Service Assessment

Record Tornado Outbreaks of May 4-10, 2003

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

Cover Photographs:

Left: F4 tornado near Girard, Kansas, May 4, 2003. (Chuck Robertson)

Right: The tornado that moved through Girard later destroyed this home in Liberal, Missouri. The gun safe in the center of the basement was used as shelter by the residents of the home. None of the residents were injured. (Ken Harding, NOAA, NWS Aberdeen, South Dakota)

Service Assessment

Record Tornado Outbreaks of May 4-10, 2003

December 2003

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

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

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

Preface

During the period May 4-10, 2003, an unprecedented number of tornadoes affected the central and southern United States. During this period, 393 tornadoes occurred across the central and southern U.S. resulting in 39 deaths across 4 states. Six of these tornadoes were classified as violent (F4) on the Fujita Tornado Intensity Scale.

Due to the magnitude of this event, a service assessment team was formed to examine the warning and forecast services provided to emergency managers (EMs), government agencies and the public. Service assessments are used to improve techniques of National Weather Service products and services to the American public through the recommendations in the report.

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

December 2003

Table of Contents

Page

Preface ii

Service Assessment Team iv

Acronyms vi

Service Assessment Report 1
- Executive Summary 1
- Event Overview 4
- Warning and Forecast Services
  - A. Storm Prediction Center (SPC). 11
  - B. WFO Pleasant Hill, Missouri 14
  - C. WFO Springfield, Missouri 18
  - D. WFO Memphis, Tennessee 22
  - E. WFO Paducah, Kentucky 27
  - F. WFO Norman, Oklahoma 33
  - G. Issues Common to All Five WFOs 38

Best Practices 41

Appendix A Fujita Tornado Intensity Scale A-1

Appendix B Direct Fatalities in Each WFO's CWA B-1

Appendix C Event Statistics, May 4-10, 2003 . . . . . C-1

Service Assessment Team

The Service Assessment team was activated on May 12, 2003. Team members visited damage areas and interviewed emergency managers, the media, and public in Oklahoma, Missouri, Tennessee and Kentucky, and visited five Weather Forecast Offices (WFOs) located in Norman, Oklahoma, Kansas City and Springfield, Missouri, Memphis, Tennessee, and Paducah, Kentucky, and the Storm Prediction Center (SPC) also in Norman, Oklahoma.

The following members were on the team.

Jim Purpura	*Team Leader,* Meteorologist In Charge (MIC), WFO Corpus Christi, Texas
Steve Letro	MIC, WFO Jacksonville, Florida
Larry Ruthi	MIC, WFO Dodge City, Kansas
Stan Levine	Warning Coordination Meteorologist (WCM), WFO Buffalo, New York
Dennis Decker	WCM, WFO Melbourne, Florida
Chris Jones	WCM, WFO Riverton, Wyoming
Paul Sisson	Science and Operations Officer (SOO), WFO Burlington, Vermont
Kurt Van Speybroeck	SOO, WFO Brownsville, Texas
Ken Harding	SOO, WFO Aberdeen, South Dakota
Jon Mittelstadt	SOO, WFO Pendleton, Oregon
John Ferree	Warning Decision Training Branch (WDTB), Norman, Oklahoma
Marilu Trainor	Western Region Headquarters (WRH), Public Affairs
Kent LaBorde	National Oceanic and Atmospheric (NOAA) Public Affairs

Other valuable contributors include:

William Lerner	NWS Headquarters, Office of Climate, Water, and Weather Services (OCWWS), Silver Spring, Maryland
Linda Kremkau	NWS Headquarters, OCWWS, Silver Spring, Maryland
Wayne Presnell	NWS Headquarters, OCWWS, Silver Spring, Maryland
Larry Dunn	MIC, WFO Salt Lake City, Utah
Paul Kirkwood	Southern Region Headquarters
Larry Mooney	MIC, WFO Denver/Boulder, Colorado
Steve Weiss	Storm Prediction Center
Russ Schneider	Storm Prediction Center

Acronyms

AWIPS	Advanced Weather Interactive Processing System
CDT	Central Daylight Time
CRH	Central Region Headquarters
CRS	Console Replacement System
CWA	County Warning Area
DAPM	Data Acquisition Program Manager
EAS	Emergency Alert System
EM	Emergency Manager
E-SPOTTER	Near real-time, web-based, two-way spotter and emergency manager communication and reporting system.
HMT	Hydrometeorological Technician
HP	Hewlett Packard
HWO	Hazardous Weather Outlook
IDP	Individual Development Plan
ITO	Information Technology Officer
LP1	Local Primary 1
LSR	Local Storm Report
MCS	Mesoscale Convective System
MIC	Meteorologist in Charge
MIS	Meteorological Information Specialist
NCF	Network Control Facility
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio
NWS	National Weather Service
OCWWS	Office of Climate, Water, and Weather Services
ORPG	Open Radar Product Generator
OST	Office of Science and Technology
PRF	Pulse Repetition Frequency
PSDA	Post-Storm Data Acquisition
QRT	Quick Response Team
RPCCDS	Radar Product Central Collection Dissemination Service
SDM	Station Duty Manual
SLS	Redefining Statement
SOO	Science and Operations Officer
SPC	Storm Prediction Center
SPS	Special Weather Statement
SRM	Storm Relative Motion
SVR	Severe Thunderstorm Warning
SVS	Severe Weather Statement
SWA	Severe Weather Alert

TOR	Tornado Warning
WCM	Warning Coordination Meteorologist
WDM	Warning Decision Making
WDSS	Warning Decision Support System
WES	Weather Event Simulator
WIN	Weather Information Network
WFO	Weather Forecast Office
ZFP	Zone Forecast Product

Service Assessment Report

Executive Summary

An unprecedented series of tornado outbreaks occurred in portions of the Great Plains, Midwest, and Mid-South of the U.S. during the week of May 4 through 10, 2003. During this seven day period, there was a total of 393 tornadoes resulting in 39 deaths. Tornado outbreaks producing violent (F4) tornadoes occurred on May 4 in the Weather Forecast Office (WFO) Kansas City and Springfield, Missouri county warning areas (CWAs) and WFO Memphis, Tennessee CWA, and on May 6 in the WFO Paducah, Kentucky CWA. A violent (F4) tornado occurred in Oklahoma City (WFO Norman CWA) May 8, and on May 9 a second tornado (F3) also struck Oklahoma City.

An assessment was made of the performance of the National Centers for Environmental Prediction's (NCEP) Storm Prediction Center (SPC), which is responsible for issuing severe weather outlooks and watches. Performances of the five WFOs responsible for issuing outlooks and warnings in the counties where the violent tornadoes occurred, was also assessed. Due to the magnitude of this event, the scope of the assessment was limited to the outbreak days of May 4, 6, 8 and 9, the SPC, and these five WFOs.

The service assessment team found the assessment process is working well for the NWS. SPC and all WFOs had anticipated the event in advance, adjusted staffing appropriate to the event, and let the public, emergency managers and the media know of the potential for severe weather and its impact. SPC and all five WFOs had read the Veteran's Day Weekend Tornado Outbreak of November 9-11, 2002 service assessment report, which had been distributed in April 2003, before the outbreaks in May began, and had either made improvements to severe weather operations based on the assessment's facts, findings, and recommendations, or already had these improvements in place. Media, emergency management, and the public interviewed by the service assessment team had praise for the outlooks, statements, watches, and warnings issued before and during the event.

A high level of service was noticed by Congress as well. On June 10, 2003, the NWS received a letter signed by 11 members of the House of Representatives' House Science Committee stating, "...many of your employees in the hardest hit areas literally lived in their weather offices, working long, stressful hours to issue the warnings that saved lives..." and "We greatly appreciate the outstanding service your agency provides to this nation and the lives you save every day."

The atmospheric features causing this extended tornado outbreak were predicted well in advance in most cases. This allowed NWS offices to plan ahead and perform at the high level noted. However, in some instances, the features leading to a tornado outbreak are not as evident

and can not be predicted as far in advance, giving NWS offices less time to prepare. Such a high level of performance can not be expected with each tornado outbreak.

During the entire 7 day period, the Probability of Detection (POD) for all tornadoes occurring in all CWAs of the 5 WFOs was .910 and the False Alarm Ratio (FAR) was .722. The average lead time for all Tornado Warnings from all 5 WFOs was 19 minutes with 70 of 73 tornadoes preceded by Tornado Warnings. The Tornado Watch average lead time to tornadoes producing fatalities during the 7 day period was 2 hours and 3 minutes. Tornado Watches are issued by the SPC. All of these values are better than national averages.

The upper level wind pattern during the week of May 4-10 was characterized by a persistent low pressure area over the western half of the United States, with a series of strong mid-level storm systems moving east daily into the central and southern Plains, and then northeast into the upper Mississippi Valley. This did not change until May 11-12 when the overall pattern shifted toward New England and an upper ridge of high pressure developed over the Rocky Mountains, ending the series of unusually active severe weather days. At the surface, a warm, moist, and unstable airmass was present across the central and southern Plains and east across the Ohio Valley and the southeast United States during the entire outbreak period. This persistent large scale pattern was accompanied by very strong west-southwest winds in the middle and upper atmospheric levels across the tornado outbreak area. All these elements combined to make ideal conditions for tornadoes across the Great Plains, Ohio Valley, and the southeast United States.

- All 39 fatalities occurred within the boundaries of both watches and warnings.
- The five WFOs had an average lead time of 19 minutes for tornadoes occurring in their CWAs during their respective outbreak days.
- Hazardous Weather Outlooks warned of the potential for severe weather as much as six days in advance.
- Violent tornadoes killed only one person in Kansas City, and none in Oklahoma City, even though they moved through densely populated areas. Media partnerships with the NWS in these cities meant a consistent warning message reached the public through the media.
- Rick Mitchell, KOCO-TV in Oklahoma City said "*It was like they <u>knew</u> what was going to happen!"*
- D.C. Rogers Clay County, Missouri Emergency Management said *"There were no surprises."*

Service Assessments are undertaken by the NWS to determine the level of service provided to customers and partners. Best practices are identified for use throughout the NWS

when feasible. Service lapses, if any, are noted and recommendations for corrective actions are made. Emergency managers, people in the media, and local residents were interviewed to obtain feedback on NWS performance.

As noted, NWS customers and partners were satisfied with services before and during the outbreak, often expressing their gratitude for the high level of performance provided. This report identifies 9 recommendations for improvements within the NWS severe weather warning process.

When implemented, the recommendations should allow for: 1) improved live broadcasting of real time severe weather reports on NOAA Weather Radio (NWR); 2) increasing the number of participants on conference calls which notify customers and partners of expected hazardous weather; 3) improved interpretation of radar velocity data; 4) increased bandwidth between Department of Defense (DOD) and NWS radars; 5) quicker methods of switching to backup communication systems at the WFOs if the main one fails; 6) sufficient bandwidth to provide customers and partners radar images during dissemination problems; 8) a summary of Local Storm Reports (LSR) issued shortly after a major storm event ends and 9) quicker posting of post event information on NWS Internet sites.

Data contained in this report were compiled by the assessment team as of July 20, 2003. Final analyses may produce statistics not matching those contained in this report.

Event Overview

Introduction

During the week of May 4-10, 2003, a record number of tornadoes occurred over the central and eastern United States, with 393 tornadoes reported in 19 states. Eight tornadoes caused 39 deaths, including 37 on May 4. The previous most active week on record was May 12-18, 1995, when there were 171 tornadoes reported. From May 4 through May 10, National Weather Service Forecast Offices issued a total of 4,050 severe convective weather warnings, with 1,090 Tornado Warnings and 2,960 Severe Thunderstorm Warnings issued. This is the most in any seven day period. On May 6 alone, 921 warnings were issued, which is the largest one day total since warning records began in 1986. The Storm Prediction Center issued 123 Tornado and Severe Thunderstorm Watches during this 7 day period, including 25 Tornado Watches that contained the rarely used "**Particularly Dangerous Situation**" wording, which is reserved for the most life threatening situations. At least 12 watches were issued each day during this period, including three days when 20 or more watches were issued (May 6, 8, and 10). Perhaps most remarkably, severe weather watches were in effect continuously from 11:40 a.m. CDT May 4 through 7:00 a.m. CDT May 9, a period of more than 115 hours. Although it is not uncommon for significant severe tornado episodes to occur during the early part of May (in fact, the climatological frequency of a significant tornado day occurring in the central U.S. is maximized at this time of year), it is extremely unusual for significant severe convective weather to occur almost every day for a seven day period.

NCEP's Global Forecast System (GFS) computer model began to portray an extensive upper level trough of low pressure developing over the western United States, indicating a favorable pattern for severe weather episodes, 5-6 days prior to the beginning of the week of May 4. The GFS and another NCEP computer forecast model, the Eta, continued to indicate this trend up to and through the 7 day period, providing strong guidance in forecasting the potential for a period of widespread severe weather.

