, a service assessment is signed by the Service Assessment Team Charter's Executive Sponsor (e.g., Assistant Administrator for Weather Services, National Oceanic and Atmospheric Administration's [NOAA] Administrator) and released to the public.

2. Event Overview

2.1. May 19, 2013

The evolution of the weather pattern through May 18 set the stage for the more intense tornadoes that affected central Oklahoma during the afternoon and evening of May 19. On May 19, abundant, low-level moisture was drawn northward across the Southern Plains resulting in a strongly unstable environment. At the same time, a dry line progressed eastward to near the I-35 corridor in central Oklahoma. Isolated thunderstorms developed by mid-afternoon as strong surface heating occurred in the moist air mass east of the dry line and a jet streak aloft approached Oklahoma from the west (**Figure 1**). The result was an environment increasingly favorable for supercell thunderstorms, with tornadoes forming across central Oklahoma into southern and eastern Kansas. NWS confirmed this environmental assessment using special rawinsonde launches from Norman and Lamont, OK, just before 1 p.m. Central Daylight Time.[1]

The storms in Kansas tended to interfere with one another soon after storm initiation; as a result, most of the tornadoes were relatively brief. Farther south into central Oklahoma, the storms remained discrete for a longer time. Observations from the NWS Twin Lakes WSR-88D radar site showed rapidly strengthening low-level winds and resultant vertical wind shear soon after the initial supercell developed near Edmond, OK. Mesonet data in central Oklahoma showed this strengthening wind shear appeared to be tied to a commensurate increase in surface winds and falling pressure as of 4 p.m. The first central Oklahoma supercell produced a damaging tornado in Edmond, followed by a long-lived tornado with up to EF3 damage near the towns of Carney and Wellston, OK. The initial supercell weakened and stopped producing tornadoes as the storm moved east of the corridor of stronger instability and vertical wind shear. A second supercell formed over east Norman and went on to produce another long-lived tornado with EF4 damage near Shawnee. Like its predecessor, the Shawnee tornadic storm weakened as it moved east of the stronger instability corridor.

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

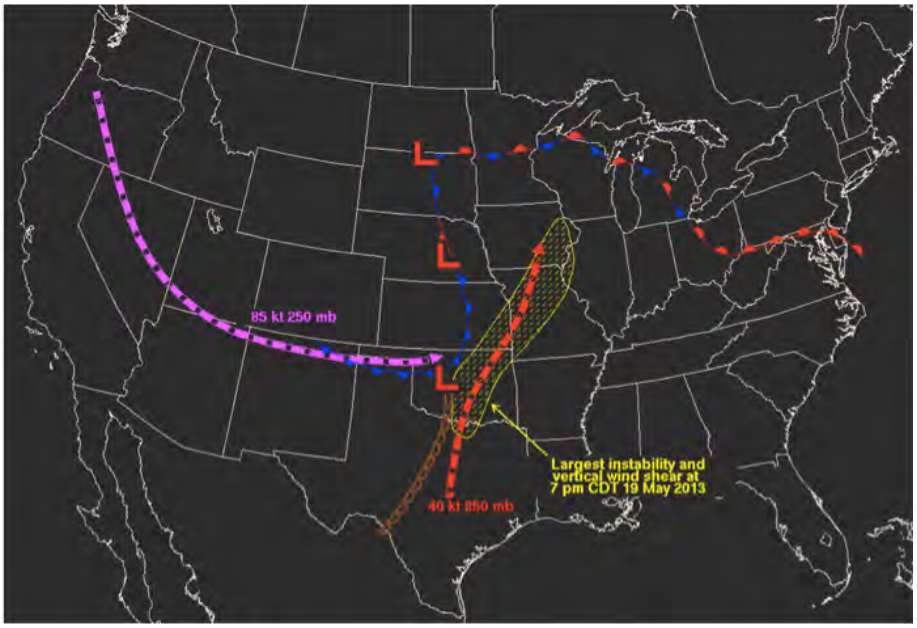


Figure 1: Weather summary chart valid at 7 p.m. on May 19, showing a synoptic setup for severe weather. *Source: SPC*

2.2. May 20, 2013

A second consecutive day of severe thunderstorms affected central Oklahoma on May 20, beginning between 2 p.m. and 3 p.m. The strongly unstable environment from the previous day remained, largely owing to a lack of overnight or early day thunderstorms. The larger-scale weather pattern was similar to the prior day, with the most focused area of vertical wind shear and instability occurring in midafternoon along the I-44 corridor from central Oklahoma to southwest Missouri (**Figure 2**). This was verified by the special midday rawinsonde launch from WFO Norman.

Thunderstorms developed during the early afternoon along the stalled frontal boundary in central Oklahoma and along the dry line into south central Oklahoma. The Moore, OK, tornadic supercell formed immediately northeast of the intersection of the dry line and the stalled front. The supercell appeared to move along the front during the time of rapid storm intensification leading up to tornado formation, as verified by radar and Oklahoma mesonet data. The Moore supercell produced a single damaging tornado in a heavily populated area, while the other storms to the south and to the northeast produced only short-lived and weak tornadoes. Like the prior day, storm interactions and the relatively narrow corridor of the most favorable conditions tended to limit the time window and spatial extent of the tornado threat. The Moore storm was the only supercell that moved along the front without immediate interference from other storms. As a result, it experienced the most favorable environment for storm-scale rotation resulting in the Moore tornado being the most intense and long-lived tornado of the day.

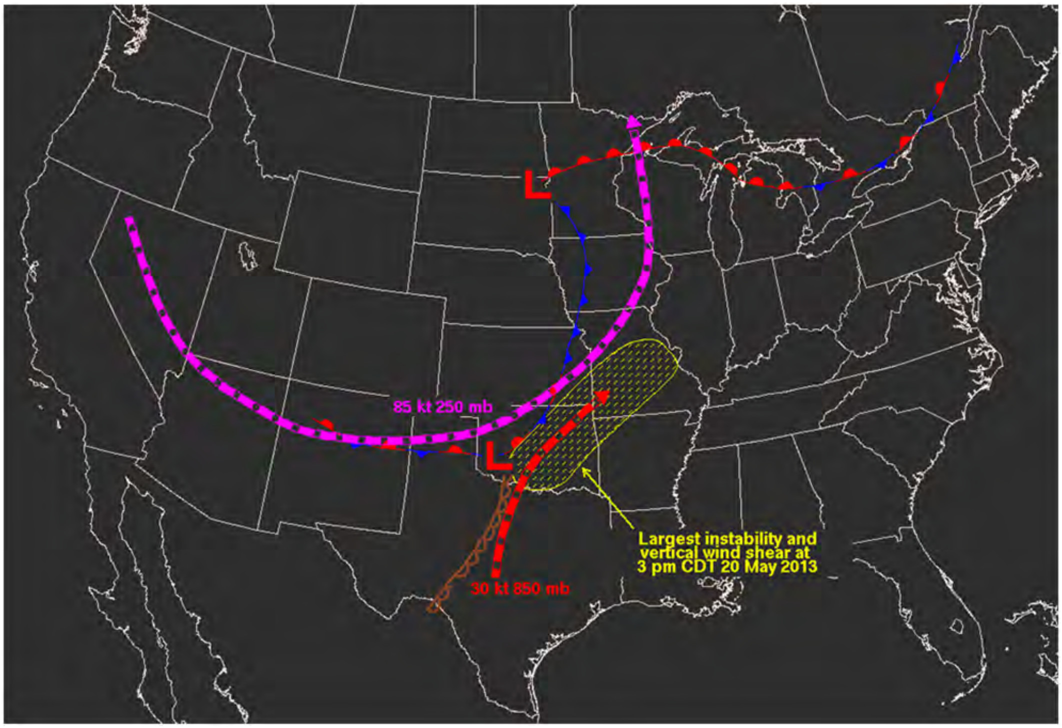


Figure 2: Weather summary chart valid at 3 p.m. on May 20, showing a synoptic setup for severe weather. *Source: SPC*

2.3. May 31, 2013

A weather pattern similar to the May 19–20 sequence developed again at the end of May (**Figure 3**). Like the previous event on May 20, the intersection of a slow-moving front and a dry line provided the impetus for severe thunderstorm development in central Oklahoma by late Friday afternoon on May 31. By 5 p.m., the Oklahoma mesonet data confirmed a zone of enhanced low-level southeasterly winds feeding into the boundary intersection where the initial supercells developed, just to the west of El Reno, OK. Additionally, high surface dew point temperatures in the mid-70s (°F) and very unstable temperature lapse rates resulted in strong to extreme instability, as evidenced by the special rawinsonde launched from WFO Norman shortly before 1 p.m. The observed environment was supportive of supercells capable of producing intense tornadoes and giant hail.

The first supercell formed near 5 p.m. and moved generally eastward to the El Reno vicinity by 6 p.m. This long-lived, intense tornado remained mostly in open country during its life cycle, which reduced overall damage and loss of life compared to the May 20 event. As on both May 19 and 20, storm interactions and a relatively narrow corridor for the most favorable conditions limited the spatial extent of the most serious tornado risk. However, regeneration of severe thunderstorms moving along a similar path from west to east resulted in 8–11 inches of rain in just a few hours, and serious flash flooding across the Oklahoma City, OK, metropolitan area.

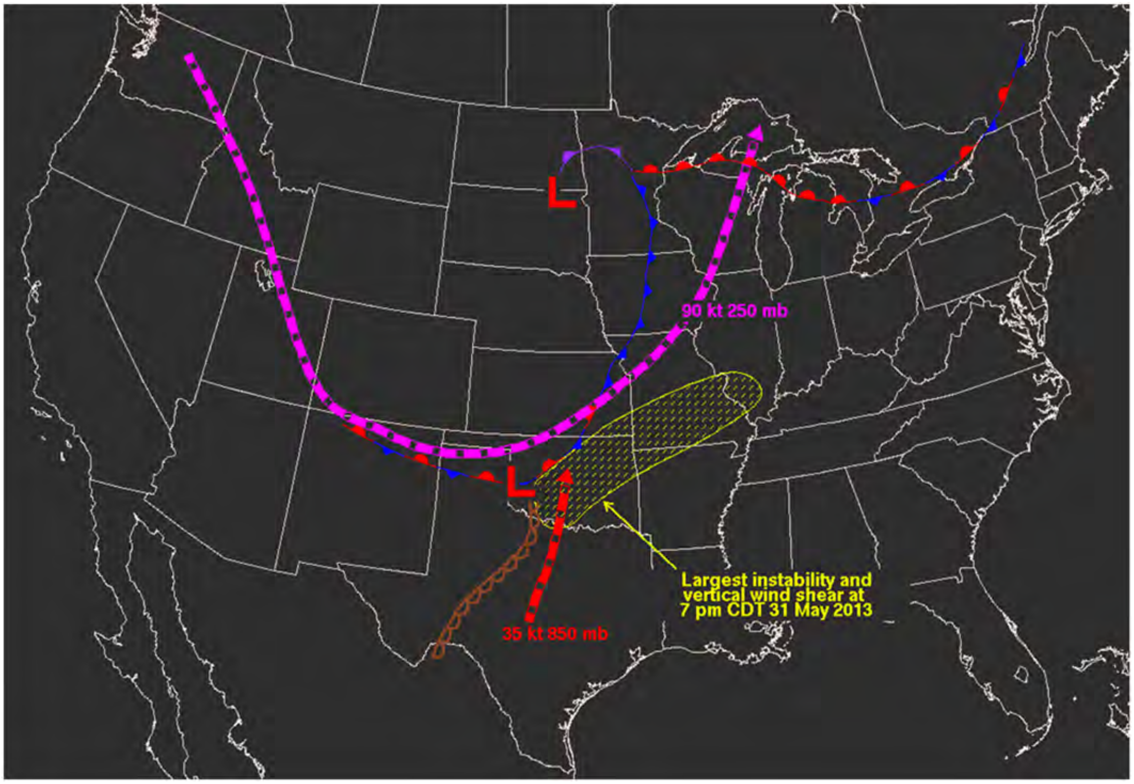


Figure 3: Weather summary chart valid at 7 p.m. on May 31, showing a synoptic setup for severe weather. *Source: SPC*

3. NWS/SPC: Facts, Findings, Recommendations, and Best Practices

3.1. WFO Services

WFO Norman experienced two consecutive days of severe weather in mid-May. On Sunday evening, May 19, an EF4 tornado struck near Shawnee, OK, and on Monday, May 20, an EF5 tornado struck Moore, OK. Eleven days later, on Friday, May 31, an EF3 tornado then struck El Reno, OK.

The WFO was well prepared for these events. The SPC severe weather outlooks were distributed to NWS partners and the public as many as 6 days in advance. WFO Norman's management staff gathered early on May 20 to coordinate and plan the communication of the message of the day. This meeting was held early in the day to ensure the message was refined before storms developed. For all three events, WFO staff provided information to EMs and the public via a number of communications channels including social media. Additionally, the WFO also provided Impact-Based Decision Support Services, and these services included briefings to EMs before and during the events, a proactive effort to disseminate Geographic Information System (GIS)-formatted, estimated damage paths, and support to the recovery efforts at the Incident Command Post.

In addition, as one member of the WFO Norman staff noted, the office's success communicating during these events was a result of best practices it had put in place long before 2013.

"Our success was due to many years of planning and practice and the relationships we've built through collaborations like meetings, drills, and exercises. These relationships weren't built overnight or the day of a tornado outbreak. It came through our StormReady presentations, weather talks and briefings, and EM events. It takes lots of hard work, like getting ready for a football game."

A traditional suite of forecast model data (e.g., North American Mesoscale Model [NAM], Global Forecast System [GFS]) is broadcast over the Satellite Broadcast Network (SBN) to the Advanced Weather Interactive Processing System (AWIPS) in the WFOs. These forecast models do not include the High Resolution Rapid Refresh (HRRR) and other high-resolution convective allowing models (CAM). However, during the tornado events, WFO Norman staff found the HRRR model and other CAM extremely valuable forecast decision aids. The WFO Norman staff found that some of the most valuable derived model fields available from the HRRR and the local models were the hourly output of reflectivity and updraft helicity. WFO staff used these derived model fields to enhance wording and make more specific time references to the approaching threats in their products. In the near-term forecasts, the HRRR model derived fields of convective elements proved more useful than the traditional suite of model fields delivered over the SBN. The traditional suite of forecast model data uses a large amount of the SBN's bandwidth resulting in very little bandwidth being available for delivery of the external model data. WFO Norman had difficulty getting some local model data quickly because of the communications limitations.

Finding 1: The HRRR model and other CAM availability in AWIPS is limited and competes for bandwidth with larger-scale model data. WFOs operate on high spatial and temporal resolutions when providing decision support services.

Recommendation 1: WFOs need the capability to ingest preferred high-resolution model data during critical times.

WFO Norman produced GIS products showing a preliminary estimate of the likely tornado track, which the office made available while the tornado was in progress in Moore, OK (**Figure 4**). The Meteorologist in Charge (MIC), serving as the radar interpreter, worked with the Information Technology Officer (ITO) to use a prototype local application on AWIPS II, the AWIPS's next-generation software, to generate the GIS files on AWIPS. The GIS files were emailed to the EMs in affected regions and to the Southern Region Regional Operations Center (SR ROC) and posted on social media. WFO Norman used all available radar data and other information to draw potential damage paths. The local application allowed the meteorologists to select points, scan-by-scan, to identify where a tornado was located. This process includes forecaster interpretation in the analysis loop and is different and separate from the rotation tracks products available from the National Severe Storms Laboratory (NSSL). The Federal Emergency Management Agency (FEMA) Director noted these products are "extremely valuable" when integrated into FEMA's GIS applications. These preliminary tracks allowed FEMA to identify the impacted areas and determine resources that might be needed for the recovery as much as 3–4 hours before resources were requested.

