Tornado Awareness

Participant Guide

Version 1.0

FEMA

NATIONAL DISASTER PREPAREDNESS TRAINING CENTER

Copyright Information

Tornado Awareness

This Printing: 2015
Printed in the United States of America

This program was supported by Cooperative Agreement Number 2009-NA-T9-K004, administered by the U.S. Department of Homeland Security, Training & Exercise Integration/Training Operations. Points of view or opinions in this program are those of the author(s) and do not represent the position or policies of the U.S. Department of Homeland Security.

FEMA's National Training and Education Division (NTED) offers a full catalog of courses at no-cost to help build critical skills that responders need to function effectively in mass consequence events. Course subjects range from Weapons of Mass Destruction (WMD) terrorism, cybersecurity, and agro-terrorism to citizen preparedness and public works. NTED courses include multiple delivery methods: instructor led (direct deliveries), train-the-trainers (indirect deliveries), customized (conferences and seminars) and web-based. Instructor led courses are offered in residence (i.e. at a training facility) or through mobile programs in which courses are brought to state and local jurisdictions that request the training. A full list of NTED courses can be found at www.firstrespondertraining.gov.

Table of Contents

This page is intentionally left blank.

Tornado Awareness

Participant Guide

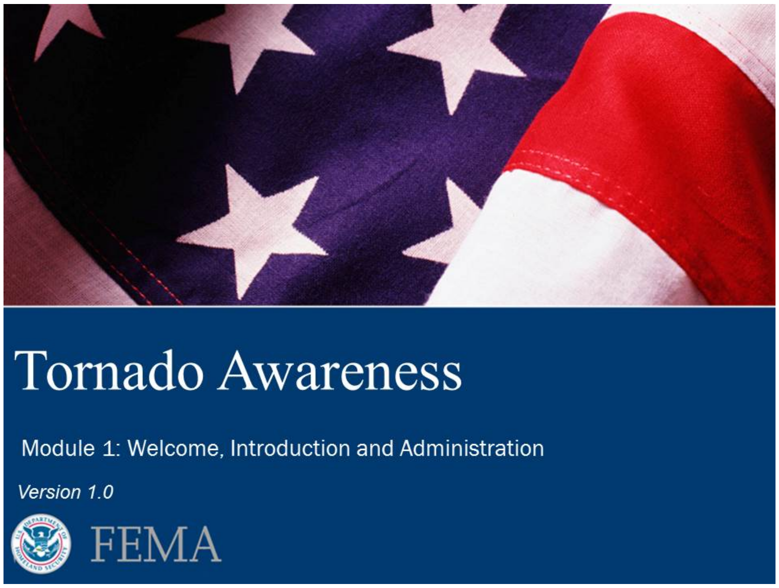
Module 1: Welcome, Introduction and Administration

Version 1.0

FEMA

This page is intentionally left blank.

Module 1: Welcome, Introduction and Administration – Administration Page



Slide 1-1. Welcome, Introduction and Administration

Duration

45 minutes

Scope Statement

In this module, the instructors will welcome participants to the course, explain how instruction will take place and provide an agenda. The instructors will also:

- Review the course purpose, goals and objectives;
- Describe the course content; and
- Wrap up any administrative details that remain.

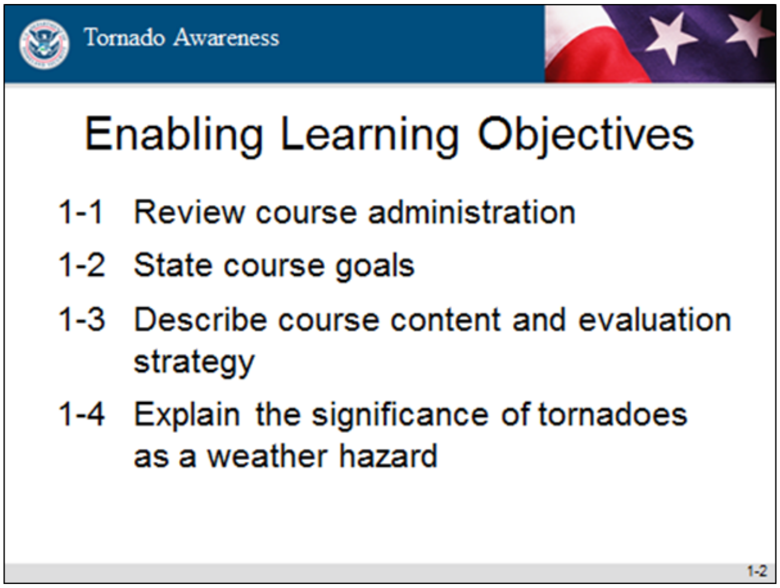
Next, the instructors will:

- Introduce him or herself and lead a round of introductions among the participants; and
- Make an assessment of the participants' existing comprehension of course materials by conducting a pre-test.