Synoptic and Mesoscale Overview

The upper level wind pattern during the week of May 4-10 was characterized by a persistent area of low pressure over the western half of the United States, with a series of strong mid-level storm systems moving east daily into the central and southern Plains, and then northeast into the upper Mississippi Valley. This did not change until May 11-12 when the pattern shifted toward New England and an upper ridge of high pressure developed over the Rocky Mountains, ending the series of unusually active severe weather days. A warm, moist airmass remained from across the central and southern Plains east across the Ohio Valley and the southeast United States.

This persistent large scale pattern was accompanied by very strong west-southwest winds in the middle and upper atmospheric levels across the tornado outbreak area. These strong winds combined with persistent warm, moist surface conditions, significant change in wind speed and

direction with height and instability to create ideal conditions for tornado development across the Great Plains, Ohio Valley, and the southeast United States.

A closer look at the four most active tornado producing days during the week-long event is provided in the next section.

A Closer Look at Individual Outbreak Days

May 4

May 4 was the most active tornado day, with 94 tornadoes reported (**Figure 1**), including seven tornadoes that produced 37 fatalities. A total of 518 severe storm reports were received by the SPC that day. A vigorous storm system in the middle levels of the atmosphere moved northeast across the northern and central Plains toward the Mississippi Valley during the afternoon and evening hours, contributing to a widespread region of severe weather extending from the central Plains into the Tennessee Valley (**Figure 2**). A deep surface low was in place over extreme northeast Kansas, with a cold front/dry line extending south and southwest from the low, and a warm front extending southeast from the low into the Tennessee Valley. The surface low combined with a vigorous mid-level storm system which moved northeast across the Great Plains during the afternoon and evening hours to spawn a widespread region of severe weather extending from the central plains into the Tennessee Valley.

May 6

Sixty three tornadoes and a total of 533 severe weather reports were received on May 6 during an outbreak that covered a large part of the southeastern quarter of the nation (**Figure 3**). There was one killer tornado that struck southern Illinois resulting in two fatalities. Mid-level analysis shows the winds were similar to the pattern just two days earlier, with a strong storm system moving across the northern and central Plains (**Figure 4**). Strong southwest winds aloft combining with warm, moist low level air were observed across the central and southern Plains into the Ohio and Tennessee Valleys. A surface low was over southwest Missouri, and its associated cold front, warm front, and dryline were the focus for severe storm development on this day.

May 8

Fifty four tornadoes and 313 total severe storm reports were received on May 8, extending along an east to west axis from eastern Colorado into the Ohio Valley, with a separate area of severe storms over eastern Virginia (**Figure 5**). Although no fatalities were caused by tornadoes on this day, a violent (F4) tornado struck the southern Oklahoma City metropolitan area during the afternoon rush hour, including parts of Moore, Oklahoma which were affected by a devastating F5 tornado on May 3, 1999. The mid-level chart in **Figure 6** is similar to patterns earlier in the week, with a strong storm system lifting northeast across the central Plains and a band of very strong southwest winds from California across the central Plains. Once again, the

surface conditions were warm and humid over the Plains creating favorable conditions for severe storms.

May 9

Thirty five tornadoes and 444 total severe storm reports were received on May 9, stretching in a large arc from southwest Texas across the middle Mississippi and Ohio Valleys then into Virginia and North Carolina (**Figure 7**). The Oklahoma City metropolitan area was struck by a significant tornado (an F3) for the second day in a row, an extremely rare occurrence.

A strong low pressure area deepened over the Great Basin as a downstream high pressure area built northward toward the Great Lakes, and an upper low moved northeast into the upper Mississippi Valley (**Figure 8**). This resulted in a broad mid level jet stream extending from the Plains into the Mississippi Valley and Great Lakes areas. A surface low was located over Lake Michigan, with a warm front extending southeast from the low into Virginia, and a cold front trailed southwest from the low into a second low over the Oklahoma Panhandle. A dryline extended southward over west Texas, with warm moist air to the east of the dryline over much of Oklahoma and Texas.

The intense mid-level storm system seen over the Great Basin in Figure 8 would prove to be the last in a week long series of storms that moved from the Pacific Ocean into the western U.S., and eventually across the central states.

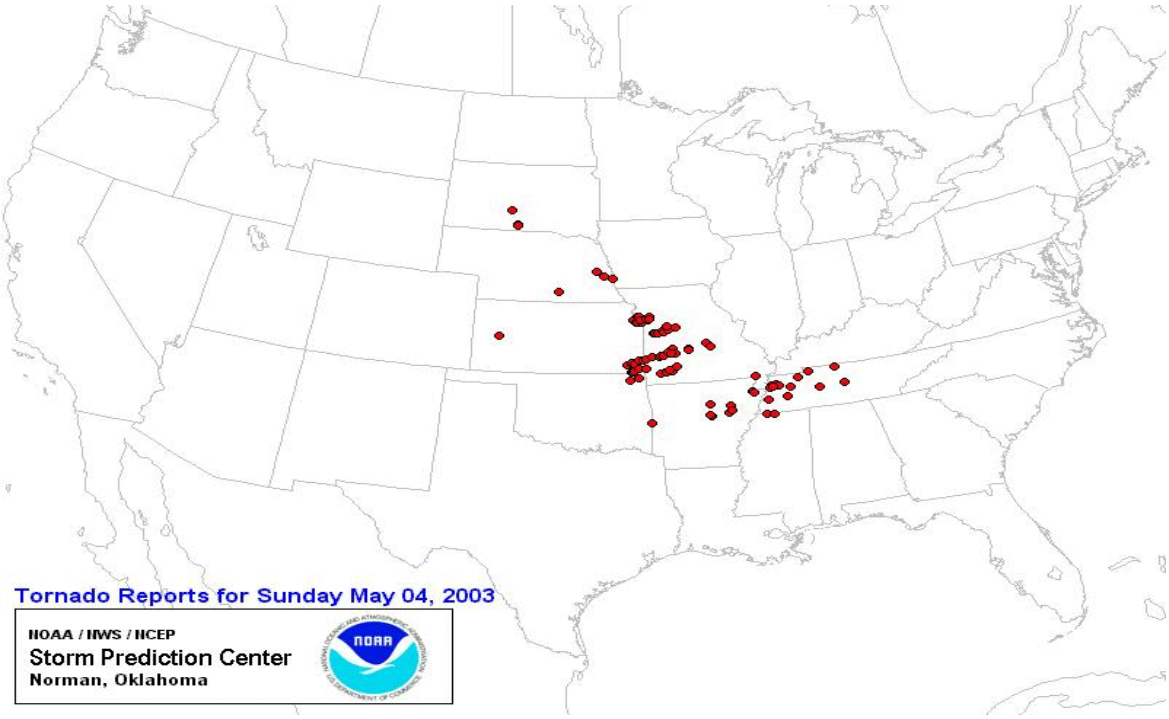

Figure 1. Tornado Reports in the U.S. for May 4, 2003. Courtesy of SPC.

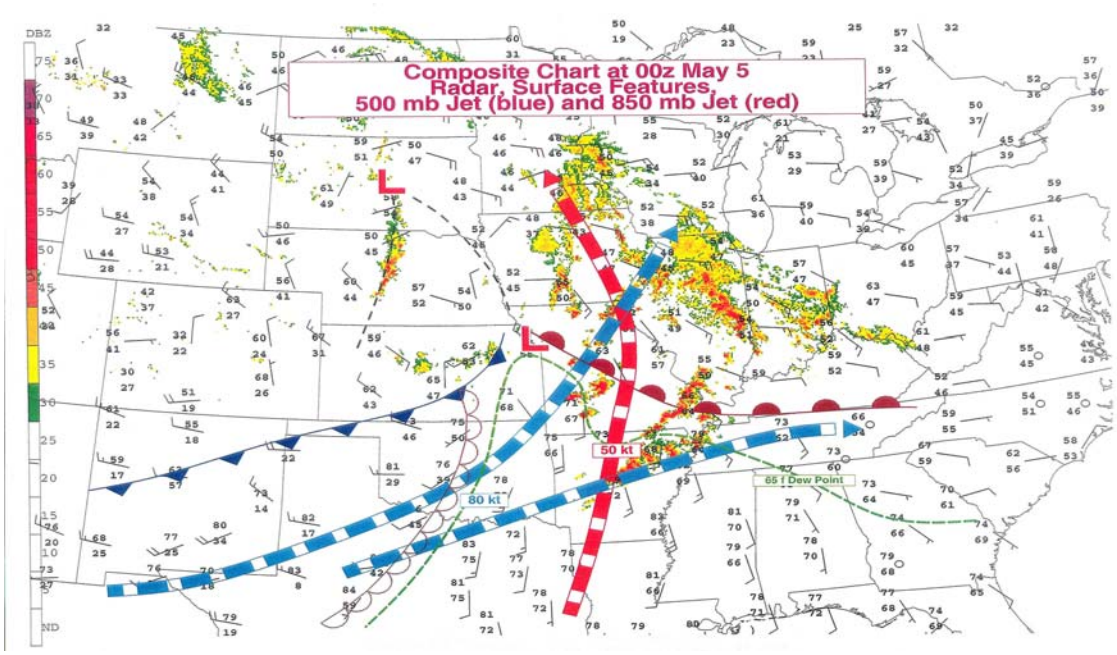

Figure 2. Composite Radar Reflectivity, Surface Fronts, 500 millibar and 850 millibar jet streams at 0000 UTC, (7:00 p.m. CDT May 4, 2003) May 5, 2003. Courtesy of SPC.

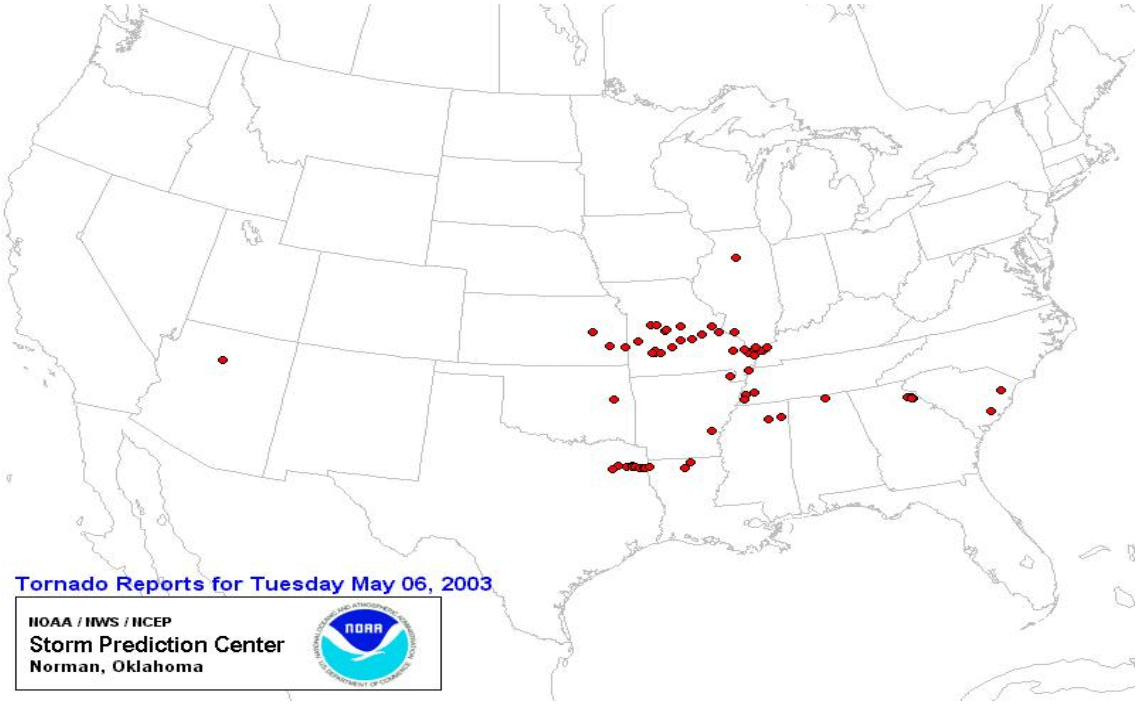

Figure 3. Tornado Reports in the U.S. for May 6, 2003. Courtesy of SPC.