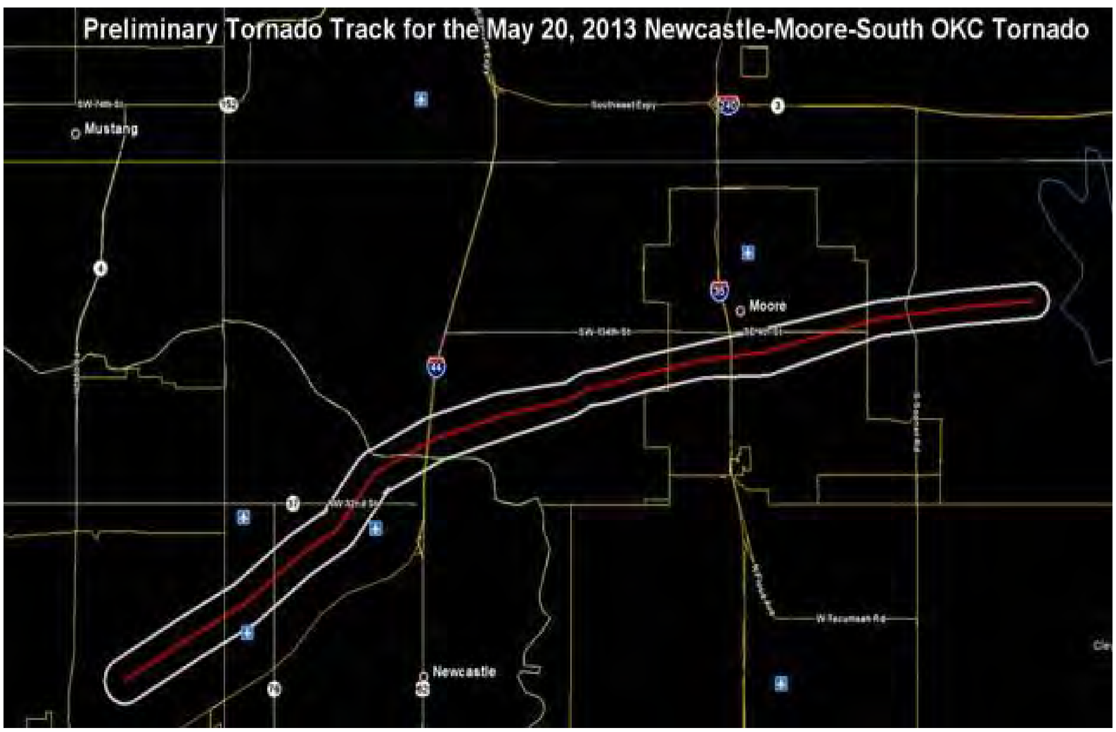


Figure 4: Moore, OK, preliminary tornado GIS track. *Source: WFO Norman*

Best Practice: WFO Norman promptly provided EMs GIS information showing likely damage areas while tornadoes were still in progress.

Fact: These GIS products saved FEMA 3–4 hours of response time and helped FEMA staff determine the need for additional urban search and rescue teams before local EMs formally requested this assistance.

Fact: The SR ROC saw the tornado track as an image on the WFO Norman Facebook page and provided the graphic to FEMA Region VI, which used it to plot the potential damage track in a GIS viewer. FEMA expressed a desire to also have the data in GIS format in the future.

Finding 2: NWS GIS products allowed many NWS partners (e.g., FEMA) to respond faster to demands for rapid information and decision support services. Currently, only WFOs using AWIPS II and a locally-developed application can create GIS products for possible tornado tracks while the tornado event is ongoing. Once NWS deploys AWIPS II to all its offices, GIS products should be provided consistently.

Recommendation 2: WFOs should be provided with the capability and procedures to create GIS products for possible tornado tracks in near real-time.

Finding 3: NWS partners want GIS tornado track information and other pertinent data. Currently, not all NWS offices are equipped to provide this information.

Recommendation 3: All NWS offices should use the Damage Assessment Toolkit (DAT) to provide damage survey information to partners in a consistent GIS-accessible format.

Finding 4: Not all offices have enough easily portable devices with geolocation to enable the direct entry of data taken in the field during the storm survey into the DAT. Consequently, some NWS personnel are choosing to install the DAT app on their personal mobile devices to facilitate the use of the DAT.

Recommendation 4: NWS should supply all WFOs with appropriate hardware, including computer tablets, with the Global Positioning System or other geolocation services, to facilitate the collection of survey information using the DAT software.

3.2. SPC Services

SPC first emailed a heads-up to the NOAA/NWS FEMA liaison on May 13 regarding the potential severe weather threat for May 17-19. On May 15, SPC sent an update to the NOAA/NWS FEMA liaison.

SPC conducted briefings with the FEMA National Watch Center and affected FEMA regional offices on Friday, May 17, for the forecast period May 18-20; on May 29, for the forecast period May 29-31; and on May 31, to update expectations for that day.

During the briefings, the SPC Operations Branch Chief provided an overview of categorical and probabilistic outlooks along with impacts, timing, and confidence in the forecasts. The briefings were followed up with summary notes sent from the FEMA liaison to the FEMA email distribution list. The SPC Director emailed NWS Leadership to provide updates on the content of FEMA briefings.

The SPC Operations Branch Chief and the SPC Director sent the FEMA briefings and heads-up emails to the Senior Director for Response/National Security Staff at the White House. The first heads-up email was sent on the morning of May 17, 2013, and mentioned the potential for a multi-day severe weather threat that included tornadoes.

SPC discussed the multi-day, severe weather potential with NOAA/NWS Legislative Affairs, on May 17. Legislative Affairs used this information to brief key legislative staff of affected states on Capitol Hill. Follow-up phone calls were held to refine forecasted impacts, as needed.

The SPC Facebook page was used to update followers on the severe weather threat. The SPC Facebook post gained 5,581 "likes" from May 17 to June 2. During 2013, the average 2-week increase in "likes" was 1070. SPC first mentioned the threat on May 13 and highlighted a prolonged period of severe weather using both text and SPC Outlook graphics. Subsequent postings included information from damage assessments conducted by WFO Norman, from radar imagery, and from historical perspectives.

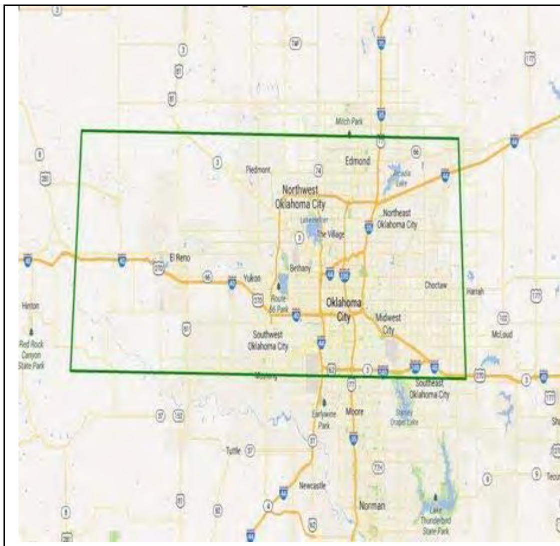
3.3. Flash Flooding

The flash flooding that occurred in Oklahoma County, OK, during the evening of May 31 and early morning of June 1 resulted in 13 fatalities, including 12 people in Oklahoma City. This was the deadliest flooding event ever for Oklahoma City. It was also the deadliest flooding event in the state since the May 26–27, 1984, flash flood in Tulsa, when 14 people perished. This event was also the deadliest flash flood in the WFO Norman forecast area since April 3–4, 1934, when 17 people were killed by a flash flood along the Washita River near Hammon, OK.

Multiple severe weather threats on May 31 created a complex warning environment for WFO Norman. (The public's reaction to the warnings is further discussed in Section 4.0). WFO Norman performed well during the crisis communication stage for this event. The office contacted multiple partners about outlooks and warnings and ample lead time was provided for people to prepare for the tornado and the flooding. Members of the public interviewed indicated they were well warned for the tornado, but not for the flash flooding. They received the warnings for the tornado from multiple sources, but not the flash flood warnings. No members of the public interviewed were aware of a flash flood warning on May 31. They felt television weather broadcasters chose to focus on the tornadoes and not the flash flooding. In fact, those interviewed indicated the flash flooding was a surprise and they did not know how to respond to the dual warning. They knew what to do for a tornado or for a flash flood, but not for both at the same time. The surprise element of the flash flooding made the public feel less confident about its safety plans.

One woman reported that she and seven other people, including family, friends, and four pets, were sheltered in a small underground cellar that started filling with water. "*We stayed in* *there until the water got too high,"* she said. *"We just hoped the tornado was over by that point."* When asked if she received the flash flood warning, she said, *"No."* Her first clue that flooding was a problem was the water in her cellar.

WFO Norman first mentioned the flash flood threat in a Hazardous Weather Outlook on Wednesday, May 29, at 11:49 a.m., and included the flood threat in all subsequent outlooks issued up to the event and in social media outlets. WFO Norman issued the first Flash Flood Watch for the event at 12:20 p.m. on Thursday, May 30. When the storm continued to produce heavy rain, WFO Norman issued a Flash Flood Warning at 7:13 p.m. on Friday, May 31 (**Figure 5**), and received the first flooding report at 8:00 p.m. Total rainfall amounts were as high as 7–8 inches in parts of the warned area (**Figure 6**). WFO Norman also held webinars with EMs on May 30 and 31, sent emails to EMs, created Graphicasts, produced YouTube Severe Weather Updates, and posted Twitter and Facebook entries at various times through May 31.

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BULLETIN - EAS ACTIVATION REQUESTED
FLASH FLOOD WARNING
NATIONAL WEATHER SERVICE NORMAN OK
713 PM CDT FRI MAY 31 2013

THE NATIONAL WEATHER SERVICE IN NORMAN HAS ISSUED A

* FLASH FLOOD WARNING FOR...
  OKLAHOMA COUNTY IN CENTRAL OKLAHOMA...
  CANADIAN COUNTY IN CENTRAL OKLAHOMA...

* UNTIL 1115 PM CDT

* AT 711 PM CDT...NATIONAL WEATHER SERVICE RADAR INDICATED HEAVY
  RAIN. UP TO THREE INCHES OF RAIN HAS ALREADY FALLEN OVER PORTIONS
  OF CANADIAN COUNTY. FLASH FLOODING IS IMMINENT.

* SOME LOCATIONS THAT WILL EXPERIENCE FLOODING INCLUDE
  OKLAHOMA CITY...EDMOND...MIDWEST CITY...DEL CITY...EL RENO...
  YUKON...BETHANY...CONCHO...MUSTANG...THE VILLAGE...WARR ACRES...
  CHOCTAW...NICHOLS HILLS...SPENCER...PIEDMONT...JONES...NICOMA
  PARK...UNION CITY...CALUMET...ARCADIA AND TINKER AIR FORCE BASE.

ADDITIONAL RAINFALL AMOUNTS OF TWO TO FOUR INCHES ARE POSSIBLE IN
THE WARNED AREA.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

MOST FLOOD DEATHS OCCUR IN AUTOMOBILES. NEVER DRIVE YOUR VEHICLE INTO
AREAS WHERE THE WATER COVERS THE ROADWAY. FLOOD WATERS ARE USUALLY
DEEPER THAN THEY APPEAR. JUST ONE FOOT OF FLOWING WATER IS POWERFUL
ENOUGH TO SWEEP VEHICLES OFF THE ROAD. WHEN ENCOUNTERING FLOODED
ROADS MAKE THE SMART CHOICE...TURN AROUND...DONT DROWN.
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Figure 5: Flash Flood Warning issued 7:13 p.m., May 31, valid through 11:15 p.m. *Source: WFO Norman*

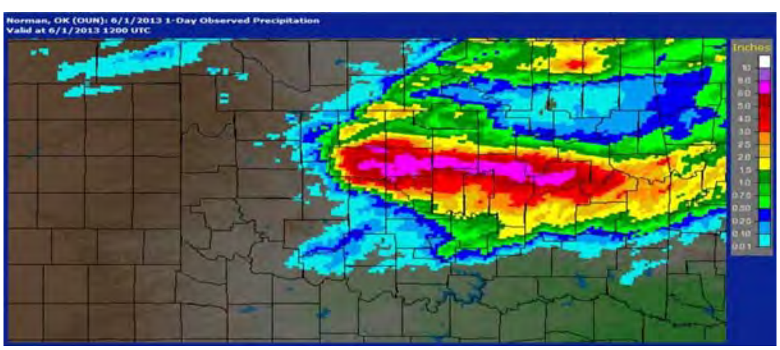

Figure 6: Observed precipitation, in inches, for central Oklahoma valid from 7 a.m., May 31, to 7 a.m., June 1. *Source: Advanced Hydrologic Prediction Service display produced by the Arkansas-Red Basin River Forecast Center (ABRFC)*

Fact: At 1 p.m. on May 31, WFO Norman tweeted, "*TORNADO SAFETY: If you choose to flee in your car, plan for and anticipate traffic jams and blocked roads, hail, heavy rain and flooding.*"

Fact: At 7:49 p.m. on May 31, WFO Norman Tweeted, *"SERIOUS FLASH FLOODING THREAT over the [Oklahoma City] OKC metro! Do not drive into areas where water covers the road!!"*

Finding 5: The NWS warned the public about the flash flooding threat, but much of the public did not get that warning. WFO Norman used social media and other dissemination methods before and during the flash flooding in the morning and afternoon of May 31.

Recommendation 5: The NWS needs to develop warning protocol when there are multiple severe weather elements in the warning so that each element of the warning is weighted based on its urgency and severity. This protocol should include wording on how the public should prepare and respond to multiple, simultaneous dangers such as tornadoes and flooding.

Finding 6: Interviews with the public indicated the broadcast media focused on the tornadoes and not the flooding during the May 31 event.

Recommendation 6: The NWS needs to provide specific educational material to the broadcast media partners on how to manage warning dissemination for multiple severe weather hazards.

In addition to WFO Norman flash flooding products and local guidance, the Weather Prediction Center (WPC) issued several national and regional flash flooding guidance products to provide situational awareness in the days leading up to the May 31 event. WPC provides an "Excessive Rainfall Outlook" to highlight flash flood threats through the next three days. The first outlook covering the day and time of the flash flooding was issued at 2:24 a.m. on Wednesday, May 29. Oklahoma City was on the southwestern edge of a slight risk area. The outlook issued at 12:55 a.m., May 30, continued to have Oklahoma City on the edge of a slight risk area, but added a moderate risk area over northeastern Oklahoma and southwestern MO (**Figure 7**). By 12:44 a.m., May 31, both the slight and moderate level areas were extended to the southwest deeper into Oklahoma with Oklahoma City in the moderate risk area (**Figure 8**). This year, the function of providing short term (0–6 hours) Mesoscale Precipitation Discussions (MPD) was transferred to WPC from SPC. These discussions focus on mesoscale features that could produce flash flooding over the next few hours.

Fact: WPC issued their first of four MPDs for the Oklahoma City area at 4:21 p.m., May 31 (**Figure 9**).