Terminal Learning Objective (TLO)

Participants will be able to state the course goals and its major module objectives as well as understand the importance of tornadoes as a weather hazard.

Enabling Learning Objectives (ELOs)



Slide 1-2. Enabling Learning Objectives

At the conclusion of this module, participants will be able to:

1-1 Review course administration.
1-2 State the course goals.
1-3 Describe the course content and evaluation strategy.
1-4 Explain the significance of tornadoes as a weather hazard.

Resources

- Instructor Guide (IG)
- Class roster
- Module 1 presentation slides
- Laptop with presentation software installed and CD-ROM capability
- Audio-visual (A/V projection unit)
- Projector screen
- Chalkboard (and chalk), whiteboard (and dry erase markers), or easel and easel paper (and permanent markers)
- Correction tape dispensers (two)
- Letter-size manila envelopes (four; one each for the course registration forms, pre-tests, post-tests, and Level 1 evaluations)
- One of each of the following items per participant:
  - Participant Guide (PG) available for download from http://ndptc.hawaii.edu/
  - Participant Handout

- Pre-test answer sheet corresponding to pre-test version
- Post-test answer sheet corresponding to post-test version

Instructor-to-Participant Ratio

2:40

Reference List

National Weather Service (NWS). 2013. NWS Weather Fatality, Injury and Damage Statistics. Accessed 2013. http://www.nws.noaa.gov/om/hazstats.shtml

Practical Exercise Statement

Not Applicable

Assessment Strategy

- Instructors observation of participant involvement in classroom discussion
- Instructor-led discussion to gauge participant grasp of module lesson topics
- Instructors administration of objectives-based pre-test to assess the knowledge participants have gained in each module
- Participant input on expectations for the training course

Tornado Awareness

Icon Map

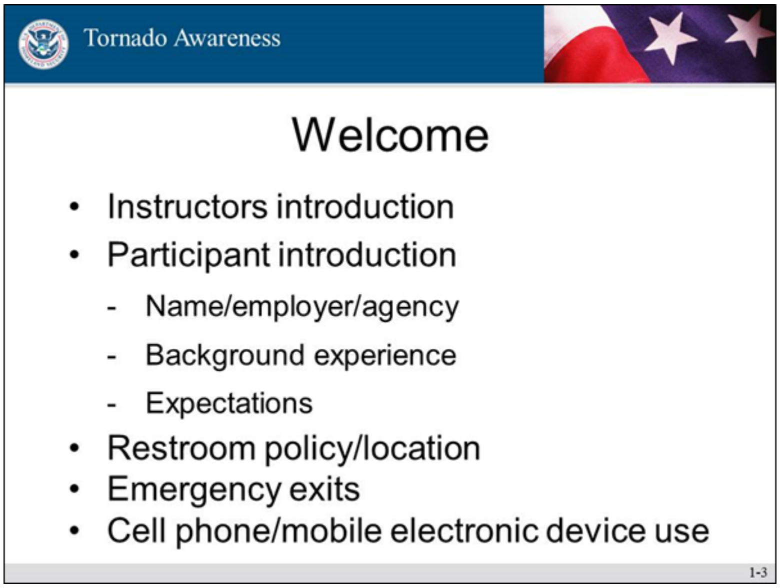
Knowledge Check: Used when it is time to assess participant understanding.

Example: Used when there is a descriptive illustration to show or explain.

Key Points: Used to convey essential learning concepts, discussions and introduction of supplemental material.

Participant Note: Used to indicate text that has been included as additional information for the participant. The text may not be directly addressed in the slide presentation or during class discussion.