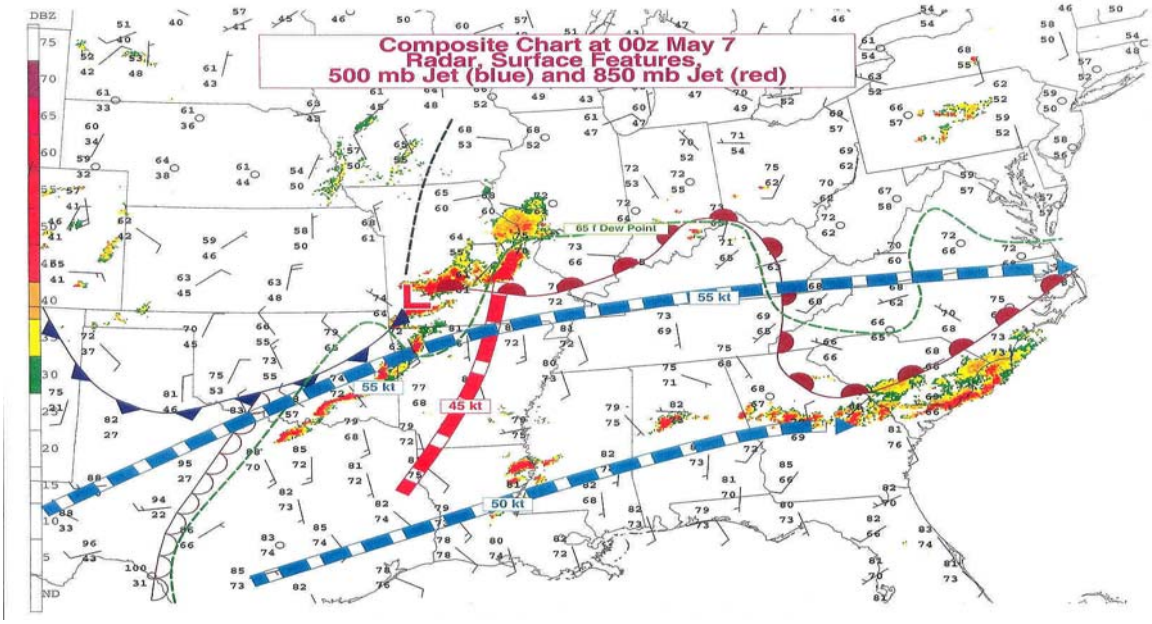

Figure 4. Composite Radar Reflectivity, Surface Fronts, 500 millibar and 850 millibar jet streams at 0000 UTC, (7:00 p.m. CDT May 6, 2003) May 7, 2003. Courtesy of SPC.

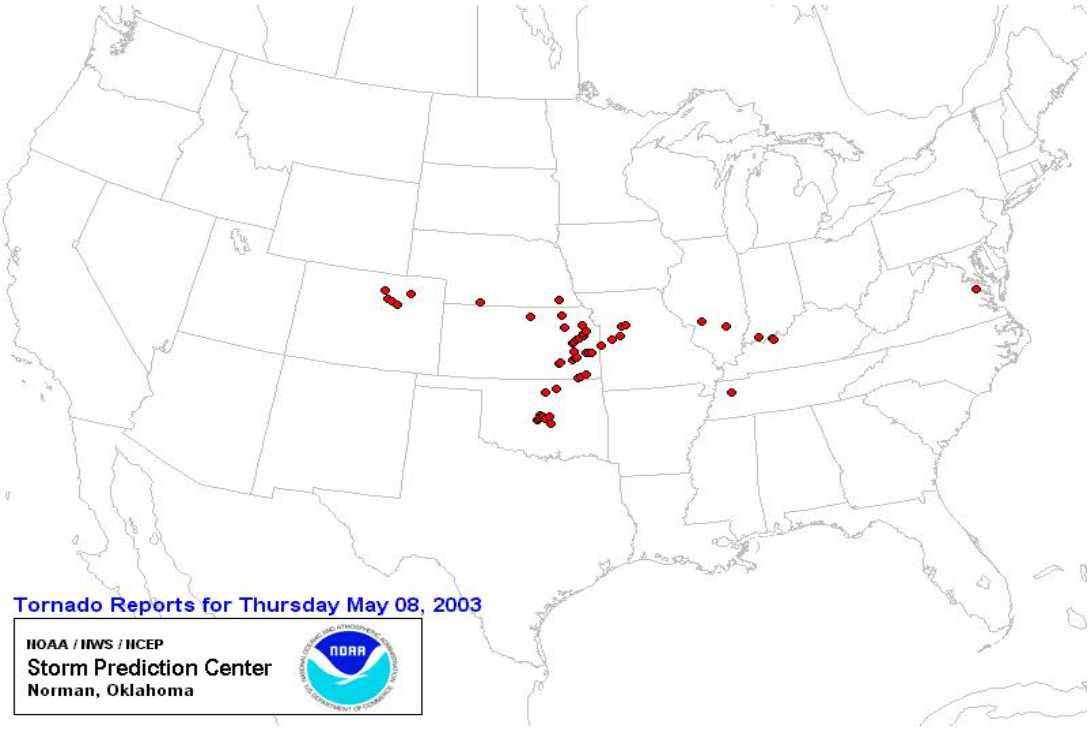

Figure 5. Tornado Reports in the U.S. for May 8, 2003. Courtesy of SPC.

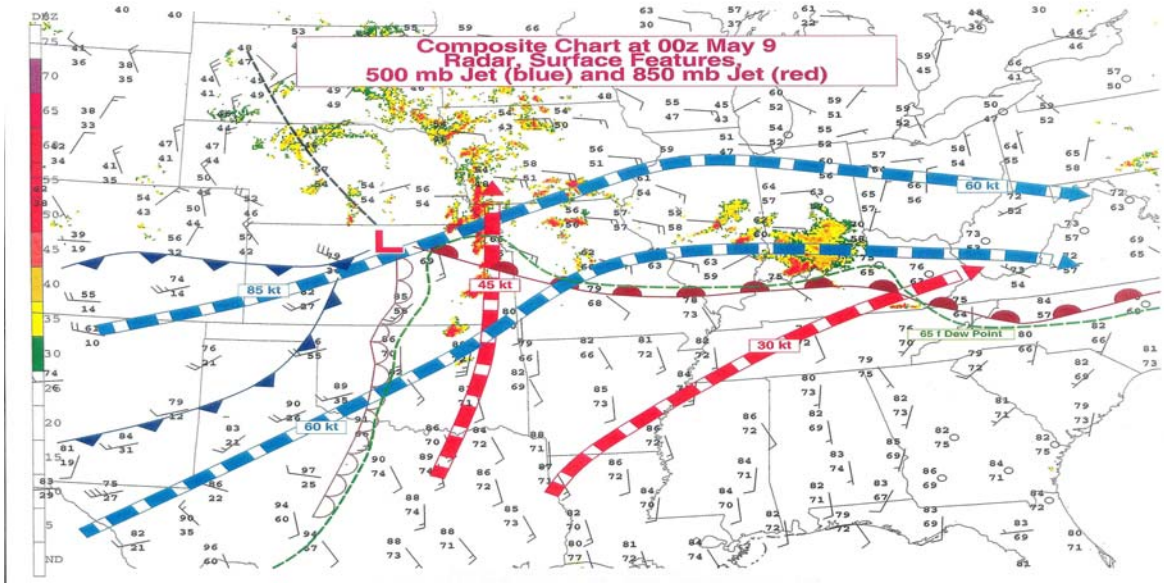

Figure 6. Composite Radar Reflectivity, Surface Fronts, 500 millibar and 850 millibar jet streams at 0000 UTC, (7:00 p.m. CDT May 8, 2003) May 9, 2003. Courtesy of SPC.

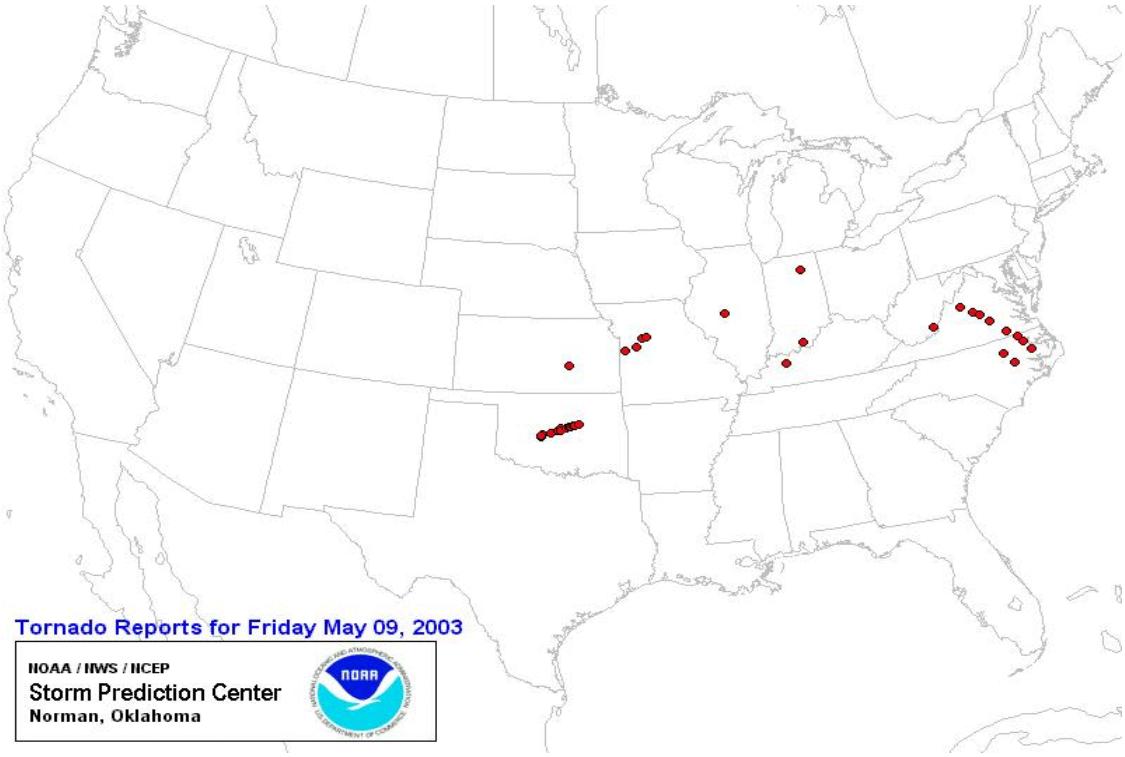

Figure 7. Tornado Reports in the U.S. for May 9, 2003. Courtesy of SPC.

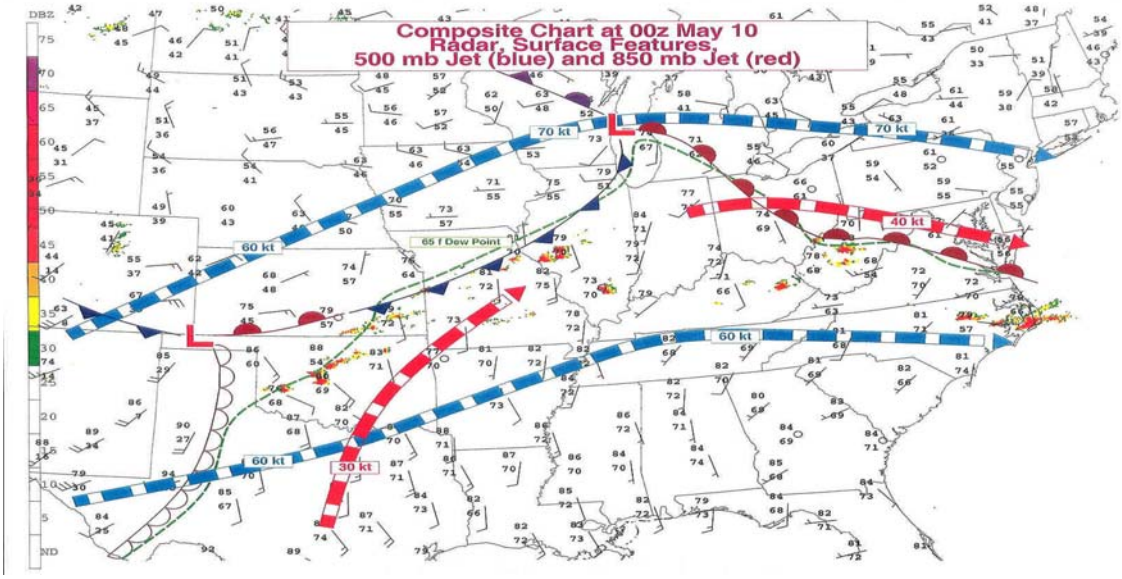

Figure 8. Composite Radar Reflectivity, Surface Fronts, 500 millibar and 850 millibar jet streams at 0000 UTC, (7:00 p.m. CDT May 8, 2003) May 9, 2003. Courtesy of SPC.

The following sections describe the chronology of events at the SPC and the five WFOs where F4 tornadoes occurred in their CWAs. No F5 (strongest category on the Fujita Intensity Scale) tornadoes occurred during this outbreak. The WFO sections are arranged chronologically beginning with WFOs Pleasant Hill, Springfield, and Memphis on May 4, WFO Paducah on May 6, and WFO Norman on May 8 and 9. The quality of service provided and any issues needing attention are discussed. Findings and recommendations, where appropriate, are included at the end of each section. A section "Issues Common to All WFOs" was added and followed by "Best Practices." Preliminary Event Statistics from each WFO are provided in Appendix C.