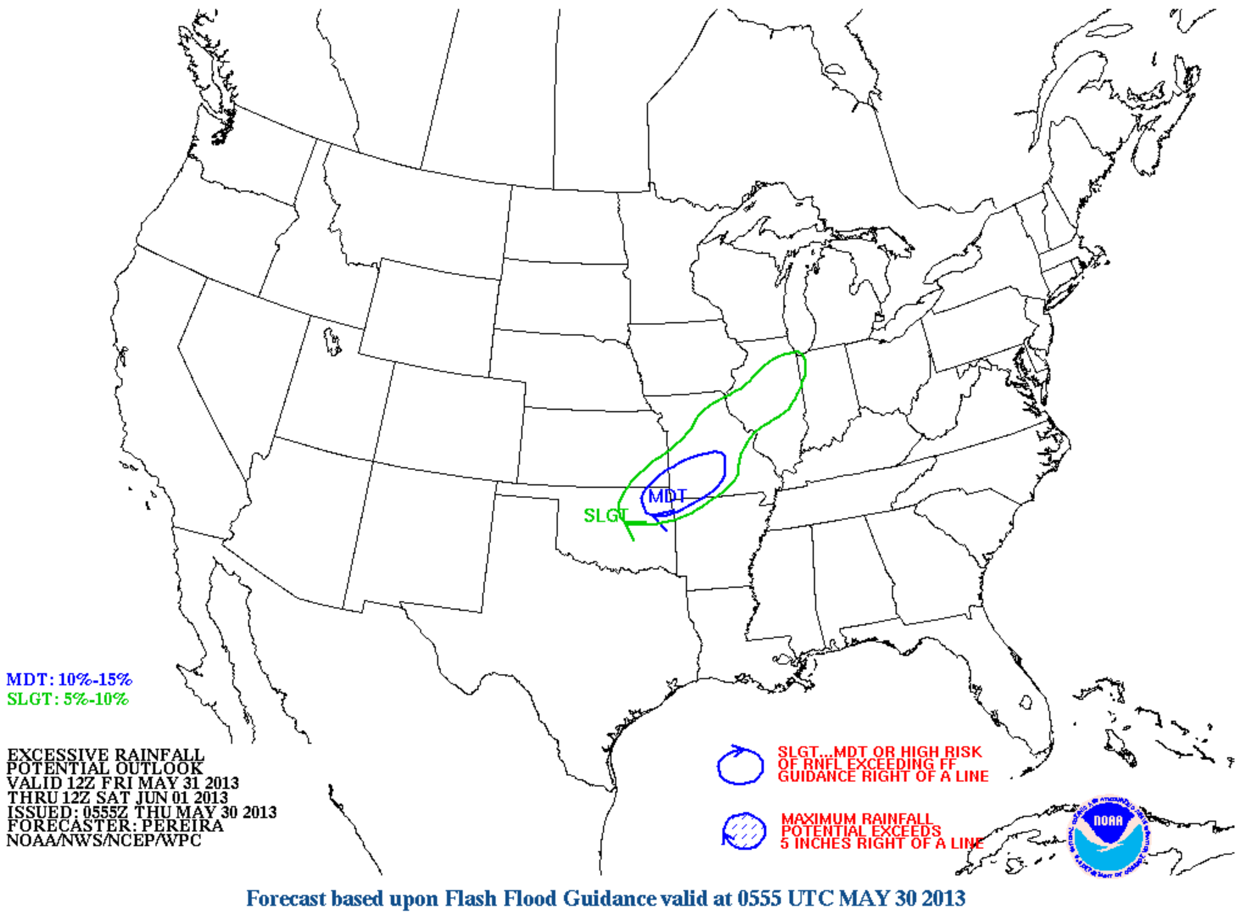

Figure 7: WPC Day 2 Excessive Rainfall Outlook issued at 12:55 a.m., May 30, valid 7:00 a.m., May 31, through 7:00 a.m., June 1, 2013. *Source: WPC*

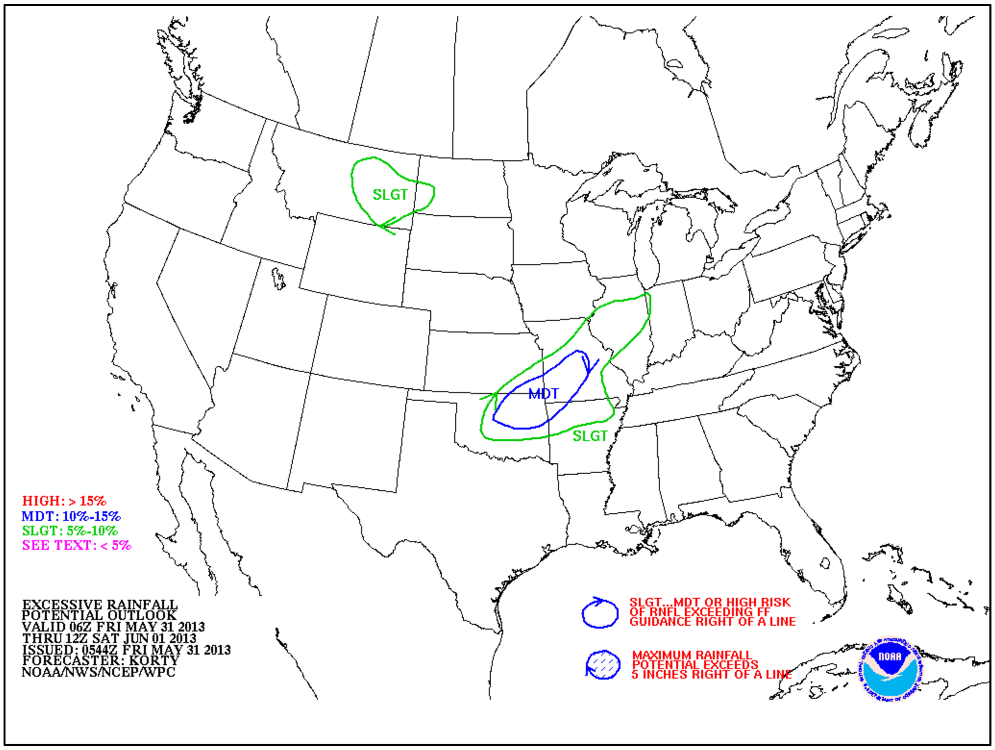

Figure 8: WPC Day 1 Excessive Rainfall Outlook issued at 12:44 a.m., May 31, valid from 7:00 a.m., May 31 through 7:00 a.m., June 1. *Source: WPC*

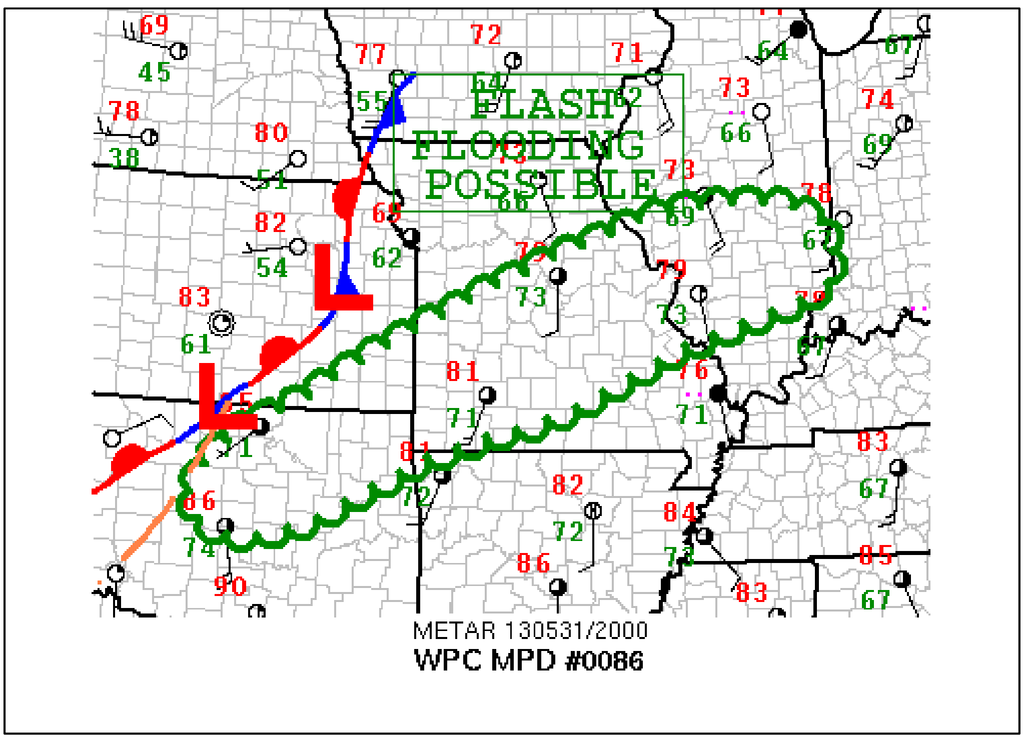

Figure 9: Graphic accompanying WPC Mesoscale Precipitation Discussion issued at 4:21 p.m., May 31, valid from 4:21 p.m. through 9:20 p.m., May 31. *Source: WPC*

3.4. Social Media

WFO Norman provided an aggressive social media presence before and during the severe weather events. WFO Norman forecasters see great value in social media as a means to establish and strengthen relationships within communities. Social media provides the WFO the ability to interact directly with the public and offer calm, direct advice (**Figure 10**). National WFO social media statistics show WFO Norman's social media efforts have paid off. Feedback from social media users show this information to be particularly valuable (**Figure 11**). Many social media updates are shared. For example, National Public Radio Station KGOU in Norman routinely links the WFO's YouTube and PowerPoint briefings to its KGOU websites, retweets the WFO messages often, and replays briefing sound bites on air.

Figure 10: WFO Norman Facebook message from 7:52 a.m. on May 20 discussing timing for possible tornadoes. *Source: WFO Norman*

Figure 11: A Facebook message from a local resident on how the reader used messages from WFO Norman during the tornadic events of mid-May. *Source: WFO Norman*

WFO Norman is one of the top NWS offices in social media engagement (**Figures 12–13**).

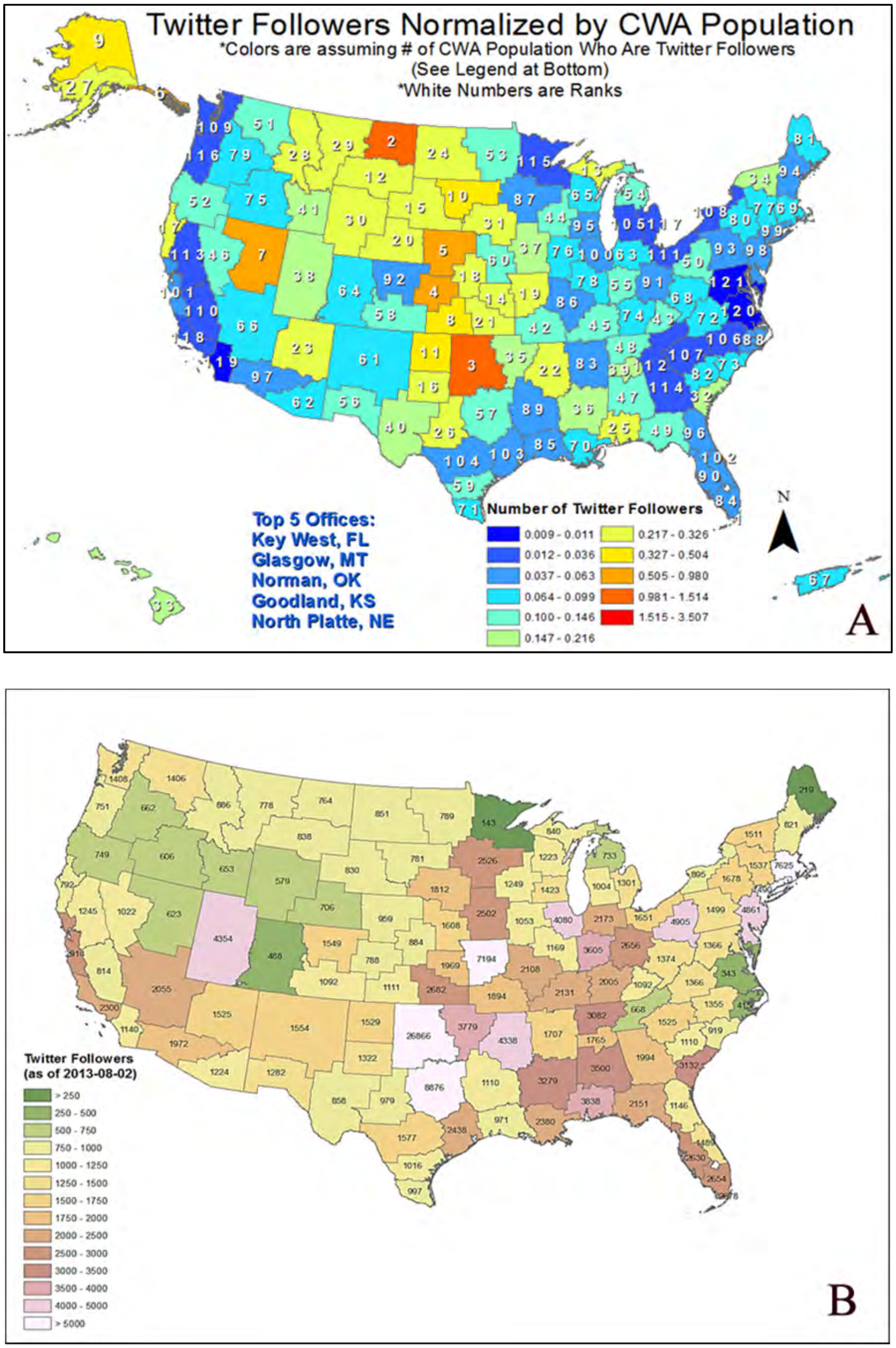

Figure 12: Twitter followers normalized by county warning area population (A) and by total number of followers (B) as of August 2013. *Source: Todd Foisy, Dustin Jordan, WFO Caribou, and Jason Straub, WFO Brownsville*

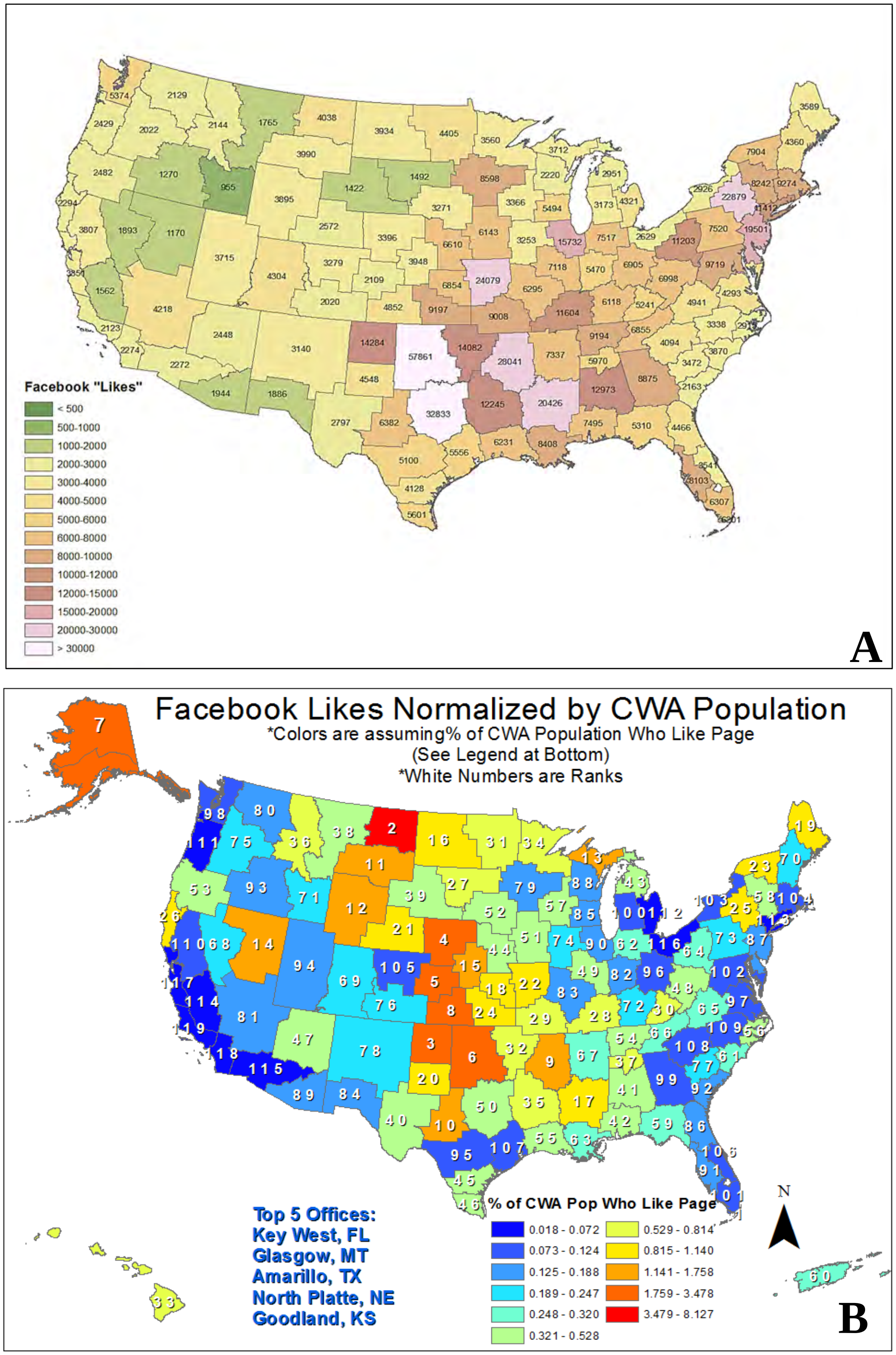

Figure 13: Facebook total "likes" (top graphic) and normalized by county warning area population (bottom graphic), as of August 2013. *Source: Todd Foisy and Dustin Jordan from WFO Caribou, and Jason Straub, WFO Brownsville*

The severe weather events in May 2013 captured the attention of many more people through social media than previous WFO Norman events. WFO Norman Twitter followers for the month of April totaled 13,771. By the end of May, the number of WFO Norman followers increased nearly 85 percent to 25,459. Similarly, Facebook "likes" for April totaled 32,629; by the end of May, that number increased to 51,153. In addition, the number of YouTube WFO Norman subscribers increased by 420 in May.