Participant Notes:



Slide 1-3. Welcome

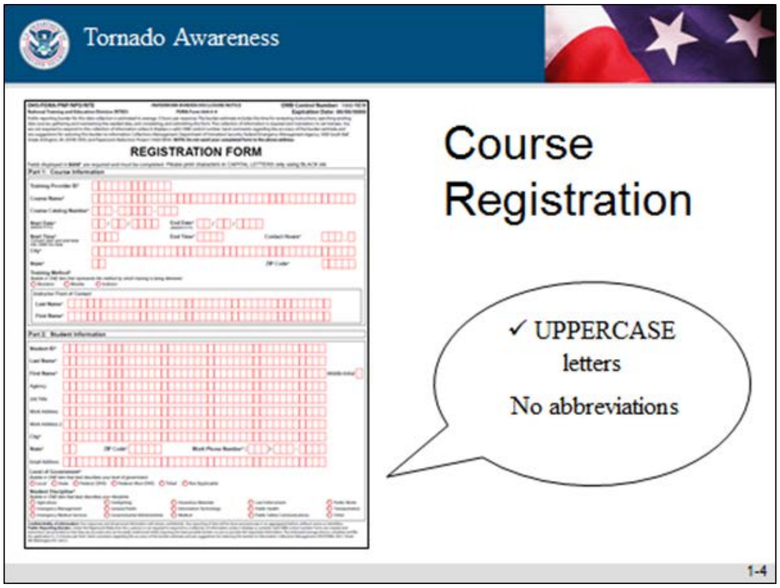
The instructors will welcome participants and provide a brief summary on the National Disaster Preparedness Training Center (NDPTC).

The instructors will lead a round of participant self-introductions. Participants are asked to provide the following information which will help the instructors to learn names as well as understand the participants' backgrounds and motivations:

- Name and organization or agency (if any);
- Reasons for taking this course;
- Background experience; and
- Intentions/expectations for taking this course.

Participants are encouraged to take an active role in the class discussions and group activities to demonstrate comprehension.

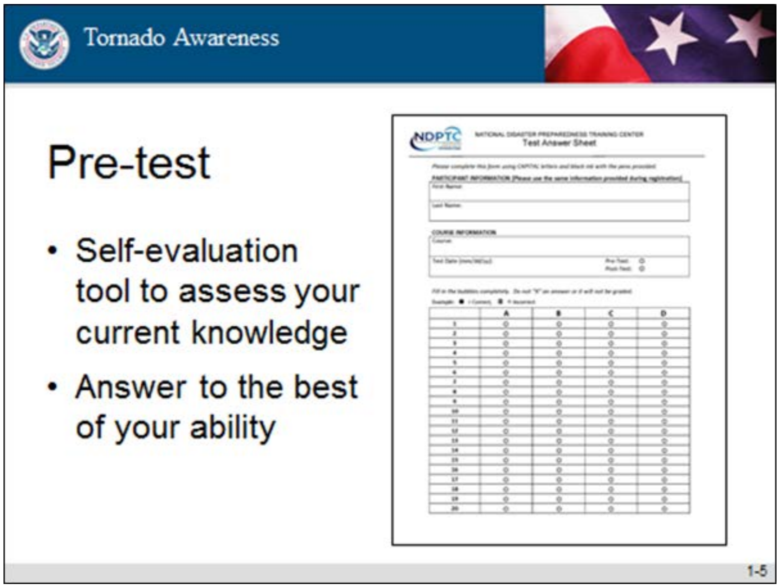
Participant Notes:



Slide 1-4. Course Registration

The instructors will distribute the course registration forms for those participants who have not yet completed the online registration and then collect them when they are completed.

Participant Notes:



Slide 1-5. Pre-test

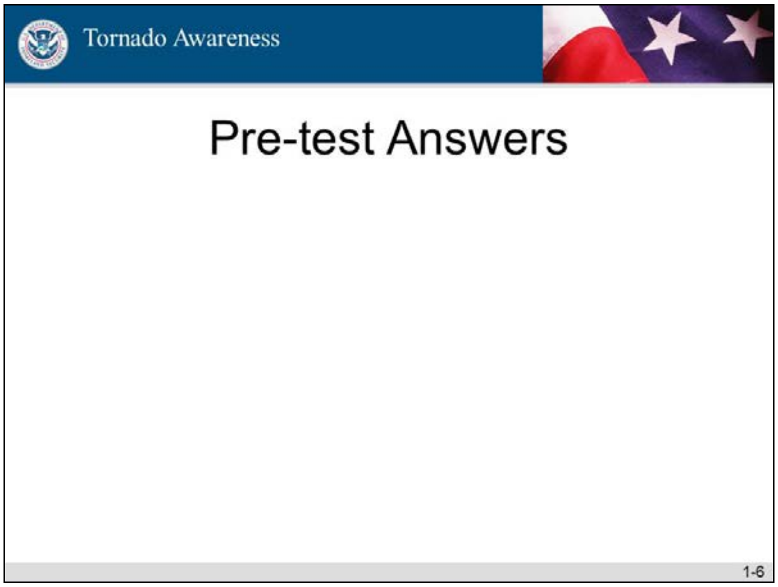
Participants should note the following:

- The pre-test is important because it provides a self-measure of knowledge as well as assumptions on the topics. It also illustrates the class content.
- Participants will have 15 minutes to complete the pre-test. Participants should work independently to complete the answers.

Participants should comply with the following instructions as they take the pre-test and indicate answers on the test answer sheet:

- Write legibly using uppercase letters.
- Use the same first name, last name, and date of birth provided on the participant registration form. This information will be used to generate a unique ID number for each participant.
- Complete the Test Date field in the upper right-hand portion of the sheet by writing the day the test is actually given.
- Fill in the Pre-Test bubble.
- Fill in each bubble completely and make sure the answers are correctly aligned on the test answer sheet.
- Write the test document ID number in the Test Doc ID field. The ID number is located in the footer of the test handout.

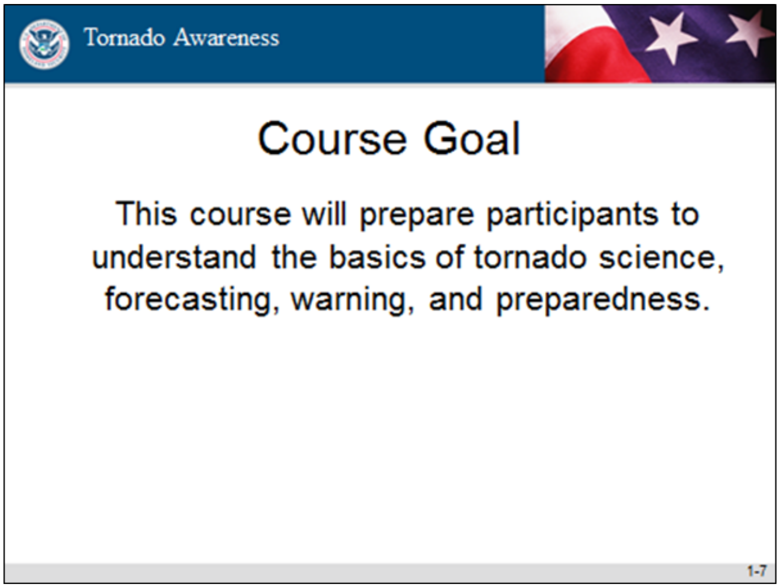
Participant Notes:



Slide 1-6. Pre-test Answers

Once everyone has finished taking the pre-test, the instructors will review the correct answers with the class. Participants should grade their own test, taking care not to make grading marks in columns A through D. Participants may also write down scores for personal reference and take any notes as needed. Participants are encouraged to write down their pre-test score somewhere other than on the pre-test or test answer sheet. The instructors will come around and collect all testing materials.

Participant Notes:



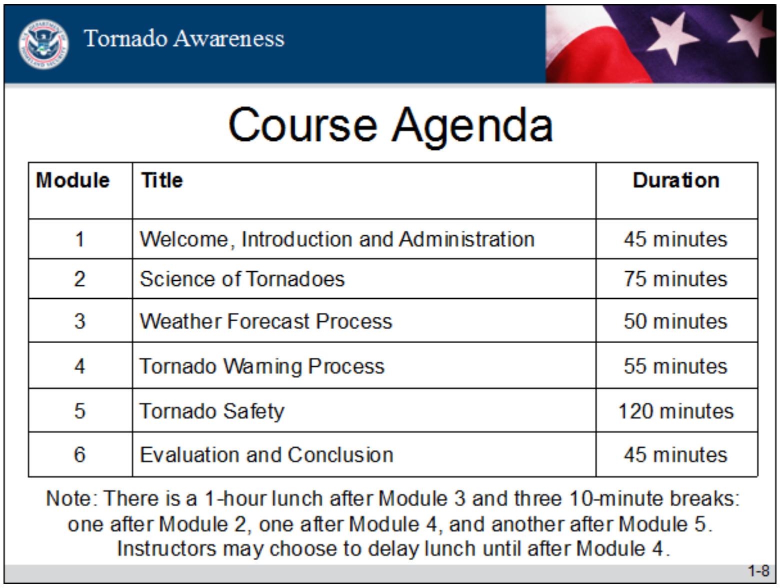
Slide 1-7. Course Goal

This course will prepare participants to understand the basics of tornado science, forecasting, warning, and preparedness.