Warning and Forecast Services

A. Storm Prediction Center (SPC)

Overview

The assessment team received emphatic, positive comments regarding Storm Prediction Center (SPC) service and skill during the week of May 4 through May 10. These comments came from NWS forecasters, emergency managers, media, and the general public.
Gary England, Oklahoma City KWTV Meteorologist, stated, *"I check the day one outlook every morning and night; it is like our bible...It's excellent. On the (May) 8 and 9 (Oklahoma City tornadoes) SPC did an excellent job."*

Statistics back up these general perceptions. All 39 tornado-related fatalities occurred within the bounds of an SPC Tornado Watch. Of the eight tornadoes that caused fatalities, seven were within the bounds of an SPC high risk outlook, and one occurred just outside the bounds of the high risk area but within a moderate risk outlook. The average lead time from tornado watch issuance to first tornado in watches where fatalities occurred was 2 hours, 3 minutes. The following table shows lead times in hours and minutes for the watches and outlooks that covered locations where tornado fatalities occurred.

Day of Month	Tornado Watch #	Lead Time to First Tornado
4	232*	3:05
4	233	2:43
4	237	1:58
4	239	0:54
6	275	1:35

* Tornado Watch 232 was replaced by Tornado Watch 237 at 6:05 p.m.

The widespread and frequent nature of the convective weather during the week required the issuance of a large number of products. SPC issued 217 Mesoscale Discussions during the week, an average of 10 discussions per each eight-hour shift. A total of 127 Tornado or Severe Thunderstorm Watches were coordinated with forecast offices and issued. Several times during the week, four watches were coordinated and issued within a one hour period. SPC staff successfully utilized technological and human resources to issue this large number of products with sufficient lead times.

In addition to the standard suite of SPC products, services were provided via the Internet and telephone. The number of Internet visitors to the SPC web site averaged just over 5.6 million hits per day (a hit is defined as an object downloaded from a web page). During the week, SPC provided background information and interviews for more than 70 wire services, and national, international and local media.

Veteran's Day Weekend Tornado Outbreak of November 9-11, 2002 Recommendations

A service assessment report for the Veteran's Day Weekend Tornado Outbreak of November 9-11, 2002, released in April 2003, contained several recommendations for SPC (See table below). SPC has already completed or made progress in most areas and as a result, actions from recommendations 2a and 2b were implemented during this event with success.

Recommendations	**SPC Actions**
Recommendation 1: The Office of Climate, Water, and Weather Services (OCWWS), SPC, and the regions should review policy on issuing or upgrading weather watches for WFOs already in warning operations.	NWSI 10-512 will update the policy on issuing or upgrading weather watches for WFO's already in warning operations. NWSI 10-512 will become effective October 1, 2003.
Recommendation 2a: The SPC should modify its SDM to provide guidance when extra staff should be brought in to handle the workload associated with a major outbreak by September 1, 2003.	Completed. The SDM has been modified accordingly. Extra staff was used during the May 4-10 period: The need for extra staff was discussed and anticipated, and as needed extra staff was called in during the weekend, forecasters came in early, and forecasters were held over at the end of shifts.
Recommendation 2b: The SPC should reconfigure its operations area to handle simultaneous multiple watch issuances by multiple forecasters by September 1, 2003.	Completed. A second workstation was implemented and has been utilized to successfully prepare, coordinate and issue simultaneous watches.
Recommendation 2c: The SPC should reexamine its policy of allowing only lead forecasters to be certified to issue watches. Any changes should be completed by September 1, 2003.	An SPC Forecaster Familiarization Program for GS-13 forecasters was implemented May 15, 2003. Training is underway and some participants have issued watches under the supervision of Lead Forecasters.
Recommendation 3: The SPC should modify its training program to include Weather Event Simulator (WES)-like simulations of major severe weather outbreaks.	SPC expects to be able to have a system to view historical data using N-AWIPS. This requires NCEP- Operations Computer Development Branch (NCO-CDB) development. Target date for completion is September 10, 2003.

B. WFO Pleasant Hill, Missouri

Overview

Significant severe weather struck the Kansas City metropolitan area during the afternoon and evening of Sunday, May 4. Nine tornadoes (2 F-4s, 3 F-2s, 3 F-1s, and 1 F-0) as well as large hail swept across the WFO Pleasant Hill (Kansas City), Missouri CWA over 9 hours. All nine tornadoes were covered by Tornado Warnings. The average lead time for Tornado Warnings was 24 minutes, with a range from 8 to 33 minutes. Only one storm fatality occurred. In Wyandotte County, Kansas, an 81-year-old man was crushed by debris as he headed for shelter while his house collapsed during the tornado. There were 43 people injured. The fatality and injury totals were minimal, considering the violent (F4) tornadoes touched down within densely populated portions of suburban Kansas City.

The WFO Pleasant Hill staff first mentioned severe weather potential for May 4 in the early morning Hazardous Weather Outlook (HWO), issued on Monday, April 28. Subsequent HWO products continued to mention the severe weather potential, gradually refining timing, location, and forecast confidence. The HWO issued at 6 a.m. CDT, Saturday, May 3, noted an increasingly favorable environment for large hail and isolated tornadoes. The next issuances of the HWO contained headlines, highlighting a severe weather outbreak Sunday afternoon, May 4. This was in addition to a high risk area over eastern Kansas and western Missouri in the early morning Convective Outlook issued by SPC at 7:53 a.m. CDT, Sunday, May 4. The SPC issued Tornado Watch 233, with the headline, **"this is a particularly dangerous situation,"** for the area at 12:45 p.m. CDT, valid through 7 p.m. CDT. The WFO Pleasant Hill senior forecaster notified all off duty personnel after the Tornado Watch was issued.

Situational awareness was high, and pre-planning and coordination allowed for effective, efficient operations during the severe weather event. The updated public forecast issued at 1:22 p.m. CDT, Sunday, May 4, added the text **"some thunderstorms may become severe with large hail, damaging winds and isolated tornadoes.**"

The first warning, a Severe Thunderstorm Warning, was issued at 2 p.m. CDT. The final warning expired at 11 p.m. During the event, 44 warnings (23 Tornado and 21 Severe Thunderstorm) were issued, in addition to 107 Severe Weather Statements, 97 Short-Term Forecasts, and 100 Local Storm Reports. The Tornado Warning for Clinton and Clay Counties in Missouri stated, **"a damaging tornado has been confirmed with the storm! This is a life-threatening situation."** Several timely Severe Weather Statements were issued for every Tornado Warning, with numerous statements providing specific tornado locations from spotter reports and emphasizing a **"tornado emergency for the northern half of the Kansas City metro area."**

This housing subdivision in north Kansas City suffered major damage on May 4.

The Senior Forecaster and MIC (acting as the Warning Coordinator) delegated warning, communications, and forecast duties. A total of 15 meteorologists worked the event, including two meteorologists from Central Region Headquarters (CRH). The MIC, SOO, and Information Technology Officer (ITO) were present from the management staff. Four amateur radio operators also worked during the event to assure a steady supply of spotter reports to the warning forecasters.

A total of three teams consisting of seven meteorologists worked as radar/warning meteorologists and Meteorological Information Specialists (MIS). The MIS is paired with a warning forecaster to collect and disseminate information for his/her warning sector. The philosophy of sectorizing the CWA assisted some radar warning teams in focusing on the most damaging storms while others were concurrently warning on lesser severe storms.

WFO Topeka, Kansas, the backup office, assumed WFO Pleasant Hill's aviation forecast responsibility during the outbreak allowing the Pleasant Hill staff to concentrate on severe weather services for the CWA.

Pre-planning and intra-office coordination resulted in a smooth transition from non-severe weather, through severe weather and into an emergency situation. Leadership from local management through the Senior Forecasters produced timely decisions regarding staffing and division of duties among the entire operations area. Pre-event and severe weather operational checklists were completed the evening before the event and the day of the event. The ITO was called in the night before the event and did a total restart of all AWIPS workstations. This appeared to contribute to stable AWIPS operation during the event. Before severe weather began, all communications systems were checked and the AWIPS Network Control Facility (NCF) was notified and asked to list the WFO as being in "critical weather watch mode." The presence of a warning coordinator, operational teams of radar operators and several MIS's, and predefined severe weather shift duties, in "flash card" form, allowed the operational staff to quickly focus on specific duties with knowledge that all necessary tasks were being completed. This practice minimized duplication of effort and maximized warning and communications performance.

The staff received several training sessions in severe weather in 2003. The operations staff had Warning Event Simulator (WES) training in February and March. The simulation included long-track supercells. In March, a severe weather seminar on warning guidance and severe weather forecast parameters was conducted, and in April, a climatology of Mesoscale Convective Systems (MCSs) seminar was presented.

Outreach and community preparedness activities by the Pleasant Hill WFO have been aggressive. Two counties (Leavenworth and Johnson in Kansas) are StormReady counties. Four municipalities in the Kansas City area (Lee's Summit, Peculiar, Belton, and Knob Knoster) are designated as StormReady cities. Discussions with emergency managers provided numerous examples of how timely training and collaboration between local governments, businesses, and the local WFO effectively saved lives. D. C. Rogers, the Director of Emergency Management in Clay County, Missouri, stated, *"There were no surprises!"*

Project Community Alert, a joint venture between the Metropolitan Emergency Manager's Committee (MEMC) and the NWS helped to market NWRs at reduced prices in the Kansas City area. At least 20,000 NWRs were sold in the Kansas City area from June 2002 through May 2003.

Television media and emergency management interviewed by the assessment team (four network television stations and five Emergency Managers) were extremely satisfied with the level of service by WFO Pleasant Hill. The network stations provided continuous live coverage of the tornado event by broadcasting Tornado Warnings, Severe Thunderstorm Warnings, Severe Weather Statements, and Local Storm Reports from the WFO. The WFO issued these products at intervals averaging 2 to 3 minutes at the peak of the event. Some of the media did mention they would appreciate a summary of the Local Storm Reports at the end of the event to assure they had all of the NWS reports **(Recommendation 8).** The QRT process took longer than expected in getting the final rating to the media, but WFO Pleasant Hill kept the media informed

as the process continued, and held a press conference to announce the final F4 ratings for the strongest tornadoes.

Gary Lezak, meteorologist for KHSB-TV, said it was a *"solid 'A' effort by the NWS."*

The assessment team also spoke to representatives of two companies representing eleven radio stations in the Kansas City area, including the Emergency Alert System (EAS) Local Primary 1 (LP1) and the Chairman of the local EAS committee. The radio media interviewed also had high praise for the warning services from WFO Pleasant Hill. However, an issue with a live NWR broadcast from the WFO was noted **(Recommendation 1).**

Issues

Fact: Live broadcasts from NWR were used frequently during the event, and were praised by the broadcasters.

Fact: During one live NWR broadcast, a Tornado Warning had just been issued and the Specific Area Message Encoder (SAME) tones on NWR activated EAS. Several radio stations played the NWS audio of the warning.

Fact: Before the end tones shutting off the NWR broadcast on EAS were received by the radio stations, the NWR operator began a live update. This live update was also broadcast on EAS radio stations across Kansas City.

Fact: The end tones of the EAS, needed to resume normal broadcasting, were never received and the commercial radio stations carried 1 to 2 minutes of "dead air" due to an open, live microphone at the WFO. Several broadcasters mentioned this error to the assessment team.

Finding 1: A live update of a Tornado Warning on NWR began before the end tones of the EAS broadcast occurred. This did not allow the EAS broadcast to end properly and resume normal broadcasting, leading to commercial radio stations carrying 1 to 2 minutes of "dead air" due to an open, live microphone at the NWR console of the WFO.

Recommendation 1a: Regions should ensure all WFOs are aware of this potential issue and instruct offices on ways to avoid it.

Recommendation 1b: The Office of Science and Technology (OST) of the NWS should find a solution to the conflict between automated CRS broadcasts and live broadcasts. NWS Training Division should develop training on the Console Replacement System (CRS) for live broadcasts, including live transmission of end tones.

C. **WFO Springfield, Missouri**

Overview

A total of fifteen tornadoes occurred in the WFO Springfield, Missouri CWA on Sunday, May 4 between 4:35 p.m. CDT and 10:40 p.m. CDT. Tornado intensities included the following ratings: 1 F-4; 4 F-3s; 1 F-1; and 9 F-0s. Five of these tornadoes resulted in 25 deaths. Many of the fatalities occurred in mobile homes, modular homes, and frame homes, and many of the homes in southwest Missouri do not have basements. Less live media coverage (as compared to the Kansas City metro area) may also have contributed to the high number of fatalities. A list of the fatalities and circumstances surrounding the deaths is given in Appendix B. There were 186 persons injured. More than 3,000 homes and businesses were damaged by the tornadoes, and preliminary property damage estimates exceeded $159 million. All of the tornadoes were covered by Tornado Warnings. The average lead time was 23 minutes, with individual county lead times ranging from 6 minutes to 53 minutes.