WFO Norman dedicated one staff member to update social media outlets during this event; this is its typical response to most medium and high-end events. The YouTube video that WFO Norman released at about 11:30 a.m. on the Monday before the Moore tornado can be seen at: http://www.youtube.com/watch?v=9Q7iUn9YfWA&feature=c4-overview&list=UUacncsbh_AhMe-CUmEMzmTg The video was praised by many partners and media for its accurate description of the day's threats, including the potential for storms to impact school dismissal during the afternoon. WFO Norman posted the video on its YouTube channel, shared it via its Twitter and Facebook pages, linked it from the WFO's web page, and emailed it to its mailing list of nearly 400 partners.

Partners also praised the expected storm development Graphicasts featured in the WFO's webinar and posted on social media and webpage. Several EMs and other partners specifically mentioned these graphics as a tool that increased their confidence about the timing and location of the thunderstorms and tornadoes, and prompted action (**Figures 14–15**).

Figure 14: WFO Norman Graphicast image discussing expected storm development during the afternoon of May 20. Graphicast issued 11:00 a.m., May 20. *Source: WFO Norman*

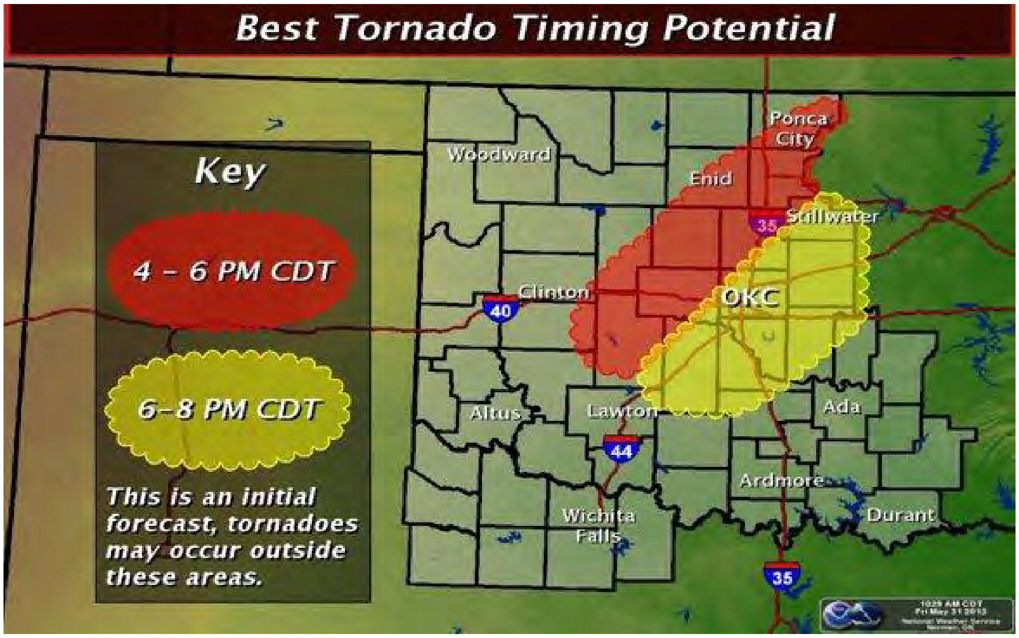

Figure 15: WFO Norman Graphicast image discussing expected tornado timing potential during the afternoon of May 31. Graphicast issued 10:29 a.m., May 31. *Source: WFO Norman*

WFO Norman conducts a weekly webinar on Mondays at 10 a.m. for its partners. In addition, WFO Norman often conducts teleconferences and webinars on an ad hoc basis for significant threats. WFO Norman forecasters focus on interpreting what to expect based on SPC and other guidance. Typically, the webinars are recorded and a version is posted on YouTube, Twitter, and Facebook. The webinar on May 20 included hospital and school administrators. EMs commented after the event that they could tell this was a dangerous event by the tone and demeanor of the WFO Norman WCM during the weekly webinar in contrast to routine webinars. This tone was in contrast to some of the other voices in the media that may have been downplaying the risk that day.

The Safety Director for the Moore Medical Center, Shane Cohea, provided the following comment via email to the WCM: *"Simply put you saved lives and we took the information you provided days before and the webinar May 20 as serious as anyone in Oklahoma! I read between the lines when others were downgrading the prediction for the day and you had a different opinion."*

Best Practice: WFO Norman offers weekly calls to its core partners, which leads to greater understanding and awareness of severe weather days.

The WFO Norman staff member who handles social media varies based on experience, interest, and knowledge. For the bulk of this WFO Norman severe weather event, the WCM provided social media updates initially and then handed off the responsibility to the social media focal point. The WFO's social media message is becoming more and more critical as another confirmation source of warnings to the public and NWS partners.

Best Practice: WFO Norman dedicated staff resources to collect and provide social media content. On an event-by-event basis, the office team edits the content of the social media posts to increase effectiveness. For example, WFO Norman did not provide the hourly, short-term text weather discussion in order to provide more emphasis in social media.

Best Practice: WFO Norman includes time stamps in Twitter entries to reduce confusion when information is retweeted.

Partners have lauded WFO Norman for their proactive approach to social media engagement. Concern was expressed that this service may not be maintained during service backup events.

Finding 7: Social media is not currently an integral part of NWS service backup operations.

Recommendation 7: The NWS should make social media an integral part of service backup operations.

The staff at WFO Norman dealt with numerous severe weather events in a 2-week period (**Figure 16**), not just the three high-impact events. Each severe weather event in central Oklahoma resulted in significant physical and emotional stress on the staff. One Senior Forecaster responsible for warnings said:

"When you're making decisions with life and death consequences, knowing that it is very likely some will die regardless of your actions, it's a heavy emotional burden to bear." Within a few weeks after the events ended, a representative from the Employee Assistance Program (EAP) was brought into the office for group counseling. A forecaster in the WFO said, *"EAP got the ball rolling. Now we can all talk about it on shift."*

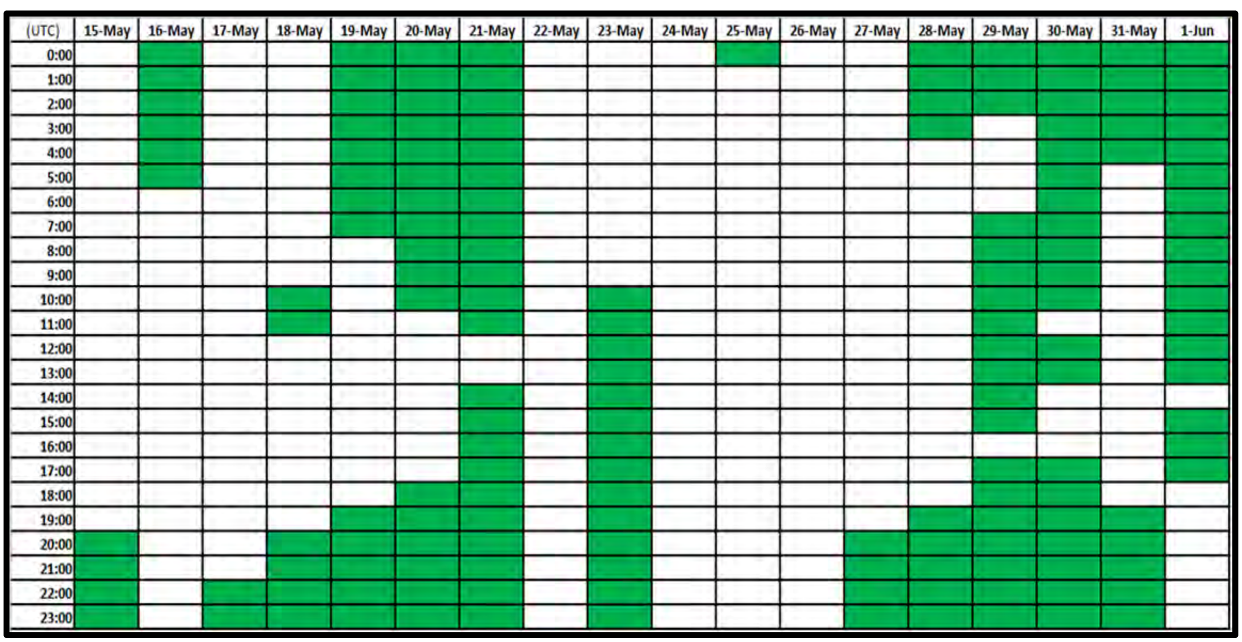

Figure 16: Green represents a watch or warning during that hour of the day for WFO Norman. *Source: WFO Norman*

Finding 8: Even though NWS has long-standing policy emphasizing EAP use at impacted offices, some NWS staff members, including management, are currently ill-equipped to both understand and deal with emotional issues resulting from high-impact events.

Recommendation 8: NWS management should receive regular refreshers on the importance of offering EAP support after major events.

3.5. EF Tornado Rating Scale

The NWS adopted the Enhanced Fujita (EF) Scale in 2007. The EF Scale measures the amount of damage a tornado causes to human-engineered structures. Wind speeds are then inferred and estimated based on an understanding of wind loads and expected failure points; however, NWS needs additional damage indicators as new observation data sources become available. Research and new sources of data have increased the ability to assess wind speeds within tornadoes and the resultant damage via damage indicators.

The EF-Scale Steering Committee, an ad hoc group consisting of Federal, State, University, and private weather enterprise experts representing many disciplines, has several proposals to refine the EF Scale and its use (Edwards et al., 2013). NWS employee participation on this committee is voluntary and not currently part of any employee's assigned duties.

The Wind Science and Engineering Center at Texas Tech University served as the original source for rating tornadoes using the EF Scale. The document proposing the change from the Fujita Scale to the Enhanced Fujita Scale states, *"...The technology of portable Doppler radar should also be a part of the EF Scale process, either as a direct measurement, when available, or as a means of validating the wind speeds estimated by the experts."*

The issue of measurements compatibility is significant. Winds measured by mobile radars at various heights above ground level (agl) are potentially not the same strength as the winds causing damage near the surface. According to Dr. Josh Wurman, Center for Severe Weather Research, it is not currently possible to derive near-surface wind speeds based on winds at some elevation aloft. Tornadoes form in several ways from different storm types; not all tornadoes have the same wind distribution.

Fact: The science is currently incomplete on the specific wind speed variations within tornadic circulations. Scientists have not determined how sampled winds above 10 meters relate to winds at 10 meters, the standard height at which wind observations are made.

NWS conducted detailed ground surveys of tornado damage on May 20, 21, and 31. Local tornado experts in the Norman vicinity, including personnel from WFO Norman, NSSL, Warning Decision Training Branch (WDTB), SPC, and the University of Oklahoma (OU), as well as noted tornado damage expert Tim Marshall performed the ground surveys. NWSI 10-1604, *Post-Storm Data Acquisition*, recommends NWS consider forming a Quick Response Team (QRT) to augment WFO efforts at rating tornadoes potentially greater than EF3. WFO Norman had the advantage of using local experts as volunteers to form a QRT, but other WFOs may not have local expertise readily available.

Using these additional experts in the survey process allowed the remaining WFO staff to provide decision support services for the recovery effort and to prepare for continued severe weather. Had these experts not been readily available, the surveying process would have been greatly delayed and support to ongoing recovery and forecast of future severe weather could have been compromised.

Finding 9: The local availability of wind damage/tornado experts to help assess multiple tornadoes, and confirm damage greater than EF3, was extremely beneficial to WFO Norman, the SR ROC, and NWSH. These wind damage/tornado experts volunteered to perform the role of a QRT without incurring any expenses to the NWS.

Recommendation 9: The NWS should continue to preserve and support the QRT concept by (1) ensuring funds are made available for future QRTs, and (2) updating NWSI 10-1604 *Post-Storm Data Acquisition* to include more specific and standardized procedures for forming (including required training) and activating a QRT.

Based on damage indicators, the Shawnee tornado was assigned an EF4 rating and the Moore tornado was assigned an EF5 rating. The El Reno tornado, with only EF3 damage found during the survey, was assigned a preliminary rating of EF5. This rating of EF5 was based on two mobile research radars (i.e., University of Oklahoma's Rapid-scan X-band Polarimetric Radar (RaXpol), and Doppler on Wheels) that sampled winds at higher wind speeds than the damage indicators would allow the team to infer. There was precedent for using such radar data to modify the EF-Scale ratings of at least six other tornadoes. These tornado events, which occurred at different WFOs, had been given a higher EF-Scale rating than the damage indicators would suggest after mobile radar data were made available. The Assessment Team believes that based on past precedent it was reasonable for WFO Norman to give the El Reno tornado a preliminary EF5 rating.

Fact: Within the El Reno tornadic circulation, the Doppler on Wheels radar sampled winds slightly above 250 mph approximately 375 feet agl and the OU RaXpol radar sampled winds in excess of 290 mph approximately 500 feet agl.

Fact: WFO Norman upgraded the EF-Scale rating on the El Reno tornado from EF3 to EF5 after consultation with numerous NSSL experts and the University of Oklahoma School of Meteorology. The El Reno tornado's width was calculated based on the diameter of EF0 winds sampled by RaXpol.

Dr. Louis Uccellini, in a policy memo dated June 6, 2013, stated, *"Directive NWSI 10-1604, Post-Storm Data Acquisition, requires us to use the EF Scale, which is an impact-based rating assigned to a tornado after extensive investigation of the damage it caused. EF ratings are determined by observed damage rather than measured wind because we have no consistent way to measure wind speed for every tornado that occurs. Adhering to NWSI 10-1604 ensures we continue to use consistent methodology throughout the country for assigning EF ratings."*
Dr. Uccellini continued by stating that an update to NWSI 10-1604 will give the option to include these data in the narrative of tornado summaries.