This course does not require any previous subject matter knowledge, so participants should not be concerned about having a background in the topics noted above. All of the knowledge required to answer intra-module and end-of-course assessment questions can be found in the course materials presented in the lectures.

This awareness-level course is targeted at participants across a broad spectrum of the community who need to be aware of the threat of tornadoes. In particular, this information should be of interest to the following: emergency managers, first responders, small businesses, corporations, federal/state/tribal governments, non-government organizations, community organizations, and typical households who need to prepare for and respond to hazards associated with tornadoes.

Participant Notes:


Tornado Awareness

Course Agenda

Module	Title	Duration
1	Welcome, Introduction and Administration	45 minutes
2	Science of Tornadoes	75 minutes
3	Weather Forecast Process	50 minutes
4	Tornado Warning Process	55 minutes
5	Tornado Safety	120 minutes
6	Evaluation and Conclusion	45 minutes

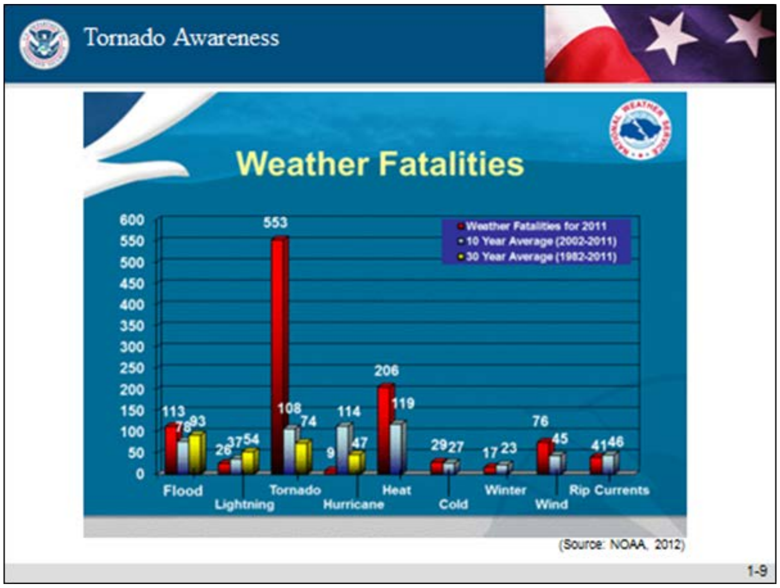
Note: There is a 1-hour lunch after Module 3 and three 10-minute breaks: one after Module 2, one after Module 4, and another after Module 5. Instructors may choose to delay lunch until after Module 4.

1-8

Slide 1-8. Course Agenda

This course is composed of six distinct modules to address various topics as well as to satisfy administrative requirements. Each session includes an introduction, lecture content, and class discussions which expand upon the topics or ideas that are presented.

Participant Notes:

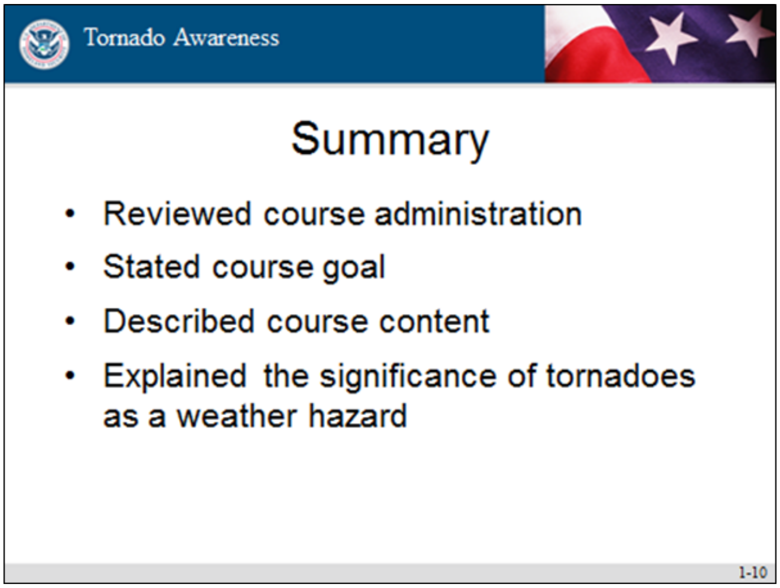


Slide 1-9. Weather Fatalities

The weather events of 2011 were particularly damaging to the United States. According to a review of select statistics (as shown on this slide):