The staff in the WFO Springfield first mentioned the severe weather potential in the May 1 HWO. The May 2 HWO highlighted the threat of isolated tornadoes for Sunday afternoon, May 4. The Saturday, May 3 2:35 a.m. CDT Zone Forecast Product (ZFP) included the headline **"severe weather outbreak possible Sunday afternoon."** The headline was changed at 7:54 a.m. CDT Sunday, May 4 to read "**tornadic storms possible this afternoon."** The SPC Day 1 Outlook, issued at 8:09 a.m. CDT, upgraded the risk category for the entire Springfield CWA from moderate to high. The HWO at 11:10 a.m. May 4, called for "**the potential of strong and particularly damaging tornadoes.**"

Conference calls were hosted by the WFO for emergency managers on Saturday evening May 3 and at 10:00 a.m. CDT Sunday. A media conference call was hosted at 11:15 a.m. CDT Sunday, May 4. The conference calls were highly praised by those who participated in them, but limitations in conference calling capabilities at the WFO resulted in some inefficiencies. A number of emergency managers were unable to join the first conference call Saturday evening because all available ports were used. WFO Springfield hosted three separate conference calls with small groups of emergency managers starting at 10:00 a.m. CDT Sunday. A separate conference call with media representatives was conducted at 11:15 a.m. CDT Sunday **(Recommendation 2).**

WFO Springfield began planning for adequate staffing at 10:00 a.m. CDT, Saturday, May 3. A maximum of 12 people staffed WFO Springfield Sunday evening, including eight Meteorologists, two Hydrometeorological Technicians (HMTs), the MIC, WCM, ITO, one ET and two amateur radio operators. Each staff member's role was well defined, and office operations went smoothly during the outbreak. The Severe Weather Operations Plan was praised by the Lead Forecasters for providing guidance regarding staffing and task assignments. All staff members interviewed noted that they felt that staffing was adequate to handle the outbreak but not excessive.

A total of 33 Tornado Warnings and 25 Severe Thunderstorm Warnings were issued covering 57 total counties beginning at 4:19 p.m. CDT Sunday, May 4 and ending at 2:33 a.m. CDT Monday, May 5. In addition, 132 Severe Weather Statements (SVSs) were issued during the outbreak, with multiple SVSs issued with each warning. Fifty nine real-time Local Storm reports (LSRs) were disseminated by the WFO during the event.

The WFO Springfield forecasters found the eight bit, full resolution Reflectivity and Storm Relative Motion (SRM) products extremely helpful in diagnosing storm structure and mesocyclone strength. Since the eight bit Reflectivity and SRM products can be combined only on the LINUX workstations, only two radar operators were able to make operational use of the combined imagery. The staff expressed some disappointment that the high resolution combined imagery was not available at all workstations.

All operational systems worked well during the severe weather outbreak. The AWIPS PX-2 failed on May 1 and was not restored to operational status until May 7 (PX-1 and PX-2 process incoming data for use in AWIPS). Since PX-1 provides redundancy, the loss of PX-2 did not have any adverse effects on operations.

The WFO Springfield staff participated in a Severe Weather Science Seminar on April 1, 2003. Topics covered include; 1) the importance of mesoanalysis; 2) an overview of office severe weather operating procedures; and 3) a review of a tornado outbreak that occurred in the WFO Springfield CWA in December 2002. In addition, the WFO Springfield SOO led the staff through a Warning Decision Making (WDM) Workshop training module. All forecasters completed two WES severe weather training simulations. The two meteorologists that issued most of the warnings during the outbreak cited the importance of the recent office reconfiguration that placed the two Linux workstations side-by-side. This allowed for better verbal communication between the warning forecasters.

Spotter training was provided to 36 of 37 counties served by WFO Springfield, including all ten counties in which fatalities occurred on May 4. During the period from January 2001 through early May 2003, WFO Springfield conducted 116 spotter training seminars. All of the county emergency managers interviewed by the assessment team indicated that frequent contact was made with WFO Springfield.

Media and emergency management officials mentioned the importance of the unprecedented conference calls that were initiated by WFO Springfield. They discussed the way the advance information allowed them to adjust staffing and make contingency plans.

"250% of service above and beyond what is normally expected."
Jimmie Swaggerty, Cedar County Emergency Manager.

"(WFO Springfield is) the most professional group I have worked with."
Jim Wakeman, Operations Director, Missouri State Emergency Management Agency.

Media in the three main markets served by WFO Springfield were interviewed. All expressed satisfaction with the overall service provided by WFO Springfield and several noted that WFO Springfield performed very well during the outbreak. Communication with WFO Springfield was described by Gary Bandy, Chief Meteorologist at KSNF TV in Joplin, Missouri as, "*exemplar*y." Morris James, news director for KTTS Radio, the Springfield LP1 station, stated, *"I have worked with a number of (NWS) offices, but by far, Springfield is the best."*

All of the media interviewed stated that in addition to the warnings, LSRs and SVSs were read on-air during the tornado outbreak. Three television stations and six radio stations provided continuous live coverage of the tornado outbreak, ranging from 90 minutes to nearly 10 hours. All six of the radio stations had spotters in the field prior to the first warning. One spotter for a station in southeast Kansas provided live reports of the F4 tornado that tracked across Crawford County, Kansas. Of the media interviewed, only one television station chose not to increase staffing as a result of the conference calls.

Reports were relayed from the public by telephone, instant messaging, and amateur radio. Another avenue that proved successful was an Internet-based software program called "E-Spotter" developed at WFO Paducah, Kentucky. A review of WFO Springfield's communication logs showed that the earliest reports of the rotating wall cloud and subsequent tornado that struck Pierce City, Missouri, came via E-Spotter. Several emergency managers and media personnel said that they use the WFO Springfield web site each day, particularly to view the HWO.

Fact: Conference calls were extremely useful to both emergency managers and the Media to plan staffing and develop other contingency plans.

Fact: The number of participants in each conference call was limited to 20 by the conference call plan.

Fact: This limitation forced the WFO to host three separate conference calls Sunday morning for emergency managers to assure that all available emergency managers could participate.

Finding 2: Limitations in conference call arrangement with telecommunication companies lessened the effectiveness and efficiency of the conference call process.

Recommendation 2: The Regional Headquarters should work with any WFOs using conference calls for hazardous weather briefings. The Regions should assure conference call capabilities of the WFO are adequate for the anticipated number of participants in the call. This should be done by June 1, 2004.

Major damage to the armory in Pierce City, Missouri

D. WFO Memphis, Tennessee

Overview

During the evening of May 4 and into early May 5, a series of tornadoes swept across the WFO Memphis CWA. The most significant was an F-4 tornado that moved along an 18 mile path, killing 11 (See Appendix B for a list of fatalities). There were 18 tornadoes (1 F-4, 2 F-3s, 3 F-2s, 9 F-1s, and 3 F-0s) that moved across the area over a 6 hour period. All of the tornadoes, that developed in the Memphis CWA May 4 and 5, were covered by Tornado Warnings**,** with the exception of the Craighead County, Arkansas, tornado. This was a weak tornado that touched down briefly before moving into Mississippi County, Arkansas. The average lead time for Tornado Warnings was 20 minutes with a range from 0 to 41 minutes. There were also 70 injuries and $100,000,000 property damage reported from these tornadoes.

This section will focus on the two most damaging tornadoes that occurred on the night of May 4 into May 5. The first was an F2 tornado that swept across Dyer County, and the towns of Dyersburg and Newbern. The second was an F4 tornado that struck Jackson in Madison County and continued on into Henderson County.

On the evening of May 1, WFO Memphis products began indicating the potential for severe weather. The 6:45 p.m. Hazardous Weather Outlook (HWO) focused on "**strong to severe thunderstorms"** for the period Saturday through Tuesday. On May 3, the 3:44 a.m. HWO indicated that some storms would be severe, especially on Sunday afternoon and Sunday night, and that spotter activation would be likely. By 5:35 p.m. Saturday, the HWO mentioned a moderate risk of severe weather for Sunday and Sunday night. The morning of the outbreak, Sunday May 4, the HWO stated the main threat would be from large hail with some tornadoes possible. The 4 a.m. Sunday ZFP mentioned severe thunderstorms for Sunday night. At 9:05 p.m. CDT May 4 WFO Memphis issued a HWO noting that the SPC had upgraded to a high risk of severe weather with the main threat being tornadoes. Tornadoes were already occurring in the area.

Tornado Watch #239 was issued for the area at 6:55 p.m. May 4 mentioning, **"this is a particularly dangerous situation."** SPC also upgraded to a high risk of tornadoes at 8 p.m.

By 6:11 p.m., the first Severe Thunderstorm Warning was issued for Clay and Greene counties in Arkansas. At 6:25 p.m. a Significant Weather Advisory (using the Special Weather Statement header - SPS) was issued for Dunklin County in Missouri. By 7:06 p.m., the first Tornado Warning was issued for Dunklin County. The last warning expired at 12:15 a.m. May 5. During the event, the Memphis WFO issued 36 Tornado Warnings, 20 Severe Thunderstorm Warnings, 70 Severe Weather Statements, 2 Local Storm Reports, and 1 Significant Weather Advisory.

WFO Memphis worked well as a team during the event. Staffing levels were appropriate to workload. The lead forecaster determined that additional staffing was needed and staff were

called in as the event began. Two amateur radio operators were also called and arrived by 7:20 p.m. The ITO, also a meteorologist, was the first to arrive and quickly took over a warning position on a LINUX workstation. Even though WFO Memphis had four staff positions vacant (including the WCM) during this event, staffing reached a maximum of 9 persons including the SOO and IT. The Lead Forecaster assumed the role of a warning coordinator and monitored the entire warning operation, as well as answered the telephone. The warning responsibilities were split into two separate sector teams, each with two members. One member of the warning team was responsible for performing radar interrogation and making warning decisions while the other assisted in warning decisions, editing, and issuing the text warning products. One forecaster handled public forecast responsibilities, SPC coordination and watch products. Another handled the aviation forecasting duties. A team, consisting of an HMT and Data Acquisition Program Manager (DAPM), monitored NOAA Weather Radio (NWR), answered the telephone, and issued area wide Short Term Forecasts. Warnings were announced to the entire operations area and automatically broadcast on NWR.

A constant flow of warnings and statements to the public and media was maintained by the WFO during the event. On average, a product was issued approximately every 2.5 minutes. WFO Memphis had partially responded to Recommendation 4d (completed by 8/15/03) from the Veteran's Day Weekend Tornado Outbreak Service Assessment.

March 2003 Recommendation	**WFO Memphis Actions on May 4**
Regions should work with WFO management to ensure issuance of SVSs per directive 10-511 and LSRs per Directive 10-517 are included in Severe Weather Operations Plans and emphasized in station drills.	A total of 70 Severe Weather Statements and 2 Local Storm Reports were issued.

The media interviewed commented that they were pleased with the large number of SVSs, but would like to have seen a constant flow of LSRs. The media mentioned a steady flow of LSRs helps support their decision to go to full time coverage.

There were, however, several issues associated with this event. Folded radar velocity data was evident in the lower elevation slices from the Memphis WSR-88D as the F4 tornado approached Jackson. The staff did not want to change the Pulse Repetition Frequency (PRF) to eliminate the range folding for fear that it might adversely affect radar sampling of other storms **(Recommendation 3).** In this case, warnings operations did not appear to be affected.

Bandwidth to the associated Department of Defense (DOD) WSR-88D radar was also an issue during these events. The data line from Columbus Air Force WSR-88D to WFO Memphis had inadequate bandwidth on May 4 and 5, and suffered loadshedding of critical products,

including the 0.5 degree Storm Relative Motion (SRM) as a result. The 8-bit reflectivity and velocity products now generated by the Open Radar Product Generator (ORPG) can not consistently be sent to the WFOs connected to these radars because of bandwidth limitations **(Recommendation 4).**

The CRS portion of NWR reported database errors after receiving a Severe Thunderstorm Warning product from WFO Little Rock, Arkansas at approximately 10:00 p.m. May 4. Following the database errors, all Severe Thunderstorm Warnings had to be recorded manually. Tornado Warnings and other products continued to be automatically broadcast on CRS. The WFO self-diagnosed and fixed the database problem on the morning of May 5.

The WFO Memphis staff was prepared for this event. During the period March-May 2003 WFO Memphis completed procedural drills on severe weather and flash flooding, and two WES training sessions, one of which was a supercell case from WFO Paducah, Kentucky.

Interviews of emergency management directors in Dyer County and Madison County, (where the fatalities occurred) indicate WFO Memphis has maintained a close working relationship with each. Dyer County has been recognized as StormReady and had hosted a spotter training session in the fall of 2002, just prior to the severe weather season.

In February 2003, a spotter training session was conducted in Jackson (Madison County) sponsored by the Office of Emergency Management. Dan Vaughn, the Madison County's Assistant EM Director stated he has regular contact with WFO Memphis. He receives all the warnings issued by the WFO via his pager. His first indication that a tornadic storm was approaching May 4 was via the pager message that came from WFO Memphis. The county EM director stated being StormReady, *"definitely helped and likely saved lives."* As the tornadoes were approaching, they deployed their spotters and were able to get information even though the NWR transmitter in Jackson was off the air as of 8:47 p.m. May 4, due to a power outage from a previous tornado in Madison County, which affected the area before the Jackson tornado struck at 11:23 p.m.