While much attention is given to the EF-Scale rating and expected wind speeds, traditional storm survey techniques are often limited by the lack of damage indicators, particularly over sparse terrain. A large, violent tornado producing no damage over open country would be rated an EF0. Often, the strongest winds in a tornado may not impact a damage indicator, or a damage indicator could be destroyed by winds much slower than occurred during the event being evaluated.

It is the Service Assessment team's opinion that when there is a discrepancy between observed ground damage and other storm information (e.g., portable radar measurements), then the additional data should be communicated in the official NWS Storm Data publication.

Finding 10: NWSI 10-1604, *Post-Storm Data Acquisition*, *NWSI 10-1605, Storm Data Preparation*, and the training NWS staff receives to rate tornadoes does not specifically address using data other than observed damage indicators.

Recommendation 10: NWSI 10-1604, *Post-Storm Data Acquisition*, should be updated to allow for additional information based on high-confidence remotely sensed data, when available. This additional rating, for example a "Doppler On Wheels sampled winds 250 mph at 300 feet agl," should be included as a searchable feature in the NWS's Storm Data database.

Finding 11: At least six other tornadoes from previous events across several WFOs were assigned a higher EF-Scale rating than the damage indicators suggested after NWS was able to evaluate mobile radar data.

Recommendation 11: All historical storms with an EF-Scale rating augmented by high-confidence remotely sensed data should be reassessed, and if appropriate, updated with this additional information once the NWS publishes the updated NWSI 10-1604, *Post-Storm Data Acquisition.*

NWSI 10-1605, *Storm Data Preparation*, along with the National Climatic Data Center Storm Events Database , and the SPC Warning Coordination Meteorologist (WCM) web page contain mostly text-based data on tornado tracks. Some specific track information is available on the SPC page for larger events, but most tornadoes are reported with a starting point, ending point, and a narrative section to describe movement. The NWS Damage Assessment Toolkit (DAT) provides storm survey teams with the ability to survey, report, and display storm damage information internally and, once quality controlled, with partners and the public. Once the update to NWSI 10-1604 is approved, WFOs will be required to report storm assessment survey results to the DAT web editor. At that time, NWS staff should have access to this GIS-based tornado track information.

Fact: The NWS Storm Data publication and National Climatic Data Center database describe tornadoes with a starting and ending point even though many tornadoes do not move in a straight line. In the May 31, 2013, El Reno example, a start and stop point completely misses the important specifics of the path and imply the tornado moved through areas it bypassed.

Finding 12: NWS Storm Data does not accurately reflect actual tornado tracks. Tornadoes are entered with a start and stop latitude/longitude, but NWS Storm Data does not preserve the actual path. WFOs are required to use the DAT website to report tornado tracks.

Recommendation 12: The official NWS StormDat Program should include a GIS-based tornado track that utilizes the DAT or GIS map track information to depict where the tornado occurred.

3.6. Rapid Evaluation of Service Activities and Performance (RESAP)

After the tornadic events of May 19–20, Southern Region Headquarters Operational Services Division organized a Rapid Evaluation of Service Activities and Performance (RESAP), known as a “hotwash” team, led by Southern Region Headquarters with input from WFO Norman, SPC, Eastern Region Headquarters, the NWS Warning Decision Training Branch, and NWSH. This hotwash team was established to learn from the tornadic and other hazardous weather events and establish new best practices and findings for other WFOs. This team created a weather summary of the May 19 and 20 tornadic events and interviewed key WFO Norman staff to better understand the timeline of events, find successful procedures and work practices, and recommend needed changes. The team met again after the May 31 event and included a member of this Assessment Team. Some of the best practices and findings, of national relevance, identified in the hotwash are included in this report. WFO Norman praised this rapid review method because the hotwash team was less formal than a national team. This Assessment Team believes the hotwash method was successful in quickly identifying best practices and recommendations; however, it cannot replace a national assessment team for larger events.

Best Practice: SR successfully employed a Rapid Evaluation of Service Activities and Performance team to review event services within the region.

After the tornadic events of May 19 and 20, WFO Norman provided onsite weather support to the Incident Command Post (ICP) to aid the recovery effort. The onsite forecaster provided support similar to what an Incident Meteorologist provides. ICP staff had difficulty identifying the onsite WFO Norman forecaster in the crowded ICP because that person was not wearing NOAA/NWS logoed apparel. In addition, when making damage surveys of the affected and damaged areas, the lack of NOAA/NWS-logoed apparel reduced staff effectiveness and delayed entry into damaged areas.

Finding 13: The lack of NOAA/NWS-logoed apparel reduced staff effectiveness while obtaining information from the public.

Recommendation 13: NWS should provide appropriately logoed apparel to employees in the field after an event, including employees providing onsite decision support services and conducting damage surveys.

3.7. Message Consistency: Responsibility for Message Consistency and IWTs

One theme that emerged is the issue of responsibility: which elements of the weather enterprise—including EMs, news media, and NWS forecasters, and others—are responsible for issuing advice to the public. Identifying the responsible elements of the weather enterprise is important to ensure the public understands how to prepare, and what warning format and content best communicates potentially life-saving information.

Many groups interviewed for the assessment mentioned several elements of these storms that were atypical, leading members of these groups to react in equally atypical ways. (See Section 4, Societal Impacts.)

WFO Norman recommended the use of helmets in safety messages over social media during the events and in severe weather preparedness handouts as a routine outreach effort. The SPC Tornado Frequently Asked Questions web page also references helmets as a safety measure. Recent studies after other large tornado events (Alabama, 2011) have indicated as many as 50 percent of the injuries and many deaths involve head trauma. The University of Alabama Injury Control Research Center offers practical advice and recommendations on including helmets as part of tornado preparedness. Early results from the University of Alabama Injury Control Research Center indicate helmets could help save lives. The inclusion of helmets as a safety device is still a matter of ongoing research.

Finding 14: The need to include helmets as a safety device during severe weather is still being researched. Early results from the University of Alabama Injury Control Research Center indicate helmets could help save lives and reduce head injuries.

Recommendation 14: The NWS should closely monitor research on helmets as safety devices during severe weather. If these recommendations are adopted as valid, the NWS should develop safety recommendations and preparedness efforts to include helmets with routine and emergency communications about tornado safety.

3.8. Working with the Media

Communication flow is a challenge with today's social media and 24-hour news environment. The WFO Norman WCM, SPC management, and the NOAA Public Affairs Officer (PAO) in Norman have considerable experience working with the media before, during, and after widespread severe weather events of national interest.

SPC and NOAA PAO have a severe weather communication plan, which assisted rapid development of an effective media plan during the May 19, 20, and 31 tornado events. During these tornado events and with the expected high demand of media requests, WFO Norman initially became overwhelmed. To meet the high demand of media requests during the May 19, 20, and 31 tornado events, the PAO, WFO Norman, and SPC worked together to prioritize media inquiries—national, local, international, radio, TV, and internet outlets. Interview requests from reporters in the impacted areas and national media were handled by WFO Norman and SPC. International media inquiries were especially high after the Moore tornado. WFO Norman and

PAO enlisted help from the SR ROC to handle these international media inquiries and WFO Norman appreciated the ability to offload the international media requests to the SR ROC.

WFO Norman, SPC, SR ROC, and NWSH provided more than 100 interviews to national, regional, local, and international media. Interview topics ranged from real-time updates on evolving severe weather potential to historical perspectives on the tornadoes and the extent to which climate change may have played a role.

Best Practice: The SPC and SR ROC, in coordination with the PAO and WFO Norman, responded to most of the national and international media requests, allowing WFO Norman to focus on select national and all local media requests and decision support services.

Finding 15: During the May 19, 20, and 31 tornado events, WFO Norman received a high demand for media requests. WFO Norman coordinated with the PAO, SPC, and the SR ROC to prioritize media inquiries, sending international requests to SR ROC and national media requests to SPC.

Recommendation 15: NWS should develop national, regional, and local plans on how to prioritize media inquiries and identify internal local and regional resources to meet press demands during significant severe weather events. The ROCs could be used to help standardize these plans.

Before and during the tornado events, WFO Norman and SPC used information from outlooks, watches, and warnings as talking points with the media. After the tornado, WFO Norman, the NOAA PAO, and SPC developed media talking points using facts about forecast products, lead times, special services provided by the WFO, description and maps of the storms' paths, and relevant historical data. These talking points were distributed to the people doing interviews in the WFO, SPC, and SRH, and provided to the NWS Operations Center. The talking points helped ensure a consistent and timely message from NWS to its partners and the public. These talking points were used for media requests and for social media posts. However, several key individuals and groups did not receive the talking points, such as Emergency Response Specialists at the FEMA Region VI Response Coordination Center and MICs from WFOs outside of the affected areas. In the future, these groups should also receive talking points to ensure a consistent message across the NWS.

The NWS does not provide guidance on how to develop talking points for weather events. Guidance should be provided and should include who is responsible for writing and approving the talking points and who can modify them as weather conditions and the environment change. Spokespeople should use consistent messaging when speaking to the media.

Finding 16: Before, during, and after the tornado events, WFO Norman, SPC, and the NOAA PAO developed and distributed talking points that were widely used. These talking points were a valuable tool.

Recommendation 16: NWS ROCs, in consultation with the NOAA PAO, should develop regional and local procedures for the development of talking points during significant weather events to help ensure a consistent media message and distribute to ROCs, NWSOC, and the NWS Communications Office.

While WFO Norman and SPC have a long history and experience working with the media after large events, the Assessment Team believes it would be beneficial for the NWS to develop or make available media training for all NWS employees who speak to the media regularly.

Finding 17: Media interest and interview requests are frequent after significant events, and NWS employees need to be able to interact confidently with the media.

Recommendation 17: NWS should develop and make media training mandatory for those NWS employees who speak with the media to help ensure a consistent media message across the NWS.

3.9. Storm Chasing

Storm chasing is a popular activity among some professional meteorologists and amateur weather enthusiasts. Typically, there are numerous storm chasers, some of whom are NWS Skywarn spotters, to observe many Great Plains tornadoes. Both spotters and storm chasers provide critical information to local law enforcement and NWS offices about the storms they are observing. The popularity of storm chasing has increased across the country. Storm chasers have documented "chaser convergence" (an assembly of vehicles, consisting of both chasers and residents, centered on a storm) in the past, especially in larger populated areas. Many storm chasers allow their position to be monitored by broadcasting their Global Positioning System coordinates to websites such as Spotternetwork.org (**Figure 17**). These positions, along with severe weather reports from storm chasers, are then displayed on computers. NWS offices can access these displays and reports and often call storm chasers to seek ground-truth information.

Three experienced storm chasers associated with past NOAA research projects were killed by the El Reno tornado and other chasers were injured. The three chasers killed, part of a research group called TWISTEX, were considered some of the most experienced and safety-minded chasers within the storm chaser community. Additionally, an amateur storm chaser that left his nearby home was killed. All eight of the direct tornado fatalities on May 31, 2013, were in vehicles, four of whom were involved in storm chasing. None of the individuals were functioning under a NOAA-sponsored research project at the time.

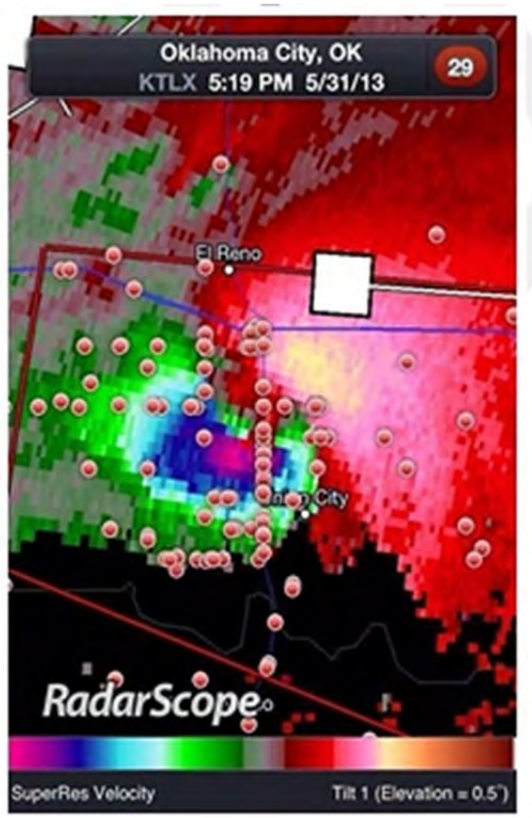

Figure 17: Red dots indicate Spotter Network-reported locations of storm chasers. *Source: RadarScope, WDT, Inc.*

It does not appear that traffic was a factor in the deaths of the TWISTEX storm chasers. Dan Robinson, a storm chaser, was directly ahead of the vehicle with the TWISTEX crew. In his post-storm chase account he wrote: *"At this point at **6:19:25 p.m.**, the white Chevy Cobalt occupied by the TWISTEX crew was immediately behind me. Other than the TWISTEX Cobalt and a red pickup truck parked along Highway 81, **there were no other vehicles in our immediate vicinity**. In other words, chaser traffic was a non-factor at our location."* Dan Robinson's video account of his experience is on YouTube at the following URL: http://www.youtube.com/watch?v=MxgU1QcFMJM.

An excellent overview of the events surrounding the death of the three chasers was produced by Skip Talbot, an experienced storm chaser. This video is provided with Talbot's permission at the following URL: http://www.youtube.com/watch?v=jVTs55W3Iag.

Several storm chasers reported the visually-deceiving nature of the El Reno storm and its apparent width. Data received, and used with permission, from a chaser compares the visible width of the tornado condensation funnels to the actual width based on RaxPol. Although the tornadic circulation was evident on radar, many chasers did not realize they were in, or as close to, the large circulation. During the time of rapid intensification, the forward motion of the circulation increased from approximately 35 mph to more than 50 mph. This speed increase, combined with a sharp left turn and intense inflow winds, made driving away from the tornado difficult (**Figures 18–20**).