- Preliminary weather fatalities totaled 1,096. This number is partly attributable to an especially active year of tornadoes.
- In the long-term 30-year average, flooding caused the most deaths, followed by tornadoes and lightning.
- In the last 10 years, heat waves and hurricanes have risen to the top of the list.
- The greater number of hurricane deaths is most likely due to the 1,833 deaths associated with Hurricane Katrina (2005).

Participant Notes:



Slide 1-10. Summary

This module welcomed participants to the course and outlined its goals, content, and evaluation strategy. Participants were apprised of the class schedule and introduced to the importance of the tornado hazard.

Tornado Awareness

Participant Guide

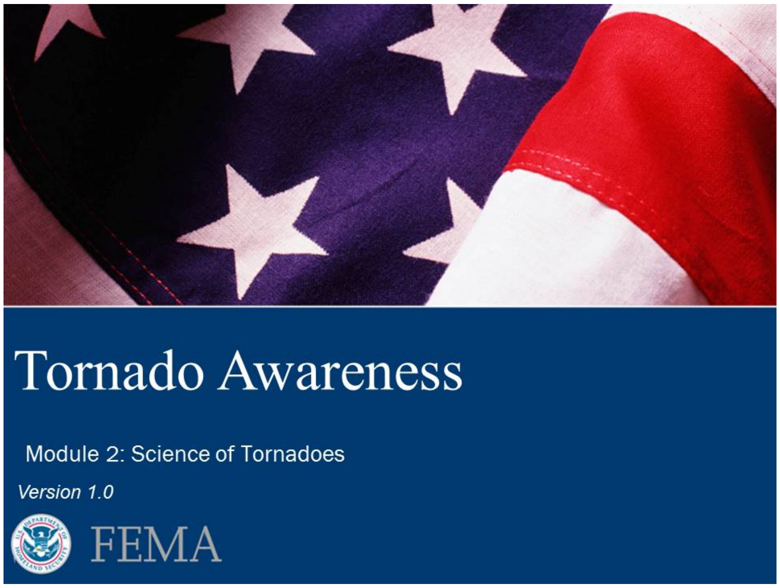
Module 2: Science of Tornadoes

Version 1.0

FEMA

This page is intentionally left blank.

Module 2: Science of Tornadoes – Administration Page



Slide 2-1. Science of Tornadoes

Duration

75 minutes

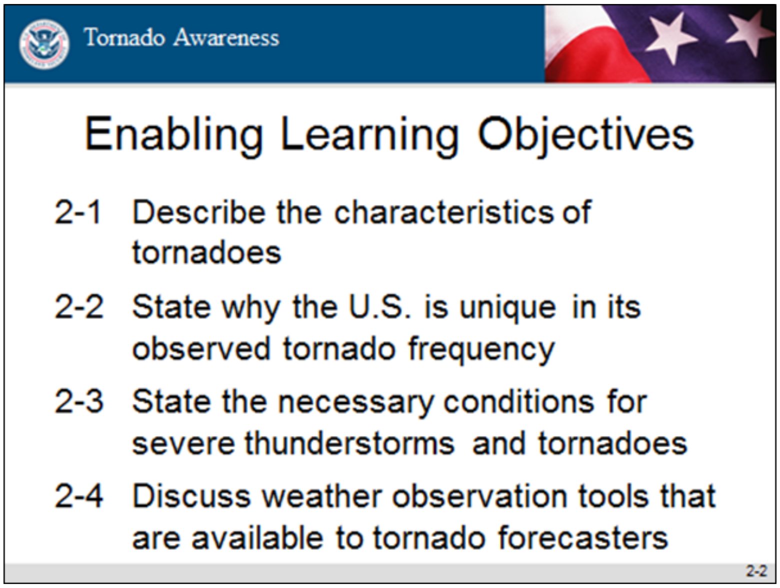
Scope Statement

In this module, the instructors will review definitions, explain concepts and provide other detailed information pertaining to the science of tornadoes. An overview of the current understanding of tornado and severe thunderstorm characteristics, conditions of formation, and detection will also be provided to the participants.