The director also stated he did not feel comfortable enough about the reliability of the Jackson NWR site to stop relying on the county's siren system to sound severe storm warnings for the area. An interview with the Memphis MIC, however, indicated this NWR system had undergone recent upgrades to its antenna and associated components and as a result, its reliability had greatly improved.

WFO Memphis has a well established amateur radio SKYWARN severe weather spotter program. There are eight SKYWARN divisions across the CWA. A roster of net control volunteers is maintained at the office and the amateur radio operators are called in during all significant severe weather events. WFO Memphis trained 1478 spotters in FY 2002, and 758 spotters through May 2003.

Local media reported that it is a common practice for WFO Memphis to conduct a briefing or press conference at the weather office prior to most significant severe weather outbreaks or winter storms. However, the threat of severe weather on May 4 and 5 was not apparent to the WFO Memphis forecasters early enough in advance to schedule a press conference prior the event.

Four of the major television stations covering the Memphis market area were interviewed. In every contact, the local television meteorologist had high praise for the performance of WFO Memphis the night of May 4 and into the morning of May 5.

Brian Teigland, WPTY ABC 24, praised WFO Memphis for issuing Special Weather Alerts during the event and the relationship between WFO Memphis and WPTY.

> "(WFO Memphis) *did a good job of getting out Special Weather Alerts (SWAs...issued under the SPS header)...it was a very thorough job.*"

> "*We have a tremendous relationship with the Memphis office. I talk to Jim Duke (WFO Memphis MIC) on a regular basis. We give them credit for their warnings and complement them on the air.*"

The station cut in live with the new SWA information and ran a severe weather message across the screen. More than one TV station used the SWA information on the air. Most of the television stations went with continuous live coverage about the time the first Dyersburg Tornado Warning was issued at 7:57 p.m.

WBBJ ABC 7 is located in Jackson where there were 11 fatalities. Meteorologist Gary Pickens stated, "*There was a good marriage between what they were putting out and what we were seeing. It gave us the opportunity to project where the storm was going. I noticed that they were able give up to 40 minutes of advanced notice, that's great lead time. It gave everyone a fighting chance to take cover and move to safety."*

Jim Jaggers, WHBQ Fox 13, used the text from Tornado Watch Number 239 which stated, "**this is a particularly dangerous situation**" to call the public's attention to the developing severe weather. Jim stated, "*We have a great relationship with the Memphis office...always have.*"

Dave Brown, Chief Meteorologist for WMC NBC 5, echoed Jim Jaggers' opinion about their relationship with WFO Memphis, "*I have had a partner relationship with WFO Memphis for 26 years. They did as good a job as anyone could have expected. They made it easy for us."*

A very successful means of communication initiated by WFO Memphis was an instant messaging system. Typically, the system would be used to inform the media of an upcoming severe warning, a change in a severe storm, or recent damage reports. The media uses the system to relay damage reports to the WFO and ask questions of the forecasters. All of the area

television stations that were interviewed, mentioned the usefulness of the instant messaging system and would like to see its use greatly expanded.

New warnings are reformatted and sent out every five minutes from WFO Memphis to computers in the office that are connected to area pager companies. This was a significant source of information for emergency management directors of Madison County and Dyer County. Both indicated it was the primary way they knew there was severe weather approaching on May 4.

Issues

Fact: Range folded Storm Relative Velocity data was evident in the lower elevation slices of the Memphis WSR-88D during a portion of the event.

Fact: The staff seemed reluctant to change the pulse repetition frequency (PRF) even though the new Open Radar Product Generator (ORPG) has simplified this task.

Finding 3: Storm Relative Velocity data from the WFO Memphis WSR-88D were not optimized for warning operations.

Recommendation 3: WFO Memphis Operational Staff should review their training on monitoring and adjusting radar sectors and PRFs to optimize velocity data for warning operations.

Fact: Frequent load shedding on the Columbus Air Force WSR-88D radar caused 0.5 degree SRM data to be lost to WFO Memphis during the May 4 severe weather event. The WFO effected a workaround, reducing the number of products on the Radar Product Set (RPS) list.

Fact: The bandwidth between NWS and DOD radars is also inadequate to view 8 bit radar data,
including Reflectivity and Storm Relative Motion.

Finding 4: Bandwidth to associated DOD WSR-88D sites is inadequate to ensure a flow of the required number and type of radar products, including 8 bit data, to enhance detection of severe weather.

Recommendation 4: NWS should work with DOD to increase bandwidth between a WFO and an associated WSR-88D. The connection should have sufficient bandwidth to assure that radar products needed for severe weather detection (including 8-bit data) are available to the warning forecasters.

E. WFO Paducah, Kentucky

Overview

A total of 21 tornadoes (1 F-4, 1 F-3, 1 F-2, 11 F-1s and 7 F-0s) were recorded across the Paducah, Kentucky CWA during the evening of May 6 through early morning on May 7. The strongest of these was a violent (F-4) tornado which moved through Pulaski, Massac, and Pope Counties in extreme southern Illinois. This tornado was on the ground between 9:32 p.m. and 10:42 p.m. on May 6, creating a 33-mile continuous path length with an average width of 2/3 of a mile. There were two fatalities from this tornado. Both fatalities occurred within the boundaries of Tornado Watch 275 and the respective Tornado Warnings for Pulaski and Massac Counties.

Nineteen of the 21 tornadoes were covered by Tornado Warnings. One weak tornado was covered by a Severe Thunderstorm Warning and there was another weak tornado that moved across portions of Hickman and Graves Counties in Kentucky that was not in a warning. The average lead time for counties in which a tornado occurred was 9 minutes and ranged from 0 to 37 minutes.

The Paducah WFO was included in the SPC's Day 2 Outlook on May 4. The WFO began to first emphasize the threat for severe weather in a HWO issued at 5:21 a.m., Monday, May 5. The HWO mentioned, **"damaging winds...large hail...and a few tornadoes will be possible."**

The HWO issued at 5:05 a.m., Tuesday, May 6, indicated the area was included in SPC's Day 1 moderate risk area. The product stated, **"Supercell storms with large hail...damaging winds and the potential for tornadoes will be possible across southeast Missouri this afternoon and evening. Damaging winds and large hail can be expected later as the storm form a line."**

The HWO was again updated at 5:41 p.m., Tuesday, May 6. The product was updated to include Tornado Watch 275 issued at 5:40 p.m. for the entire WFO Paducah's CWA. The product mentioned a significant severe weather outbreak was expected. A Special Weather Statement, issued shortly thereafter at 6:04 p.m., advised all to **"Remain vigilant. Be prepared to take quick action should severe weather be observed or a warning be issued."**

A 20-minute "Meet Me" conference call was initiated by the WCM around 7 p.m., May 6, to alert the WFO's customers and partners. Two hours prior to the call, approximately 50 persons, including emergency managers, state police, and media, were contacted via cell phone, pager, and e-mail with the use of "EM Notification" software. In addition, storm spotters, emergency managers, etc., participating in a locally developed program known as "E-Spotter" were notified.

The WFO Paducah staff met briefly the morning of May 6 at 8 a.m. for both a weather briefing and to assess staff availability. Additional staff were called in early in the event.

The WFO Paducah Station Duty Manual (SDM) defined the roles for each position during severe weather events. For an event where moderate to extensive severe weather is expected, the staffing guidelines are to have 10 people on duty. For the event on May 6, staffing ranged between 12 and 14, and included the MIC, SOO, WCM, and ESA. Due to staff familiarization with roles as defined in the SDM, no one perceived any duplication of duties, yet all felt the level of service provided would have been impossible with any lesser staffing.

In addition, two amateur radio net controllers reported to the WFO Paducah office at 8:30 p.m. Prior to the arrival of the net controller, the WCM, who is a licensed amateur radio operator, had been monitoring, since 6 p.m., the Cape Girardeau, Missouri, amateur radio repeater for communications describing storms approaching the Paducah WFO.

WFO Paducah issued 144 severe weather products between 7:44 p.m., May 6, and 1:28 a.m., May 7. There were 40 Tornado Warnings, 45 Severe Thunderstorm Warnings, 36 Local Storm Reports, and 23 Severe Weather Statements.

There were some significant communications issues at WFO Paducah during this event. At approximately 10:54 p.m. CDT, the AWIPS frame-relay circuits for WFO Paducah failed. AWIPS Network Control Facility (NCF) was notified at 10:58 p.m. and worked quickly to reestablish a backup connect via a 56-kbps dial connection at 11 p.m. CDT. This dial backup circuit was used until 5:27 a..m., May 7. The telephone company's trouble ticket indicated the outage was caused by a power problem at their Pulaski, Illinois, facility.

Four high-priority severe weather products sent from Paducah were delayed more than 60 seconds. All four appear to have been sent during the outage. The products were as follows:

- Tornado Warning for Ballard County Kentucky took 5 minutes and 24 seconds to reach NCF
- Severe Weather Statement took 5 minutes and 11 seconds
- Preliminary Local Storm Report took 3 minutes and 19 seconds
- Tornado Warning for Pope County Illinois took 1 minute and 2 seconds

When the AWIPS frame-relay network fails, dial backup can take several minutes to implement. There is no alarm at the local office that the primary AWIPS frame-relay has failed **(Recommendation 5).**

After dial backup was initiated, it became apparent that the 56 kbps bandwidth was insufficient to transmit lower priority products, such as radar data from three associated WSR-88Ds and Internet traffic, in a timely manner. Radar data reaching NCF were delayed by times ranging from 16 minutes to 2 hours, 45 minutes from 11:16 p.m., May 6 through

6:07 a.m. May 7. Connectivity with the Central Region Internet web server was also disrupted. This also delayed communication for Internet-based applications such as E-Spotter **(Recommendation 6).**

WFO Paducah utilized E-Spotter extensively during the event to receive and provide critical information. This software also allowed for the rapid sharing and heightened seriousness (**"extremely dangerous situation"**) simultaneously relayed to multiple emergency managers for the deadly F4 tornado.

WFO Paducah had extensive coordination during the event with local and state officials. One example of this coordination was the repeated contact with the Illinois State Police Post in Ullin, Illinois. Accurate forecasts were provided to the post of where the F4 tornado could potentially cross Interstate 24. Contact with Metropolis, Illinois 9-1-1 Communication Dispatcher led to the movement of Massac County firemen away from the tornado to a safe shelter.

A late winter/early spring staff training program at WFO Paducah had just concluded prior to the week of May 4. As part of this program, each forecaster completed at least two WES cases. One case was on high precipitation supercells intersecting a boundary which produced a tornado in April 2002 in the Paducah CWA. The second case was from WFO Des Moines, Iowa on April 11, 2001, that included mini-supercells producing multiple tornadoes. Additional training encompassed various COMET (Cooperative Program for Operational Meteorology, Education, and Training) modules and webcast seminars. Severe Weather seminars earlier in the year reviewed the April 2002 tornado case. A full staff Severe Weather Roundtable Session was held in February 2003. This dedicated session included discussion of total office operations during severe weather.

The following WFO Paducah special teams were key contributors to the overall readiness of this event: the WFO Paducah Tornado Team (responsible for post-event assessments), the WFO Paducah Quick Response Verification Team (responsible for calling individuals and businesses for storm reports), and the WFO Paducah Storm Damage Survey Team (responsible for field surveys of storm damage). All of these team members had gone through early 2003 spring meetings to review procedures and mission goals.

WFO Paducah accomplished an aggressive 2003 SKYWARN spotter training campaign. From January through March 2003, 48 SKYWARN spotter training seminars were taught by a team of eight WFO Paducah staff instructors. In addition, the Paducah WCM and MIC have been very active in working with counties and communities in the Storm Ready program. WFO Paducah's SOO also developed a specialized radar training course for emergency managers that has been frequently requested.

The WFO Paducah staff is active in preparedness and outreach events. Numerous public, emergency management, and media workshops and outreach activities were noted by the service assessment team.