Figure 18: Analysis from Gabe Garfield showing "visible vs. actual" tornado width. Red markers approximate visible tornado width and blue markers approximate actual width of the tornadic circulation. *Source: Skip Talbot*

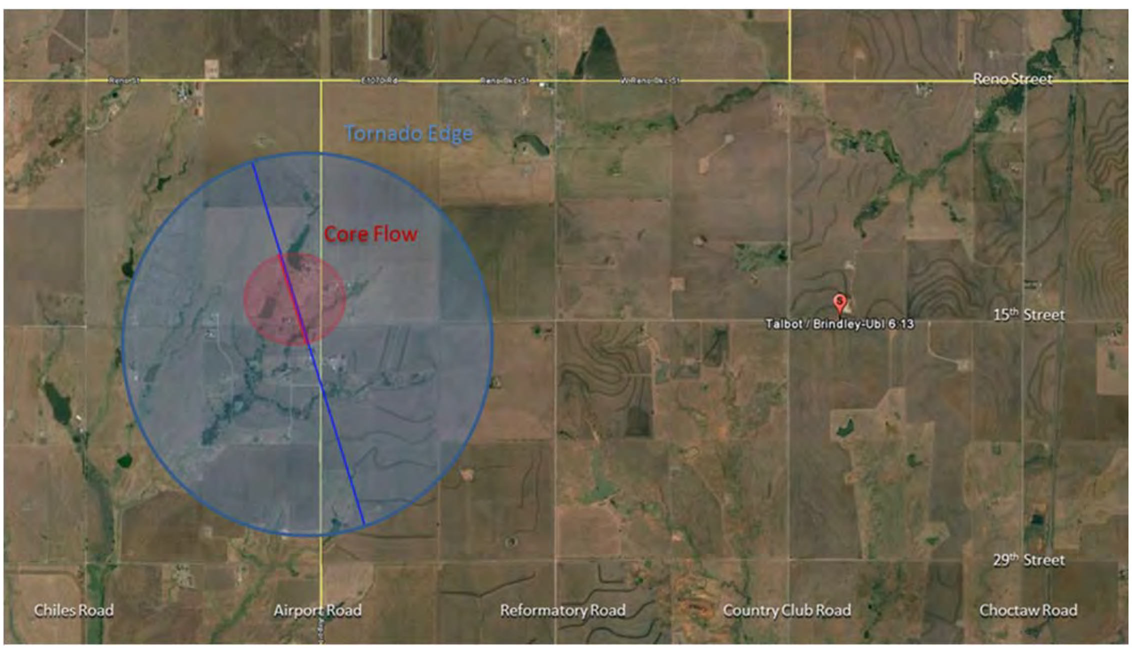

Figure 19: Visible vs. RaxPol-derived El Reno tornado width. *Source: Gabe Garfield*

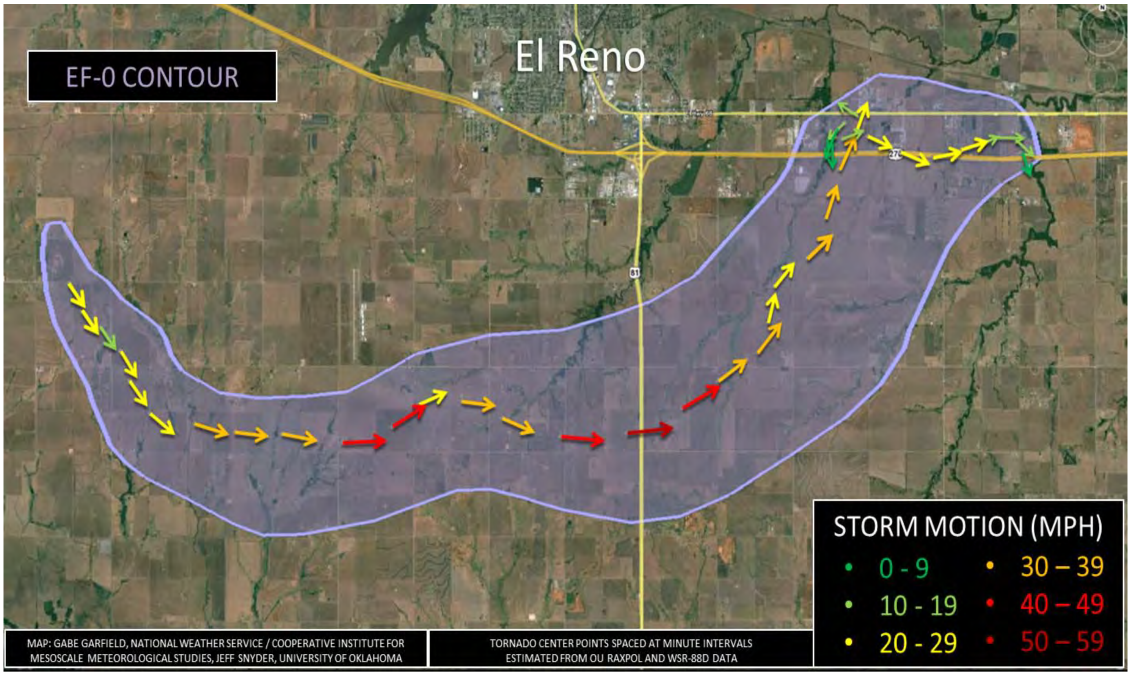

Figure 20: Estimate of the El Reno tornado speed. *Source: Gabe Garfield and Jeff Snyder*

Fact: On May 31, all eight of the direct tornado fatalities occurred in vehicles. Four of those killed were engaged in storm chasing.

Finding 18: Although none of the storm chasers who died were acting as a NWS Skywarn spotter, such storm chasers provide the NWS with storm reports.

Recommendation 18: During the next routine Skywarn training sessions, WCMs should reinforce spotter safety and the rules outlined in NWSI 10-1807, *The Skywarn® Weather Spotter Program.* These safety rules should then be reinforced in all future Skywarn training sessions.

4. Societal Impacts: Facts, Findings, and Recommendations

The social science analysis is organized to provide a 3-part guide to understand responses to NWS activities before, during, and after these tornadoes.

- Part 1: The severe weather emergency planning phase of the event includes all NWS and partner efforts to prepare the public for tornadoes *prior to* each tornado. This phase includes emergency planning and risk communication activities: those messages designed to increase awareness of the timing of weather events, of possible weather types and severity, and of appropriate preparation measures.
- Part 2: Crisis response communication is any messaging activity *during the onset* of the severe weather event, including warnings and directions on what action to take immediately.
- Part 3: Severe weather recovery includes activities *after* the events that help the public respond to the severe weather impacts and to restore capabilities as quickly as possible.

The role of the NWS and its partners is critical. EMs, media representatives such as broadcast meteorologists, hospital administrators, and other public officials all play a vital role. The relationships between the NWS and these partners are also highlighted.

4.1. Emergency Planning: Collaborative Preparedness

Responsibility emerged as a major theme from the social impacts assessment. Specific questions include the following:

- Which elements of the weather enterprise are responsible for ensuring that the advice given to a specific public audience matches earlier preparedness information?
- Should the public expect that the advice they receive during a severe weather event will reflect pre-event preparedness information?
- Will the warnings the public needs to save their lives be presented in a language and format they understand?

Many groups interviewed mentioned several elements of these storms were atypical of past events. In particular, the unusual nature of the storms and circumstances on May 31 led many to react in equally atypical ways.

Most of those interviewed thought the events of May 19 and 20 were more typical of what people have come to expect of the weather and the weather enterprise in Oklahoma. Notifications from the NWS went out days ahead of these events, so EMs and the media felt they had sufficient time to enact their organizational plans. Further, members of the public noted they had heard about severe weather at least 24 hours ahead of time and were more aware of the impending hazardous weather than they had been in the past. When asked about their response to warnings on these 2 days, most people said they had adequate time to take shelter and did so. In fact, because the tornado on May 20 was similar to other events in terms of its early afternoon timing and the nature of the forecast discussions about the heightened potential severity, some people thought they had time to drive out of the path of the storm.

Likewise, EMs said they had sufficient time to enact their organizational plans, including those for several area hospitals. These plans allowed the facilities enough time to shelter not only their own patients and employees but also those members of the public who took shelter there, many with their pets. Even many of those who tragically lost their lives on May 19 and 20 had taken actions corresponding to the plans they had practiced.

Planning for sheltering needs was raised by many of the respondents interviewed. The messaging by the NWS and the broadcast media for the May 19 and May 20 events indicated people should take shelter underground, if possible. Interviews with the public indicated that in the May 20 event some people did evacuate ahead of the storms. The respondents indicated that they know to get into a shelter or away from a storm and that if they cannot shelter, they should drive away. However, they also know they need lead time to take these actions and that they should only drive away from a tornado if they can see where the tornadoes are located. Public respondents indicated that they know not to try to evacuate in the dark.

This response suggests that even during storms as destructive as the May 20 event, local residents enacted their emergency plans and survived above ground in predetermined shelters. Shelters ranged from interior closets and bathrooms to safe rooms. Underground shelters or underground cellars, where available, were also used successfully. People relied on the familiarity of the messages they had heard from forecasters and EMs, as well as the consistency of their own individual and family plans. Confidence in emergency plans is central to preparedness. The respondents are confident because they have frequent reason to practice their severe storms plans. Most of the respondents appear to be prepared for strong tornadoes given the frequency of tornado threats in the area.

On May 31, slow moving storms around rush hour, and the context of recent events, resulted in confusion, frustration, and, sadly, more fatalities. Large numbers of people acted in ways that differed significantly from their typical safety plans due to increased, uncharacteristic fear following the May 20 event. Many people indicated they were actually ashamed of the actions they took, such as evacuating rather than seeking shelter, and said they should have known better. Many respondents, from forecasters to members of the public, talked about how "weird" the day was, and how "strangely" the storms behaved and moved in unexpected directions. The movement of the storms, the geographic location of the storms, and flash flooding seemed to set the stage for an atypical severe weather day.

The public felt the fear induced by the May 20 event led people to take actions on May 31 they would not normally take. During the May 31 event, the NWS, EM, and media gave similar messages about sheltering. There were also messages that people should evacuate if they could not get underground. Respondents noted this message is not new and had been given in the past, especially during times of larger and more destructive tornadoes. Many members of the public, as well as some EMs and other weather-savvy experts, mentioned that, given the fear they felt after the storms on May 19–20, this advice to evacuate overrode their typical emergency plans and advice about sheltering in place. The NWS and its partners cannot assume the public will respond appropriately when two major events occur close together. The fear induced from the first event may cause people to respond in unanticipated ways. The atypical response of many residents evacuating from the tornadoes rather than following shelter plans led to the traffic jams and accidents on May 31.

An example of the phenomena occurred in 2005 in Houston, TX, in anticipation of Hurricane Rita. Hurricane Rita approached the Texas coast a few weeks after Hurricane Katrina devastated Mississippi and Louisiana. When evacuations were suggested for what was being forecast as a potential Category 5 hurricane, Houston area residents fled in panic, something they would not likely have done had they not just witnessed the devastation from Hurricane Katrina.

In addition, the May 31 storms occurred on a Friday around rush hour when many residents were already in vehicles. People followed atypical media advice to immediately drive south as storms were bearing down on Oklahoma City.

Some weather warning professionals heightened public anxiety by telling listeners they would be unable to survive if not underground, but only a few actually included calls to action. When presented with impact-based warnings, it is critical that the NWS provide appropriate calls to action and sheltering advice. People questioned their emergency plans, and searched for advice about what actions to take. Driving south was one of the main pieces of advice offered in the context of this enhanced language. As one tornado survivor said, *"People knew not to get in cars; it should have kicked-in when they touched their door handle: No. Shelter in place. But the fear took over. Especially if you had a weatherman you've trusted all your life tell you to get in your car and drive. So many did."*

Other partners of the weather enterprise urged listeners to stay calm in spite of the potential for tornadoes. For example, emails sent from one EM to hospital leadership asked questions that urged groups to activate their organizational plans while keeping calm and focused:

> *"SCHOOLS AND BUSINESSES, please take a look at your plans this morning! Do you have a way to know that weather is forming and may be a threat? Do you have places identified as to where to seek refuge? All this said, please just be prepared—not scared."*

This approach, combining reminders about the need to stay focused and composed while encouraging people to review the plans that they had already practiced, led to decisions that saved lives.

It seems the weather-warning official's tone and approach to notify people about severe weather can shape whether the public follows their own emergency plans or abandons them in the face of contrary advice. When a complicated situation occurs, such as the May 31 tornadoes and flash flooding, people experience a nuanced layering of reactions and emotions. What is rational in the moment is not as simple as hearing a warning and taking shelter. This is how expert communities have defined rationality during a tornado warning. In research by Silva, Jenkins-Smith, Ripberger, Herron, Carlson, and James (unpublished because it is in preparation) over 3,000 respondents in the most tornado-prone regions of the country, including Oklahoma, were asked directly about driving away from a tornado. For "moderate" through "severe" tornado warnings, only 7 percent of respondents said they would "drive away"; however, when the warning level rises to "devastating" or "incredible," the percentages increased to 14.5 percent

and 18.3 percent, respectively. These preliminary findings suggest that very high-severity storms may cause a significant change in public response. These findings should be considered in the context of the complex matrix that constitutes a warning paradigm. It should be noted that neither wording nor warnings *alone* result in individuals' decisions to take protective actions, but rather warnings coupled with other salient variables, particularly that of experience, propel people into action. As reported in the NWS Central Region Service Assessment for the Joplin, Missouri, tornado of May 22, 2011 (released in July 2011), which can be found at: http://www.nws.noaa.gov/os/assessments/pdfs/Joplin_tornado.pdf
"Previous experiences with tornadoes were shown to have an influence in the way residents perceived their risk and responded to the warnings."

The weather enterprise should collaborate more closely on their risk communication planning for severe weather. They should coordinate these plans with the public to ensure a clear and consistent action plan that will most effectively save lives. After the May tornadoes, to assist in this effort, the Oklahoma Governor's office held a meeting with the chief meteorologists from the Oklahoma City and Tulsa TV stations, and NWS personnel. The meeting was led by the Oklahoma Department of Emergency Management to develop better messaging and response in complex situations, such as the May 31 event. This meeting was an example of the Integrated Warning Team (IWT) approach to problem solving. IWT meetings have been supported across many WFO areas of responsibility and have generally strengthened relationships among members.

Fact: Many people from all levels of the weather enterprise and several different stakeholders cited the unusual nature of the storms on May 31 as one reason for following advice to drive south during an active severe weather event.

Finding 19: The weather enterprise did not present a uniform message concerning safety and shelter actions, nor was the flash flooding threat uniformly broadcast.

Recommendation 19: The NWS should develop common hazardous weather resources, tips, and advice, such as a website, to facilitate IWTs year-round. WFOs should alternately host and participate in these IWT workshops with their local weather enterprise partners, including health and aging services, local indigenous populations, military installations, and other previously overlooked partners.

Best Practice: Emergency managers cited as important to their preparation for severe weather those messages from administrators that encouraged them to remain calm and enact their emergency plans. These reminders helped them focus on tasks they had practiced before the event and allowed them to stay composed and effective during the event itself.

4.2. Emergency Planning: Cultural Issues in Oklahoma

Nearly everyone interviewed mentioned the competitive nature of weather media coverage in Oklahoma, which many people described as "hyped" or "overblown." Still, many members of the public described their news sources as "trusted," noting forecaster accuracy and the ability to "get it right." Similarly, many broadcast professionals noted the unusually weather-savvy nature of the public in their awareness of and planning for severe weather. For example, when surveyed, it was common to find the public understood specific tornado terminology, such as supercells, noted the EF-Scale ratings of historical tornadoes, and referred to sheltering best practices, such as “shelter in place” and “interior most rooms.” As one local media professional noted, *“This is such a weather town. We don’t ‘dumb down’ our weather talk. We’re free to discuss weather terms like supercells, the different models, and whether or not they’re in agreement. There’s a lot of pressure to get it right.”*

On the other hand, the frequency of tornado events in Oklahoma can lead people to take some warnings for granted. One tornado survivor said: *“You’re weather aware but become numb to weather, accustomed to it. Not a good thing. You don’t have that sense of urgency. We certainly didn’t have it on May 20.”*

It would seem the nature of weather awareness itself is different for populations across the country and the same population after recent severe weather. One tornado can prime people’s emotional responses and fears for the next event, as the May 20 event did for the May 31 storms. This awareness is flexible and context-dependent, sometimes even seeming to disappear in a jolting event like the May 20 tornado. People may need to use the emergency plans they have put in place and, hopefully, practiced enough times that it becomes routine. This ability to call upon near-intuitive levels of preparedness, however, only works if it is consistent with the advice and information coming from expert sources. This near-intuitive type of preparedness was illustrated in the 9-11 terrorist attacks in 2001 at the offices of Morgan Stanley. For many years, employees had been trained regularly on how to evacuate from the offices if a disaster should occur. On 9-11, the employees of Morgan Stanley did not panic as they enacted their evacuation plan, which saved most of the company’s personnel when the building collapsed. Knowing the plan means having the confidence to take action and eliminating confusion about what you should do.