Terminal Learning Objective (TLO)

Participants will understand the current state of tornado science.

Enabling Learning Objectives (ELOs)



Slide 2-2. Enabling Learning Objectives

At the end of this module, participants will be able to:

2-1 Describe the characteristics of tornadoes.
2-2 State why the U.S. is unique in its observed tornado frequency.
2-3 State the necessary conditions for severe thunderstorms and tornadoes.
2-4 Discuss weather observation tools that are available to tornado forecasters.

Resources

- Instructor Guide (IG)
- Module 2 presentation slides
- Laptop with presentation software installed and CD-ROM capability
- Audio-visual (A/V projection unit)
- Projector screen
- Chalkboard (and chalk), whiteboard (and dry erase markers), or easel and easel paper (and permanent markers)
- One of each of the following items per participant:
  - Participant Guide (PG) available for download from http://ndptc.hawaii.edu/
  - Participant Handout

Instructor-to-Participant Ratio

2:40

Reference List

Bluestein, Howard B. 1999. *Tornado Alley*. New York. Oxford University Press.

Bluestein, Howard B. 2009. "The formation and early evolution of the Greensburg, Kansas, Tornadic supercell on 4 May 2007." *Weather and Forecasting*, 24, 899-920. doi: 10.1175/2009WAF2222206.1

Brooks, H.E. 2013. "Severe thunderstorms and climate change." *Atmospheric Research,* 2013. 123(0): p. 129-138.

Cintineo R.M. and D.J. Stensrud. 2013. "On the Predictability of Supercell Thunderstorm Evolution." *Journal of the Atmospheric Sciences,* 2013. 70(7): p. 1993-2011.

DeLuca, M. 2013. "As tornadoes neared, drivers hit the road – with deadly results." *U.S. News,* May 31. Accessed 2013. http://usnews.nbcnews.com/_news/2013/05/31/18666671-as-tornadoes-neared-drivers-hit-the-road-with-deadly-results?lite

Federal Emergency Management Association. 2013. "Tornadoes." Accessed 2013. http://www.ready.gov/tornadoes

Masters, Jeff. 2013. "A Night of Tornado Chaos in Oklahoma City: 9 Killed, 71 Injured." *Dr. Jeff Masters' WunderBlog 2013.* Accessed 2013. http://www.wunderground.com/blog/JeffMasters/comment.html?entrynum=2422

National Oceanic and Atmospheric Administration NWS: Storm Prediction Center. 2013. Frequently Asked Questions (FAQ). Accessed 2013. http://www.spc.noaa.gov/faq/

NWS: JetStream – Online School for Weather. 2013. Accessed 2013. http://www.srh.weather.gov/jetstream/

NWS Weather Forecast Office (WFO): Birmingham, AL. 2013. "Tuscaloosa-Birmingham Tornado – April 27, 2011." Accessed 2013. http://www.srh.noaa.gov/bmx/?n=event_04272011tuscbirm

NWS WFO: Norman, OK. 2013. "The May 31-June 1, 2013 Tornado and Flash Flooding Event." Accessed 2013. http://www.srh.noaa.gov/oun/?n=events-20130531

NWS WFO: Norman, OK. 2013. "The Tornado Outbreak of May 20, 2013." Accessed 2013. http://www.srh.noaa.gov/oun/?n=events-20130520

Oklahoma Department of Emergency Management. 2013. "Situation Update 7. Situation Update May 24, 2013. Accessed 2013. http://www.ok.gov/OEM/Emergencies_&_Disasters/2013/20130518_Severe_Weather_Event/20130524_Situation_Update_7.html

Rauber, R. M., J. E. Walsh, and D. J. Charlevoix. 2008. *Severe & Hazardous Weather: An Introduction to High Impact Meteorology*. Dubuque: Kendall/Hunt

Sandlin, Lee. 2013. *Storm Kings: The Untold History of America's First Tornado Chasers.* New York: Pantheon.

Schmidlin, T.W., et al., 1998. *Behavior of vehicles during tornado winds.* Journal of Safety Research.

Schneider, B. 2012*. Extreme weather: A guide to surviving flash floods, tornadoes, hurricanes, heat waves, snowstorms, tsunamis and other natural disasters.* New York: Palgrave Macmillan.

Simmons, K. M., and D. Sutter. 2011. *Economic and Societal Impacts of Tornadoes*. Boston: American Meteorological Society.