The WFO Paducah staff received a number of positive comments from both EMs and media:

> Keith Davis, Massac County, Illinois, 9-1-1 Coordinator, stated, *"Based on the warning phone call you (the NWS) made to his cell phone, a number of firemen were able to make it to safe shelter near Round Knob just before the second (tornadic) storm got to them. Needless to say, they are **very, very grateful** to you (the NWS) for making that extra call."*
>
> Justin Gibbs, SKYWARN Coordinator at Murray State University in Calloway County, Kentucky, *"It happened again and you all still nailed it. As always, you all handled a very dangerous situation well. **Impeccable work** on the (Massac) event, the northern Graves damage, and our damage here. We really **appreciated having the amateur radio operator in there**, and having us **well informed on E-spotter**."*
>
> A recorded telephone message to WFO Paducah's WCM , *"I just wanted to tell **the Paducah staff** that they **saved some people's lives out here tonight**. We were not looking especially for that second storm. We lost all power and lost pretty much everything but the NOAA weather radios. Tell your people they did a **phenomenal, phenomenal job** tonight and we are **very much appreciative** down here in Calloway County."*

Through their Weather Information Now (WIN) telephone tree, WFO Paducah keeps an open telephone to the public 24 hours a day, seven days a week. This service provides direct access to a staff member any time a need arises. During this tornado outbreak, 3 to 4 staff members staffed the phones at all times. This communication outlet served to pass on vital information to the general public. The Local Emergency Planning Committee from Henderson County Kentucky said,

> *"Thank you for your **immediate telephone availability, so we can talk to a person**. This also gives us the opportunity to ask quick questions and get immediate response and answers. Keep up the **good work on communications**!!"*

The Paducah Sun Newspaper featured a front page article on May 11, 2003, that focused on "what it's like to work at the National Weather Service" when an ongoing event of this magnitude occurs. ***"Controlled Chaos"*** was the descriptive term used to begin the article. It was then quickly defined by staff members that qualified it by, *"Everybody knew what their job was and they did it."*

Issues

Fact: On May 6, 2003, at approximately 10:54 p.m. CDT, the AWIPS frame-relay circuits for WFO Paducah failed. Connectivity was reestablished by NCF (AWIPS Network Control Facility) on a 56 kbps dial connection by about 11:00 p.m. CDT. This dial backup circuit was

used until 5:27 a.m. on May 7, 2003. The phone company's trouble ticket indicated the outage was caused by a power problem at their Pulaski, Illinois facility.

Fact: AWIPS met applicable requirements for high priority message availability during this event.

Fact: The NCF operator's performance was exemplary in restoring WFO Paducah's connectivity within two minutes of receiving the IT Operations (ITO) alarm from the site, even though the alarm arrived four minutes after the actual frame relay outage occurred.

Fact: Four high-priority severe weather products sent from WFO Paducah, including Tornado Warnings, were delayed on the AWIPS WAN from 62 seconds to 5 minutes, 24 seconds due to the failure. The products were not delayed for other methods of dissemination such as NOAA Weather Radio.

Fact: When the AWIPS frame-relay network fails, dial backup can take several minutes for NCF to implement.

Fact: There is no alarm at the local office that the AWIPS frame relay line has failed.

Finding 5: Time needed to send critical severe weather products was lost during this failure of the frame-relay circuit.

Recommendation 5a: NWS should assure the AWIPS software notifies the WFO operations staff that a frame relay circuit failure has occurred and dial backup has been implemented.

Recommendation 5b: NWS should develop methods to reduce the amount of elapsed time between a frame relay outage and when this outage generates an IT Operations (ITO) alarm at the NCF operator's console.

Fact: The 56 kbps dial backup to the AWIPS frame-relay network is used to transmit lower priority products including radar images.

Fact: Radar data reaching NCF was delayed in excess of 16 minutes from 11:16 p.m. CDT May 6 through 6:07 a.m. May 7 due to the limited bandwidth of the dial backup line. The peak delay reached was 2 hours 45 minutes.

Fact: Media and Emergency Managers rely on timely radar images via the Radar Product Central Collection Dissemination Service (RPCCDS) to make timely decisions or provide information for their communities.

Finding 6: The 56K bandwidth currently used by the NWS for frame-relay backup is inadequate in situations such as severe weather outbreaks. In these instances, multiple

radars may be sending images to the RPCCDS, and critical partners and customers depend on timely receipt of these images.

Recommendation 6: The Office of Science and Technology (OS and T) should re-evaluate bandwidth requirements for AWIPS dial backup or determine other ways to reduce delays in customer receipt of radar and other critical data.

This two-story home in western Massac County, Illinois suffered F4 damage. The remnants of the upper floor are seen in the distance.

F. WFO Norman, Oklahoma

Overview

During the five day period between May 6 and May 10, the CWA of WFO Norman, Oklahoma was impacted by an extended period of severe weather. The WFO experienced severe weather in its CWA every day, including tornadoes on May 7, 8, and 9.

By far, the most significant day was May 8 and this day will be the primary focus of this

section. On May 8, a violent (F4) tornado swept across Moore and south Oklahoma City along a 19 mile path. The tornado injured 135 and caused significant damage to a General Motors assembly plant and Tinker Air Force Base. There was a 21 minute lead time for the Tornado Warning on this storm and it produced no fatalities. The tornado produced $110,000,000 damage. Two other tornadoes, both F0 intensity, struck south Oklahoma City, and Red Rock (in northern Oklahoma) with no injuries or fatalities and only tree damage reported. All 3 tornadoes were covered by Tornado Warnings. Average lead time was 17 minutes, with a range from 15 to 21 minutes.

May 9 was also a significant severe weather day as seven tornadoes moved across southwest and central Oklahoma. The most significant was a strong (F3) tornado that moved through northwest Oklahoma City along an 18 mile path. This tornado caused 10 minor injuries and no direct fatalities. There was a 41 minute lead time for the Tornado Warning on this storm. All seven tornadoes (1 F-3, 4 F-1s and 2 F-0S) were covered by Tornado Warnings. The tornadoes had an average lead time of 38 minutes, with a range from 26 to 45 minutes. The tornadoes produced $10,000,000 damage.

Services Before and During May 8 event

Severe weather awareness in this area was already elevated by recent severe weather and by the anniversary of the May 3, 1999 F5 tornado which killed over 40 people in Grady County, Moore and south Oklahoma City. The Moore and south Oklahoma City area were again affected by the May 8 event.

The WFO recognized early on May 8 that severe weather was likely. The 7:00 a.m. Hazardous Weather Outlook (HWO) noted the SPC slight risk covering the area, and mentioned **"The most likely time...will be from mid afternoon through late tonight."** The HWO also urged storm spotter groups and emergency management officials to plan for severe weather operations "**...from around 3 p.m. through this evening."** The WFO updated the HWO at noon, upgrading the severe risk from slight to moderate, and mentioning the "**...risk of a few tornadoes."**

At 1:35 p.m., the SPC issued Tornado Watch #304 including much of WFO Norman's CWA. By 2:26 p.m., the first storms began to appear on radar, and the WFO began issuing experimental Warning Decision Updates, discussing the potential for severe weather in the developing cells. At 2:30 p.m., the WFO conducted a live NOAA Weather Radio (NWR) briefing on all of their transmitters, discussing the likelihood of severe weather. Extra staffing was made available. Frequent Regional Weather Discussions, Warning Decision Updates and Significant Weather Advisories were issued as storms continued to develop. The HWO was updated at 3:40 p.m. to include a high risk, including the Oklahoma City metropolitan area.

From the time of the first Tornado Warning in Grady County at 4:33 p.m., until the last Tornado Warning expired at 6:45 p.m., the WFO issued a total of 60 products, including 5 Tornado Warnings, 3 Severe Thunderstorm Warnings, 24 Severe Weather Statements, 6 Local

Storm Reports, 9 Significant Weather Alerts, 8 Warning Decision Updates, and 5 Regional Weather Discussions. (The Significant Weather Alerts and Regional Weather Discussions are experimental products). In addition, live NWR coverage was provided from 5:13 p.m. through 6:00 p.m.

Throughout the day, the WFO website included experimental graphics depicting the increasing threat of severe weather and likely time and area of development.

The thunderstorm which spawned the F4 tornado was first identified in a Warning Decision Update at 3:45 p.m. This was followed by several intervening update products. A Severe Thunderstorm Warning was issued for Grady County at 4:09 p.m., and was upgraded to a Tornado Warning at 4:33 p.m. While this initial warning was not verified, it did heighten awareness for the next downstream counties, McClain and Cleveland, which mark the beginning of the Oklahoma City metro area.

The WFO issued a Tornado Warning for McClain County, Cleveland County and southern portions of Oklahoma County at 4:49 p.m., specifically mentioning the city of Moore in Cleveland County. It was in Moore the first reports came in of a tornado touching down near state Highway 37 and Western Avenue at 5:10 p.m. Upon receiving this report, the WFO went to "live" coverage on the Oklahoma City NWR for the duration of the event, providing near real-time information from spotters via amateur radio and telephone reports. The WCM provided live broadcasts on NWR. The tornado continued through Oklahoma County, striking a General Motors plant and Tinker Air Force Base, and finally lifted near Choctaw in eastern portions of the county at 5:40 p.m. A second storm produced a brief F0 tornado in Red Rock in northern Oklahoma with no injuries and only damage to trees.

There were eleven operational staff members working during the event, including the MIC, SOO, and WCM. There were two routine product forecasters, 2 warning forecasters utilizing a sectorized warning approach, two warning coordinators (the MIC and SOO), and one forecaster dedicated to writing Significant Weather Advisories as a "heads-up" for downstream counties. There were also 3 public service personnel to collect data and handle phone calls.

Services Before and During the May 9 event

The May 9 morning Hazardous Weather Outlook mentioned SPC's moderate risk of severe weather from late afternoon Friday through early Saturday morning, and specifically mentioned that "**...**tornadoes will also be possible." SPC issued Tornado Watch #320 for central Oklahoma at 3:35 p.m., valid until 9:00 p.m.

The WFO had been issuing warnings for storms in the north Texas part of their CWA throughout the day. During the afternoon, severe storms producing large hail developed in central and southwest Oklahoma, including the Oklahoma City metro area, and continued into the evening hours. WFO products were plentiful in number, frequency and variety. Throughout

the 16 hour event, a total of 211 products were issued, including 61 Severe Weather Statements, 38 Local Storm Reports, 38 Severe Thunderstorm Warnings, 29 Significant Weather Advisories, 16 Warning Decision Updates and 13 Tornado Warnings. Live NWR broadcasts were also done from 10:00 PM to 11:30 PM as the storms moved across the Oklahoma City metro area.

Staffing during the event was comparable to that on May 8, with as many as 12 operational meteorological staff on duty, including the MIC, SOO, and WCM. Three sectors of warning operations were utilized to provide greater focus on individual storm systems.

Information common to both events

Staff interviewed expressed concern with regard to the performance of the AWIPS HP workstation to keep up with a rapidly developing event in multiple locations. At least one forecaster had to revert to manually editing Severe Weather Statements to maintain a constant flow of products. (The AWIPS workstation upgrades being implemented nationwide will address this performance concern.) During both events, the WFO provided constant live coverage on the Oklahoma City NWR transmitter. These live broadcasts provided a constant flow of the latest information from all available sources, including WSR-88D and Terminal Doppler Weather Radar (TDWR), storm spotters, then media, and other sources. At the same time, traditional text products, such as the Severe Weather Statement were still being issued frequently **(Recommendation 7)**.

With a history of repeated tornado strikes (the most recent being the May 3, 1999 F5 tornado in virtually the same location as as the tornado on May 8), the Oklahoma City population is well aware of the threats tornadoes pose to their area. The WFO outreach efforts capitalize on this built-in awareness, and the emergency management and media outlets surveyed indicate considerable effort on the part of the WFO to build and maintain relationships and assist in education and outreach efforts. One emergency manager stated that he is in contact with the WFO WCM "...at least every other week."

Feedback from the emergency management community at the state, county and local levels was unanimously positive. All individuals contacted indicated that they were briefed "well in advance" of the actual event, and were fully aware that a dangerous situation existed. All expressed great confidence in the local WFO staff and specifically mentioned that they considered the local WFO as their most valuable source of real-time weather information. Oklahoma emergency managers have efficient access to real-time NWS radar and forecast information through an Internet decision support system.

The following items were specifically mentioned by the emergency management personnel as being especially valuable:

- Proactive coordination and communication efforts to provide a two-way flow of information

- Experimental graphics posted on the Internet

- Timely post-event evaluations and information, especially on the Internet

- Numerous, timely, short and to the point Severe Weather Statements

Gayland Kitch, The Emergency Management Director in Moore, whose community has been struck by tornadoes on October 4 , 1998, May 3, 1999, and May 8, 2003 said, *"Thanks once again for having made possible over the years a tremendously strong program of weather support for the emergency managers of the state of Oklahoma, and also in providing the training for us to properly use the products."*

The quote below, from Oklahoma Governor Brad Henry, illustrates how well customers perceived services and products from WFO Norman during the event.

> "*They (NWS) did such a tremendous job of giving early warning to the residents of Oklahoma about these storms in such a manner that it enabled people to seek appropriate shelter. I believe that was a major factor contributing to the fact that we had only one (indirect) fatality, and frankly, minimal serious injuries."*

Service Assessment team members interviewed two televison meteorologists, one from KOCO and one from KWTV in Oklahoma City. Both of them said they have excellent rapport with staff at both the NOAA SPC and the WFO in Norman. During both events, broadcasters provided continuous coverage featuring updated warnings and forecasts from the NWS as well as reports from their storm spotters who were chasing the tornadoes. Broadcasters were in unison in their accolade that the "NWS warnings were excellent, timely, and the forecasts were out there in advance." Broadcasters said they agreed with the urgent tone of the Tornado Warning issued May 9 as an F3 tornado moved across northwest portions of the Oklahoma City metro area.