Discussions with members of the public revealed how they planned and prepared with the assistance of the NWS, broadcast meteorologists, and EMs. One way of thinking about how a community can prepare for an event is to consider how a community plans and practices for specific disasters at different societal levels, from individuals and families, to cities and towns. If families have a plan of action in place, for example, and this plan is reinforced by various sources all conveying the same advice, then the likelihood that people will take actions that match their plans increases. On a broader level, EMs developing consistent plans and advice increases the success of community plans. This also means people at all levels come to expect and rely on predictable advice and responses from each other and from expert sources. When families and communities expect severe weather to play out in typical ways and receive advice to repeat previous safety messages, they will likely execute their emergency plans in predictable ways, such as taking shelter, seeking additional information, and evacuating their homes when necessary.

One key aspect of preparing for severe weather, then, is building relationships between different expert sectors and public groups. The NWS has done an exceptional job of coordinating with EMs in Oklahoma, and, in recent years, that close coordination has expanded to include other partners in the health care, school administrator, military, higher education, and public safety communities. All of these groups received email updates and were well represented in the severe weather briefings provided by WFO Norman leading up to all the tornado events.

EMs and emergency personnel indicated they had received the NWS briefings either directly or indirectly from WFO Norman, as well as information through NWSChat in the days leading up to the May 19 event. They expected this information and perceived it had been timely and accurate. The public in the region are well-educated about the threats of severe weather, especially tornadoes, and generally, know where to take shelter. During EF4 and EF5 strength tornadoes, however, the public appeared to question the efficacy of their safe plans for tornadoes.

NWS needs to partner with the rest of the weather enterprise to increase educational efforts directed toward specific protective actions for future events. The NWS and its partners need to determine what the suggested protective actions should be for EF4 and EF5 tornado events. This consensus then needs to be provided to the public through continuous education outreach activities by the NWS, broadcast media, EMs, and other emergency planners.

Finding 20: State, county, and city EMs received emails announcing special NWS severe weather briefings directly from WFO Norman. This coordination with key partners is critical to the success of the integrated warning system.

Recommendation 20: The NWS should strongly encourage its core partners (i.e., members of the EM community; Federal, state, and local governments; and members of the media) to become more involved in IWTs to better enable them to serve the public.

Finding 21: The NWS educational outreach activities concerning sheltering in place have not fully reached the public in regard to safety plans for tornadoes.

Recommendation 21: The IWTs should develop educational outreach activities about protective actions in complex events such as sheltering in place during violent tornadoes and multiple hazards, including flash flooding.

4.3. Risk Communication: Sheltering and Pets

Populations differ in their response to risk communication, including how people decide to take shelter from severe weather. EMs interviewed acknowledged the lack of public shelters and the complicated nature of opening buildings to the public. Some EMs cited the fear that people would leave their homes close to a tornadic event and get caught in their cars, which is much more dangerous than sheltering in most homes. Other EMs were concerned about their ability to shelter large numbers of residents in communities lacking private safe rooms and underground shelters. Members of the public mentioned the most common places for shelters included an interior bathroom or closet, a basement, or a friend's basement, and a community shelter or neighbor's shelter. Less commonly mentioned were public buildings such as churches, schools, and government offices.

Complicating the issue of sheltering is the increasing desire for families to shelter with their pets. Pets created a significant planning problem for the public and institutions in responding to calls for action. These events included numerous stories of people showing up at hospitals, office buildings, schools, and even their place of employment with their pets, demonstrating the importance of considering pets in shelter plans and weather warnings. As many EMs noted, they will not turn people needing shelter away, so accommodating pets creates a hazard for places such as hospitals, both for patients and staff, as well as for the people who have come there to shelter.

As studies conducted on hurricane evacuations have noted, people are much more likely to take life-saving actions if they know about and are directed to options that allow them to assure their pets will be safe. Although the timeframe for offering sheltering options for pets is significantly shortened for tornadoes, partners should explore options for people who take pets with them to public buildings. This planning should be done ahead of the crisis and with sufficient notice for the public to be aware of alternatives and options. A crisis is not the time to communicate new advice and information, but rather to implement plans already in place.

Fact: Numerous people interviewed, both EMs and members of the public, indicated an increase in the number of people taking shelter with their pets.

Fact: Public buildings, such as hospitals, were overwhelmed by the number of people taking shelter with their pets.

Most public places will not turn people away just because they have pets. This can create complicated and potentially dangerous situations when animals are not restrained or are confined with people in medically sterile facilities, such as hospitals.

Finding 22: Hospitals have found themselves overwhelmed with people seeking shelter, including people with pets. Hospitals have attempted to initiate risk communication to help people understand that they need to control pets when they seek shelter. This risk communication does not appear to have been effective because people continue to bring pets and not control them. During the May 31 event, even more people than usual sought shelter in the hospitals so contiguous events may lead to more of a problem than usual.

Recommendation 22: The NWS should work with EMs and the broadcast media to include pet preparations and shelter alternatives in their risk communication.

4.4. Risk Communication: Sirens

Several EMs and members of the public mentioned sirens as a main alerting system for severe weather. EMs in the WFO Norman area have agreed to test sirens on Saturdays at noon. Some public groups have been informed that a siren sound means, "seek further information." The EM for Moore said a siren also means, "take shelter." Thus, the interpretation of the siren means different things to EMs, different public groups, or even people across different jurisdictions. This finding is consistent across several NWS service assessment reports (i.e., Historic Derecho, 2012; Joplin, 2011; Historic Tornadoes, 2011; Super Tuesday, 2008; and

Mother's Day, 2008). Research about sirens is mixed. Some experts suggest sirens should not be used since they cause confusion if they are not heard during an event or if they are heard but are not followed up with a standardized means of communicating, "all's clear." Other experts suggest that sirens are one of many important ways people receive weather warnings, especially when they are outdoors and away from traditional delivery methods, such as television or NOAA Weather Radio All Hazards. The latter fact was substantiated by conversations with residents who mentioned hearing the sirens on both May 20 and May 31 and stated it was one of the warnings that convinced them to take shelter.

Fact: WFO Norman has engaged major central Oklahoma cities for the past several years on siren policies.

Finding 23: Local siren policies differ. Members of different public groups interpret sirens differently. Some people respond by seeking more information while others assume a threat is immediate and take shelter. There seems to be no standard policy to help people understand an "all's clear" after a siren warning. WFO Norman has provided advice to major central Oklahoma cities for the past several years on siren policies.

Recommendation 23: Consistent with other assessments, this team supports recommendation Number 4 in the Central Region Service Assessment, *Joplin, Missouri Tornado – May 22, 2011*, only in that the NWS should provide advice to local EMs to develop or update siren policies and procedures. "*The NWS should collaborate with partners throughout the weather enterprise to provide a better coordinated weather message. Guidance should be developed to assist partners in the development of local warning system and siren strategies that work in conjunction with NWS warnings rather than independent of them.*"

4.5. Crisis Communication: Non-English Speaking Public

Oklahoma City has a large Hispanic and Latino population, many of whom do not speak English. Hispanics are one of the fastest growing populations in the United States. According to the U.S. Census Bureau, 12 percent of people in the United States speak Spanish at home. This group is a significant demographic. Among those killed during the May 31 tornado and ensuing flooding was a Guatemalan family whose primary language was Spanish. In interviews with EMs and broadcast meteorologists, they acknowledged that there are insufficient forecast and warning resources for those who do not speak English.

Only a few radio and television stations broadcast in Spanish, and, of those that do, few if any employ meteorologists. Most of these stations rely on NWS information. For example, WFO Norman's staff noted they often are interviewed by Telemundo, a Spanish network, and that the media company will come to the WFO to ask for on-air explanations of forecasts. While there is a relationship between the NWS and Spanish language media outlets, it needs to be strengthened. It is a one-way communication flow to the Spanish media that then translates for its clientele. Additionally, the Spanish media market is small in the Oklahoma City area. Depending on media outlets to translate and transmit vital message does not take into account problems these stations may face during the event. In this case, one Spanish media source had to take shelter and go off the air.

In many locations, local NWS warning products are only available in English, including NOAA Weather Radio All Hazards, the most fundamental mechanism for getting weather warnings. Broadcast meteorologists and EMs acknowledge the gap. No one group is responsible for translating forecasts for members of any non-English speaking group; instead, each group mentioned others as responsible for translating warnings.

With easy access to online translation tools it would seem a simple issue to translate English words into Spanish; however, cultural differences in interpreting words can cause problems. For example, Telemundo noted that the phrase "tornado emergency" does not mean anything different than "tornado warning" in Spanish-speaking communities and so meaningful distinctions between an average tornado and a catastrophic one are lost. Thus, crisis communication for non-English speakers relies on Spanish-speaking sources such as Telemundo.

Hospital administrators affected by the May tornadoes noted a marked increase in the number of Spanish-speaking individuals taking shelter at their facilities during severe weather. Administrators noted entire families sought shelter and that one person generally translated for the group. A hypothesis for the number of non-English speaking people in these spaces is that hospitals, like churches, are synonymous with safety, refuge, and accessibility.

The NWS should enhance partnerships with non-English speaking partners such as Spanish media outlets, churches, and civic organizations to integrate them into the weather enterprise and to develop solutions for reaching their non-English speaking clientele. IWTs could be the foundation for including these partners in the planning process.

After the severe weather events in Oklahoma, Telemundo mentioned how well FEMA and other government agencies were received by the Spanish-speaking population because those agencies had Spanish-speaking representatives able to explain the help they were providing. Telemundo said a Spanish-speaking representative is much more effective than using an interpreter, because the Spanish-speaking population can relate better to someone speaking their language directly rather than through a translator.

Fact: Hospitals have seen an increase in the number of Spanish-speaking families who do not speak English taking shelter in their facilities during severe weather.

Fact: There are only a few sources of Spanish-language forecasts and warnings. This is a reason why people who speak primarily Spanish were negatively affected during the May tornadoes. This gap is true for speakers of many other languages, such as Vietnamese, of which there is also a significant population in Oklahoma.

The May 2013 Oklahoma Tornadoes and Flash Flooding Service Assessment Team reaffirms Finding and Recommendation 71 of the *Hurricane Irene, August 21–30, 2011* service assessment for the NWS to develop a comprehensive program to address the informational needs of the growing Spanish language community during high-impact events. *"This program should include a cadre of mobile, decision support meteorologists/hydrologists who are not only Spanish speakers, but are trained to deal with local and national media and local decision makers. This* *trained group should be available for deployment in decision support roles as needed, providing interviews and translation for social media sites such as Facebook.*"

A few NWS offices, such as WFO Brownsville, have already successfully included images and other non-verbal forms of communication to their warnings and related products. Details on Brownsville program are available online at the following URL: http://www.publicaffairs.noaa.gov/releases2006/mar06/noaa06-r213.html.

Finding 24: The NWS cannot consistently provide specialized language services for all non-English speaking entities. Images and other non-verbal forms of communication should be added to the products and information exchange.

Recommendation 24a: The NWS, working with the entire weather enterprise, should initiate risk communication for non-English speakers and other underrepresented groups. This should include the incorporation of images and other non-verbal forms of communication to NWS warning products and information exchange. Outreach to organizations that work with these populations can help design risk communication strategies to meet the needs of these populations.

Recommendation 24b: The NWS should establish a procedure for local non-English speaking decision support services before, during, and after severe weather events.

4.6. Crisis Communication: Social Media

Social media has become increasingly important in the warning process. Social media serves as an important and reliable communication medium during active weather events, especially when other traditional media forms, such as television, fail because of power outages. WFOs should have plans that determine who will monitor, push, and pull information to different partners and public groups.

Many forecasters, EMs, and media personnel acknowledged the importance of social media to their jobs, especially for collecting storm reports and photographs of damage. Most admitted, however, that social media communications is largely one-way and they do not have time or resources to build a two-way rapport. Further, during severe weather events, EMs and the media noted they have insufficient staff to manage communications and so only minimally use Facebook or Twitter. One EM, for example, said she was so swamped by the May 31 tornadoes she decided not to push any social media information. She cited a Red Cross survey suggesting it can take up to an hour to respond to social media requests during an emergency, and so rather than have to abandon people in the middle of an event, she opted not to engage. She pointed out, *"You can't just auto-tweet or leave social media and then come back to it during an event. You need consistent monitoring so you don't miss a request or a need."* Thus, social media was underused as a communication tool.

Of those that did use social media, best practices included the use of common and familiar hashtags on Twitter, which stay uniform across weather events (e.g., #okwx) and those that are developed for specific events by public groups and professionals alike. Further, some EMs noted that social media pushed both good information and misinformation. The misinformation sometimes originated from other sources, such as television, and then was redistributed over social media. Misinformation about recovery efforts tended to originate *within* social media.

WFO Norman performed exceptionally during the crisis communication stage. The office reached multiple partners with outlooks and provided significant lead-time for preparation activities. The public indicated it was well-warned for all events, with the exception of the flash flooding on May 31. WFO Norman also has an aggressive social media policy, pushing out warnings and forecasts and sharing damage information. The office was able to push out a remarkable number of warnings and details about impacts, as well as respond to the different requests and issues raised by constituents. WFO Norman built a relationship with social media users before the event by soliciting information and answering concerns and offering useful information. This strategy is key to success with this communication platform. Social media is a two-way relationship, one built over time and by listening as much as advising.

Most of the residents surveyed said they use social media applications on their cell phones to get warning and forecast information. Many of these applications were specific to local news stations.

Finding 25: NWS partners indicated there was limited time and a lack of personnel to engage in two-way, social media communication. They monitored the communication from the public, looking for message distortion, but they did not return communications because they felt they could not do so consistently given the gravity of the events and a lack of social media experts on staff. During these events, WFO Norman dedicated staff members to providing social media updates.

Recommendation 25a: All NWS offices should designate a function to build relationships on social media prior to severe weather and send out relevant, real-time information on multiple social media platforms during severe weather.

Recommendation 25b: For those offices without a social media-savvy presence, NWS should invest in training that highlights best practices.

4.7. Recovery

Survey participants stated that WFO Norman was extremely effective communicating via social media on recovery issues and helping people understand weather conditions and recovery activities as the recovery was initiated on May 19–20, and in the period between the May 20 and May 31 events.

Finding 26: Given that the May 31 event was atypical, the recovery period after the May 20 event could have been used by all members of the weather enterprise to help prepare the population for the next significant storm. As the May 31 event unfolded, social media could have been used to help prepare for abnormal responses to the atypical event. This event occurred in the late afternoon and early evening and the storm was moving in a manner that was not typical for storms in this location. It was producing a significant amount of rain and moving very slowly. WFO Norman highlighted this information before and during the events, but a more consistent message would have been presented if all in the weather enterprise had followed suit.

Recommendation 26: The NWS, along with its weather enterprise partners, should reinforce common safety messages to the public during initial recovery after each event to highlight what worked well and what did not in the event.

Appendix A: Acronyms

AGL	Above ground level
AWIPS	Advanced Weather Interactive Processing System
AWIPS II	AWIPS's next-generation software
CAM	Convective Allowing Models
EAP	Employee Assistance Program
DAT	Damage Assessment Toolkit
EM	Emergency Manager or Management
EF	Enhanced Fujita (Scale)
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
GFS	Global Forecast System
GIS	Geographic Information System
IBW	Impact Based Warnings
ICP	Incident Command Post
ITO	Information Technology Officer
IWT	Integrated Warning Team
HRRR	High Resolution Rapid Refresh model
MIC	Meteorologist in Charge
MPD	Mesoscale Precipitation Discussion
MPH	miles per hour
NAM	North American Mesoscale Model
NWSOC	National Weather Service Operations Center
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Lab
NWS	National Weather Service
NWSI	NWS Instruction
NWSH	National Weather Service Headquarters
OCWWS	Office of Climate, Water, and Weather Services
OUN	WFO Norman, OK
PAO	NOAA Public Affairs Officer
QRT	Quick Response Team
RaxPol	Rapid-Scanning X-band Polarimetric Doppler
RESAP	Rapid Evaluation of Service Activities and Performance
ROC	Regional Operations Center
SBN	Satellite Broadcast Network
SPC	Storm Prediction Center
SR ROC	Southern Region Regional Operations Center
WDTB	Warning Decision Training Branch
WCM	Warning Coordination Meteorologist
WFO	Weather Forecast Office
WPC	Weather Prediction Center
WSR-88D	Weather Surveillance Radar, 1988 Doppler

Appendix B: Findings, Recommendations, & Best Practices

Definitions

Best Practice – An activity or procedure that has produced outstanding results during a particular situation that could be used to improve effectiveness and/or efficiency throughout the organization in similar situations.

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

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

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

Findings and Recommendations

Finding 1: The HRRR model and other CAM availability in AWIPS is limited and competes for bandwidth with larger-scale model data. WFOs operate on high spatial and temporal resolutions when providing decision support services.

Recommendation 1: WFOs need the capability to ingest preferred high-resolution model data during critical times.

Finding 2: NWS GIS products allowed many NWS partners (e.g., FEMA) to respond faster to demands for rapid information and decision support services. Currently, only WFOs using AWIPS II and a locally-developed application can create GIS products for possible tornado tracks while the tornado event is ongoing. Once NWS deploys AWIPS II to all its offices, GIS products should be provided consistently.

Recommendation 2: WFOs should be provided with the capability and procedures to create GIS products for possible tornado tracks in near real-time.

Finding 3: NWS partners want GIS tornado track information and other pertinent data. Currently, not all NWS offices are equipped to provide this information.

Recommendation 3: All NWS offices should use the Damage Assessment Toolkit (DAT) to provide damage survey information to partners in a consistent GIS-accessible format.

Finding 4: Not all offices have enough easily portable devices with geolocation to enable the direct entry of data taken in the field during the storm survey into the DAT. Consequently, some NWS personnel are choosing to install the DAT app on their personal mobile devices to facilitate the use of the DAT.

Recommendation 4: NWS should supply all WFOs with appropriate hardware, including computer tablets, with the Global Positioning System or other geolocation services, to facilitate the collection of survey information using the DAT software.

Finding 5: The NWS warned the public about the flash flooding threat, but much of the public did not get that warning. WFO Norman used social media and other dissemination methods before and during the flash flooding in the morning and afternoon of May 31.

Recommendation 5: The NWS needs to develop warning protocol when there are multiple severe weather elements in the warning so that each element of the warning is weighted based on its urgency and severity. This protocol should include wording on how the public should prepare and respond to multiple, simultaneous dangers such as tornadoes and flooding.

Finding 6: Interviews with the public indicated the broadcast media focused on the tornadoes and not the flooding during the May 31 event.

Recommendation 6: The NWS needs to provide specific educational material to the broadcast media partners on how to manage warning dissemination for multiple severe weather hazards.

Finding 7: Social media is not currently an integral part of NWS service backup operations.

Recommendation 7: The NWS should make social media an integral part of service backup operations.

Finding 8: Even though NWS has long-standing policy emphasizing EAP use at impacted offices, some NWS staff members, including management, are currently ill-equipped to both understand and deal with emotional issues resulting from high-impact events.

Recommendation 8: NWS management should receive regular refreshers on the importance of offering EAP support after major events.

Finding 9: The local availability of wind damage/tornado experts to help assess multiple tornadoes, and confirm damage greater than EF3, was extremely beneficial to WFO Norman, the SR ROC, and NWSH. These wind damage/tornado experts volunteered to perform the role of a QRT without incurring any expenses to the NWS.

Recommendation 9: The NWS should continue to preserve and support the QRT concept by (1) ensuring funds are made available for future QRTs, and (2) updating NWSI 10-1604 *Post-Storm Data Acquisition* to include more specific and standardized procedures for forming (including required training) and activating a QRT.

Finding 10: NWSI 10-1604, *Post-Storm Data Acquisition, NWSI 10-1605, Storm Data Preparation*, and the training NWS staff receives to rate tornadoes does not specifically address using data other than observed damage indicators.

Recommendation 10: NWSI 10-1604, *Post-Storm Data Acquisition*, should be updated to allow for additional information based on high-confidence remotely sensed data, when available. This additional rating, for example a "Doppler On Wheels sampled winds 250 mph at 300 feet agl," should be included as a searchable feature in the NWS's Storm Data database.

Finding 11: At least six other tornadoes from previous events across several WFOs were assigned a higher EF-Scale rating than the damage indicators suggested after NWS was able to evaluate mobile radar data.

Recommendation 11: All historical storms with an EF-Scale rating augmented by high-confidence remotely sensed data should be reassessed, and if appropriate, updated with this additional information once the NWS publishes the updated NWSI 10-1604, *Post-Storm Data Acquisition.*

Finding 12: NWS Storm Data does not accurately reflect actual tornado tracks. Tornadoes are entered with a start and stop latitude/longitude, but NWS Storm Data does not preserve the actual path. WFOs are required to use the DAT website to report tornado tracks.

Recommendation 12: The official NWS StormDat Program should include a GIS-based tornado track that utilizes the DAT or GIS map track information to depict where the tornado occurred.

Finding 13: The lack of NOAA/NWS-logoed apparel reduced staff effectiveness while obtaining information from the public.

Recommendation 13: NWS should provide appropriately logoed apparel to employees in the field after an event, including employees providing onsite decision support services and conducting damage surveys.

Finding 14: The need to include helmets as a safety device during severe weather is still being researched. Early results from the University of Alabama Injury Control Research Center indicate helmets could help save lives and reduce head injuries.

Recommendation 14: The NWS should closely monitor research on helmets as safety devices during severe weather. If these recommendations are adopted as valid, the NWS should develop safety recommendations to include helmets with routine and emergency communications about tornado safety.

Finding 15: During the May 19, 20, and 31 tornado events, WFO Norman received a high demand for media requests. WFO Norman coordinated with the PAO, SPC, and the SR ROC to prioritize media inquiries, sending international requests to SR ROC and national media requests to SPC.

Recommendation 15: NWS should develop national, regional, and local plans on how to prioritize media inquiries and identify internal local and regional resources to meet press demands during significant severe weather events. The ROCs could be used to help standardize these plans.

Finding 16: Before, during, and after the tornado events, WFO Norman, SPC, and the NOAA PAO developed and distributed talking points that were widely used. These talking points were a valuable tool.

Recommendation 16: NWS ROCs, in consultation with the NOAA PAO, should develop regional and local procedures for the development of talking points during significant weather events to help ensure a consistent media message and distribute to ROCs, NWSOC, and the NWS Communications Office.

Finding 17: Media interest and interview requests are frequent after significant events, and NWS employees need to be able to interact confidently with the media.

Recommendation 17: NWS should develop and make media training mandatory for those NWS employees who speak with the media to help ensure a consistent media message across the NWS.

Finding 18: Although none of the storm chasers who died were acting as a NWS Skywarn spotter, such storm chasers provide the NWS with storm reports.

Recommendation 18: During the next routine Skywarn training sessions, WCMs should reinforce spotter safety and the rules outlined in NWSI 10-1807, *The Skywarn® Weather Spotter Program.* These safety rules should then be reinforced in all future Skywarn training sessions.

Finding 19: The weather enterprise did not present a uniform message concerning safety and shelter actions, nor was the flash flooding threat uniformly broadcast.

Recommendation 19: The NWS should develop common hazardous weather resources, tips, and advice, such as a website, to facilitate IWTs year-round. WFOs should alternately host and participate in these IWT workshops with their local weather enterprise partners, including health and aging services, local indigenous populations, military installations, and other previously overlooked partners.

Finding 20: State, county, and city EMs received emails announcing special NWS severe weather briefings directly from WFO Norman. This coordination with key partners is critical to the success of the integrated warning system.

Recommendation 20: The NWS should strongly encourage its core partners (i.e., members of the EM community; Federal, state, and local governments; and members of the media) to become more involved in IWTs to better enable them to serve the public.

Finding 21: The NWS educational outreach activities concerning sheltering in place have not fully reached the public in regard to safety plans for tornadoes.

Recommendation 21: The IWTs should develop educational outreach activities about protective actions in complex events such as sheltering in place during violent tornadoes and multiple hazards, including flash flooding.

Finding 22: Hospitals have found themselves overwhelmed with people seeking shelter, including people with pets. Hospitals have attempted to initiate risk communication to help people understand that they need to control pets when they seek shelter. This risk communication does not appear to have been effective because people continue to bring pets and not control them. During the May 31 event, even more people than usual sought shelter in the hospitals so contiguous events may lead to more of a problem than usual.

Recommendation 22: The NWS should work with EMs and the broadcast media to include pet preparations and shelter alternatives in their risk communication.

Finding 23: Local siren policies differ. Members of different public groups interpret sirens differently. Some people respond by seeking more information while others assume a threat is immediate and take shelter. There seems to be no standard policy to help people understand an "all's clear" after a siren warning. WFO Norman has provided advice to major central Oklahoma cities for the past several years on siren policies.

Recommendation 23: Consistent with other assessments, this team supports recommendation Number 4 in the Central Region Service Assessment, *Joplin, Missouri Tornado – May 22, 2011*, only in that the NWS should provide advice to local EMs to develop or update siren policies and procedures. *"The NWS should collaborate with partners throughout the weather enterprise to provide a better coordinated weather message. Guidance should be developed to assist partners in the development of local warning system and siren strategies that work in conjunction with NWS warnings rather than independent of them."*

Finding 24: The NWS cannot consistently provide specialized language services for all non-English speaking entities. Images and other non-verbal forms of communication should be added to the products and information exchange.

Recommendation 24a: The NWS, working with the entire weather enterprise, should initiate risk communication for non-English speakers and other underrepresented groups. This should include the incorporation of images and other non-verbal forms of communication to NWS warning products and information exchange. Outreach to organizations that work with these populations can help design risk communication strategies to meet the needs of these populations.

Recommendation 24b: The NWS should establish a procedure for local non-English speaking decision support services before, during, and after severe weather events.

Finding 25: NWS partners indicated there was limited time and a lack of personnel to engage in two-way, social media communication. They monitored the communication from the public, looking for message distortion, but they did not return communications because they felt they could not do so consistently given the gravity of the events and a lack of social media experts on staff. During these events, WFO Norman dedicated staff members to providing social media updates.

Recommendation 25a: All NWS offices should designate a function to build relationships on social media prior to severe weather and send out relevant, real-time information on multiple social media platforms during severe weather.

Recommendation 25b: For those offices without a social media-savvy presence, NWS should invest in training that highlights best practices.

Finding 26: Given that the May 31 event was atypical, the recovery period after the May 20 event could have been used by all members of the weather enterprise to help prepare the population for the next significant storm. As the May 31 event unfolded, social media could have been used to help prepare for abnormal responses to the atypical event. This event occurred in the late afternoon and early evening and the storm was moving in a manner that was not typical for storms in this location. It was producing a significant amount of rain and moving very slowly. WFO Norman highlighted this information before and during the events, but a more consistent message would have been presented if all in the weather enterprise had followed suit.

Recommendation 26: The NWS, along with its weather enterprise partners, should reinforce common safety messages to the public during initial recovery after each event to highlight what worked well and what did not in the event.

Best Practices

Best Practice: WFO Norman promptly provided EMs GIS information showing likely damage areas while tornadoes were still in progress.

Best Practice: WFO Norman offers weekly calls to its core partners, which leads to greater understanding and awareness of severe weather days.

Best Practice: WFO Norman dedicated staff resources to collect and provide social media content. On an event-by-event basis, the office team edits the content of the social media posts to increase effectiveness. For example, WFO Norman did not provide the hourly, short-term text weather discussion in order to provide more emphasis in social media.

Best Practice: WFO Norman includes time stamps in Twitter entries to reduce confusion when information is retweeted.

Best Practice: SR successfully employed a Rapid Evaluation of Service Activities and Performance team to review event services within the region.

Best Practice: The SPC and SR ROC, in coordination with the PAO and WFO Norman, responded to most of the national and international media requests, allowing WFO Norman to focus on select national and all local media requests and decision support services.

Best Practice: Emergency managers cited as important to their preparation for severe weather those messages from administrators that encouraged them to remain calm and enact their emergency plans. These reminders helped them focus on tasks they had practiced before the event and allowed them to stay composed and effective during the event itself.

Appendix C: Direct Tornado and Flash Flood Fatalities

DATE	SEX	AGE	LOCATION/CIRCUMSTANCES
May 19	M	79	Mobile home
May 19	M	76	Vehicle
May 20	F	29	Sheltering at convenience store
May 20	M	4 months	Sheltering at convenience store
May 20	F	49	Sheltering at convenience store
May 20	F	38	Sheltering in home, closet
May 20	F	45	Sheltering in home, closet
May 20	M	46	Sheltering in home, closet
May 20	F	40	Sheltering in home, closet
May 20	F	70	Sheltering in home, closet
May 20	M	54	Home
May 20	F	7	Sheltering in home, bathtub
May 20	F	4	Sheltering in home, bathtub
May 20	M	65	Sheltering in home, bathtub
May 20	F	49	Sheltering in home, closet
May 20	M	39	Sheltering in home
May 20	M	63	Sheltering in business
May 20	F	90	Sheltering in home
May 20	F	51	Sheltering in home
May 20	M	8	Plaza Towers Elementary School
May 20	F	9	Plaza Towers Elementary School
May 20	M	9	Plaza Towers Elementary School
May 20	F	9	Plaza Towers Elementary School
May 20	F	9	Plaza Towers Elementary School
May 20	F	9	Plaza Towers Elementary School
May 20	M	9	Plaza Towers Elementary School
May 31	M	67	Vehicle, driving from El Reno to Chickasha
May 31	M	35	Vehicle, storm chasing
May 31	F	26	Vehicle, parked along I-40
May 31	M	17 days	Vehicle, parked along I-40
May 31	M	32	Vehicle
May 31	M	55	Vehicle, storm chasing
May 31	M	24	Vehicle, storm chasing
May 31	M	45	Vehicle, storm chasing

May 31	M	65	Vehicle, flash flood
May 31	M	8	sheltering in drainage ditch - flash flood
May 31	M	4	Sheltering in drainage ditch, flash flood
May 31	M	33	Sheltering in drainage ditch, flash flood
May 31	F	34	Sheltering in drainage ditch, flash flood
May 31	M	4	Sheltering in drainage ditch, flash flood
May 31	F	7	Sheltering in drainage ditch, flash flood
May 31	F	34	Sheltering in drainage ditch, flash flood
May 31	M	21	Sheltering in drainage ditch, flash flood
May 31	F	3	Sheltering in drainage ditch, flash flood
May 31	F	4	Sheltering in drainage ditch, flash flood
May 31	M	3	Sheltering in drainage ditch, flash flood
May 31	F	5 months	Sheltering in drainage ditch, flash flood

Appendix D: List of Interviewed Subjects for Public Response Research

- Shane Cohea, Manager of Safety Services and Emergency Preparedness, Norman Regional Health Care System
- Don Lynch, Emergency Manager, Shawnee, Oklahoma
- Gayland Kitch, Director of Emergency Management, City of Moore, Oklahoma
- Putnam Reiter, EOC Manager, Oklahoma Department of Emergency Management
- Keli Cain, Public Information Officer, Oklahoma Department of Emergency Management
- Kurt Gwartney, National Public Radio, KGOU, Norman, Oklahoma
- Frank Barnes, Emergency Manager, Oklahoma City Emergency Management
- Julie Robberson, Executive Secretary, Norman Regional Health Care System

Qualitative Public Interviews

Interviewed 30+ people from counties impacted by all three tornado events

- Tuesday, July 23, 2013, interviews with concert attendees and concert venue personnel, Rock for Oklahoma Tornado Benefit Concert, Chesapeake Arena, Oklahoma City, OK
- July 21-25, 2013, random interviews with members of the public

Appendix E: References

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