The WCM sent a note to broadcast meteorologists on May 8 informing them that the NWS would be experimenting with a new product, the Warning Decision Update. Reactions include:

> "*Both products are excellent. OKC guys probably didn't get to monitor the warning decision bulletins, but I followed them closely and they were right on...giving critical information. I got to use them last night, and again an awesome product. Regional weather discussions are well appreciated, especially from spotters."*
> Andy Wallace, KSWO.

> "*It was like they <u>knew</u> in advance what was going to happen!*" Rick Mitchell, KOCO-TV

"We found the Warning Decision Update useful on Thursday and Friday. It was nice to read what you guys were thinking, and to get a heads up on the potential for warnings. It was also helpful to read about things that you were noticing that we may have overlooked. All in all, I found this product very useful, and I hope it will continue."
Frank Johnson, KOCO-TV

Service Assessment team members interviewed 26 people in Moore about the May 8 tornado. Everyone in this sample group acknowledged awareness of the possibility of severe weather in the area as early as the previous day and said they remember hearing media reports of impending severe weather the morning of their events.

Issues

Fact: Severe Weather Statements were not individually broadcast on NWR during live programming.

Finding 7: Severe weather reports received from phone, amateur radio, and other sources for inclusion in Severe Weather Statements were simultaneously broadcast during live NWR programming, thus speeding the process of disseminating critical information to the public.

Recommendation 7: WFO Norman station instructions should assure that the information from Severe Weather Statements, and other pertinent information from other sources, be included in the live NWR broadcasts to speed the dissemination of fast changing information.

The General Motors Manufacturing Plant in southeast Oklahoma City after the May 8 tornado.

G. Issues Common to All Five WFOs

Since most WFOs are issuing numerous LSRs during severe weather outbreaks, a common request from the media was a summary LSR be issued shortly after the event ends. Since so many LSRs are issued during major events, they felt it would possible to miss some reports **(Recommendation 8).**

The public and the media continue to increase use of the Internet for information such as forecasts and data such as radar data. For the period May 4 through 10, Southern Region web server computers recorded an average of over 22.5 million hits per day (a hit is defined as an object downloaded from a web page), Central Region recorded an average of over 16.5 million hits per day and SPC alone had an average of 5.6 million hits per day. Since there is high demand on Internet resources during major severe weather outbreaks, Central Region Headquarters has set up a priority username and password system for emergency managers to obtain the most timely radar data.FF

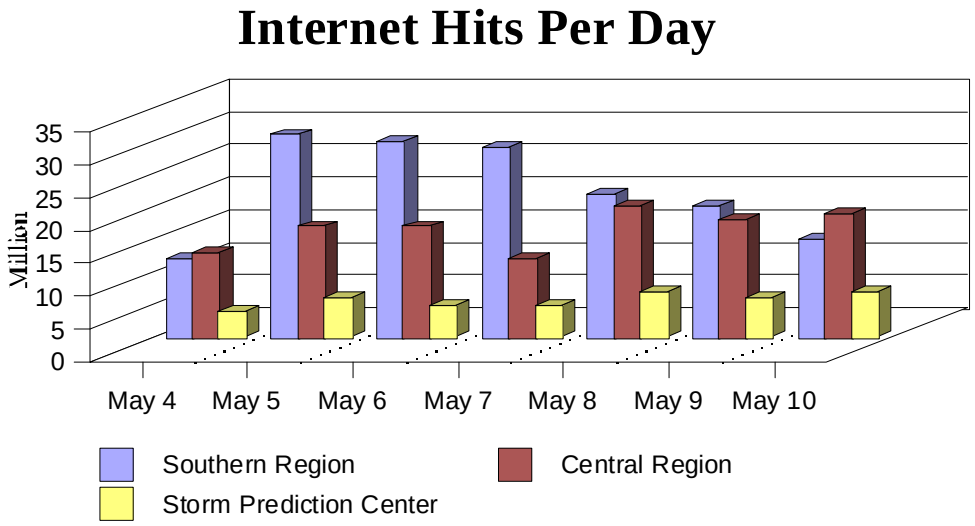

Figure 9. Number of "hits" on web servers (in millions) for Southern Region Headquarters, Central Region Headquarters and the Storm Prediction Center during the period May 4-10, 2003.

All of the WFOs and the SPC posted information including maps of storm surveys and tornado damage images to their pages after their respective events. Many favorable comments were received by the service assessment team with regard to information posted on the WFO's/SPC Web Page. However, some WFOs began to post information as soon as 2 to 3 hours after the event, while one WFO did not post any information until 4 days after their outbreak.

The regions should encourage WFOs to, as resources permit, quickly post storm information on their web pages **(Recommendation 9).**

Issues

Fact: Most WFOs issued numerous real-time LSRs during their tornado outbreaks.

Fact: A frequent media request during interviews was for summary LSRs to be issued at the end of the event.

Fact: There is no requirement in NWS Directive 10-517 for summary LSRs at the end of major weather events.

Finding 8: Since real-time LSRs may be numerous during severe weather outbreaks, the media and emergency mangers need a summary LSR issued at the end of the event. This summary will recount all LSRs issued during the event.

Recommendation 8: NWS Directive 10-517 should be revised to require summary LSRs shortly after the end of a major severe weather outbreak.

Fact: Media and emergency managers interviewed praised both the WFOs and the SPC for information posted to web pages. The most used information included text forecasts, graphical forecasts, and storm survey and damage images.

Fact: SPC and all WFOs posted information concerning their respective outbreaks on their web pages.

Fact: Some WFOs posted information concerning their respective outbreaks several hours after the event, while others posted no information until 4 days after the event.

Finding 9: WFOs should place priority on timely posting of storm information on their web pages, including damage surveys and storm damage images after major events.

Recommendation 9: The Regions should work with all WFOs to emphasize the value of quickly placing post-storm information on their Internet web pages for their respective media, emergency managers, and the public.

Best Practices

Improved Services to Customers and Partners

1. WFO Memphis, Tennessee utilized instant messaging and paging to notify partners of impending severe weather.

2. WFO Paducah, Kentucky and Pleasant Hill, Missouri used a notification system called "E-Spotter" to alert spotters and emergency managers of severe weather potential.

3. WFOs Pleasant Hill and Springfield, Missouri and Norman, Oklahoma routinely stop and restart their AWIPS workstations before an outbreak of severe weather, to help assure adequate workstation performance. The WFO Pleasant Hill ITO did a complete restart of all workstations prior to their May 4 outbreak.

4. WFO Springfield, Pleasant Hill, and Paducah utilized conference calls with emergency managers to alert them of the severe weather threat well in advance.

5. WFO Pleasant Hill mapped out their severe weather position utilization plan in advance. The warning coordinator for the event assigned "flash cards" to each person during the event with clearly defined duties for each position.

6. WFO Norman conducted a live severe weather briefing on NOAA Weather Radio.

7. Central Region Headquarters staff members were dispatched to WFO Pleasant Hill to augment staffing during their May 4 severe weather event, and assisted office operations in the days after the event.

Appendix A

Fujita Tornado Intensity Scale[1]

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

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

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

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

Appendix B

Direct Fatalities in Each WFO's CWA

WFO Pleasant Hill - May 4

No.	Age	Gender	Location	Circumstances
1	81	M	Kansas City, Ks.	Heading for Shelter

WFO Springfield - May 4

No.	Age	Gender	Location	Circumstances
1	50	F	Cherokee County, Ks. 4N/2W Galena	At home. Thrown 500 feet from home.
2	80	M	Cherokee County, Ks near Badger	In frame home which was destroyed
3	73	F	Cherokee County, Ks near Badger	In frame home which was destroyed
4	48	F	Crawford County, Ks Ringo	In mobile home
5	68	M	Crawford County, Ks. Ringo	In mobile home
6	87	F	Crawford County, Ks. Franklin	In frame home
7	40	F	Greene County, Mo Battlefield	Outdoors
8	53	M	Camden County, Mo 5 SW Camdenton	In mobile home
9	75	M	Camden County, Mo 6 S Camdenton	At home
10	76	F	Camden County, Mo 6 S Camdenton	At home

11	70	M	Jasper County, Mo. Carl Junction	In frame home.
12	62	F	Jasper County, Mo Carl Junction	In frame home
13	63	F	Christian County, Mo 4.5 N Clever	In frame home
14	88	M	Barton County, Mo 2 W Liberal	In frame home, on way to basement
15	52	F	Lawrence County, Mo. Marionville	Modular home
16	39	F	Lawrence County, Mo. 1 N Marionville	Mobile home
17	20 wks	M	Lawrence County, Mo 2 N Monett	In mobile home
18	46	F	Lawrence County, Mo 2 N Monett	In mobile home
19	Unk	M	Lawrence County, Mo Pierce City	In field house
20	40	M	Cedar County, Mo Stockton	In frame home
21	34	M	Cedar County, Mo Stockton	Outdoors
22	86	M	Cedar County, Mo Stockton	Handicapped, could not get to basement
23	49	M	Dallas County, Mo Urbana	In modular home
24	47	M	Dallas County, Mo Urbana	In modular home
25	83	F	Camden County, Mo 4 NNW Decaturville	In frame home

11	70	M	Jasper County, Mo. Carl Junction	In frame home.
12	62	F	Jasper County, Mo Carl Junction	In frame home
13	63	F	Christian County, Mo 4.5 N Clever	In frame home
14	88	M	Barton County, Mo 2 W Liberal	In frame home, on way to basement
15	52	F	Lawrence County, Mo. Marionville	Modular home
16	39	F	Lawrence County, Mo. 1 N Marionville	Mobile home
17	20 wks	M	Lawrence County, Mo 2 N Monett	In mobile home
18	46	F	Lawrence County, Mo 2 N Monett	In mobile home
19	Unk	M	Lawrence County, Mo Pierce City	In field house
20	40	M	Cedar County, Mo Stockton	In frame home
21	34	M	Cedar County, Mo Stockton	Outdoors
22	86	M	Cedar County, Mo Stockton	Handicapped, could not get to basement
23	49	M	Dallas County, Mo Urbana	In modular home
24	47	M	Dallas County, Mo Urbana	In modular home
25	83	F	Camden County, Mo 4 NNW Decaturville	In frame home

WFO Memphis

No.	Age	Gender	Location	Circumstances
1	31	F	Rural Madison County, Tn.	In mobile home
2	34	M	Rural Madison County, Tn.	In mobile home
3	8	M	Rural Madison County, Tn.	In mobile home
4	40	F	Rural Madison County, Tn.	In mobile home
5	39	M	Rural Madison County, Tn.	In mobile home
6	44	F	Rural Madison County, Tn.	In mobile home
7	23	F	Rural Madison County, Tn.	In mobile home
8	7	M	Rural Madison County, Tn.	In mobile home
9	53	M	Rural Madison County, Tn.	Found in street, was visiting a mobile home in area
10	22	F	Jackson	Apartment building
11	1	M	Jackson	Apartment building

WFO Paducah

No.	Age	Gender	Location	Circumstances
1	65	F	Massac County, Il NW of Joppa	In mobile home
2	53	M	Pulaski County, Il Grand Chain	In home

WFO Norman - May 8/9

None

Appendix C

Event Statistics

WFO Kansas City, Missouri (EAX)
May 4, 2003

# Tornadoes	9
# Tornado Warnings	23
Average Lead Time for Tornado Warnings	24 minutes
# Severe Thunderstorm Warnings	21
Fatalities	1
Injuries	43
Homes Destroyed	223
Homes Damaged	1103
Damage Costs	~$143 million

WFO Springfield, Missouri (SGF)
May 4, 2003

# Tornadoes	15
# Tornado Warnings	33
Average Lead Time for Tornado Warnings	23 minutes
# Severe Thunderstorm Warnings	25
Fatalities	25
Injuries	143
Homes Destroyed	1143
Homes Damaged	2024
Damage Costs	~$159 million

WFO Memphis, Tennessee (MEG)
May 4, 2003

# Tornadoes	18
# Tornado Warnings	34
Average Lead Time for Tornado Warnings	20
# Severe Thunderstorm Warnings	20
Fatalities	11
Injuries	70
Homes Destroyed	353
Homes Damaged	4834
Damage Costs	$100,000,000

WFO Paducah, Kentucky (PAH)
May 6, 2003

# Tornadoes	21
# Tornado Warnings	40
Average Lead Time for Tornado Warnings	9
# Severe Thunderstorm Warnings	32
Fatalities	2
Injuries	38
Homes Destroyed	205
Homes Damaged	453
Damage Costs	$27,000,000

WFO Norman, Oklahoma (OUN)
May 8, 2003

# Tornadoes	3
# Tornado Warnings	5
Average Lead Time for Tornado Warnings	17
# Severe Thunderstorm Warnings	3
Fatalities	0
Injuries	135
Homes Destroyed	375
Homes Damaged	1923
Damage Costs	~$110 million

WFO Norman, Oklahoma (OUN)
May 9, 2003

# Tornadoes	7
# Tornado Warnings	13
Average Lead Time for Tornado Warnings	38
# Severe Thunderstorm Warnings	38
Fatalities	0
Injuries	7
Homes Destroyed	57
Homes Damaged	930
Damage Costs	~$10 million