Simmons, K. M., and D. Sutter. 2012. *Deadly Season: Analysis of the 2011 Tornado Outbreaks.* Boston: American Meteorological Society.Trapasso, C., R. Schapiro, and L. McShane. 2013. "Twin tornadoes touch down in Queens and Brooklyn." NYDailyNews.com, September 8, 2012. Accessed 2013. http://www.nydailynews.com/new-york/tornado-touches-queens-brooklyn-article-1.1154892

Practical Exercise Statement

Not Applicable

Assessment Strategy

- Instructors observation of participant involvement in classroom discussion
- Instructor-led discussion to gauge participant grasp of the subject matter
- Instructors engagement of participant involvement with requests for local examples and experiences

Tornado Awareness

Icon Map

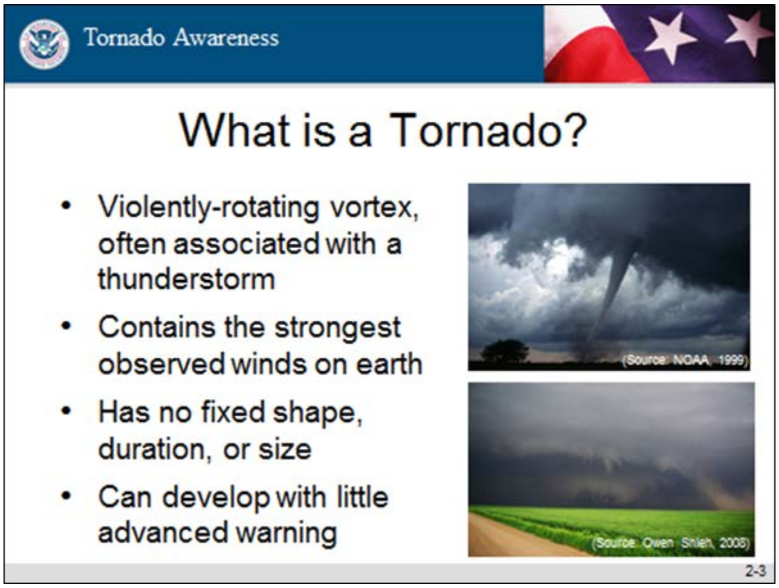
Knowledge Check: Used when it is time to assess participant understanding.

Example: Used when there is a descriptive illustration to show or explain.

Key Points: Used to convey essential learning concepts, discussions and introduction of supplemental material.

Participant Note: Used to indicate text that has been included as additional information for the participant. The text may not be directly addressed in the slide presentation or during class discussion.

Participant Notes:

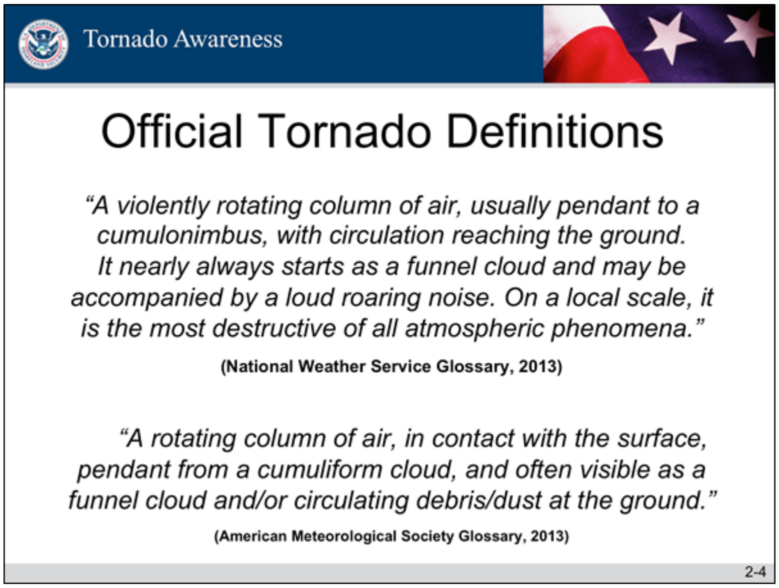


Slide 2-3. What is a Tornado?

The characteristics of a tornado include the following descriptions:

- Violently-rotating vortex, often associated with a thunderstorm;
- Contains the strongest observed winds on earth;
- Has no fixed shape, duration, or size; and
- Can develop with little advanced warning.

Participant Notes:



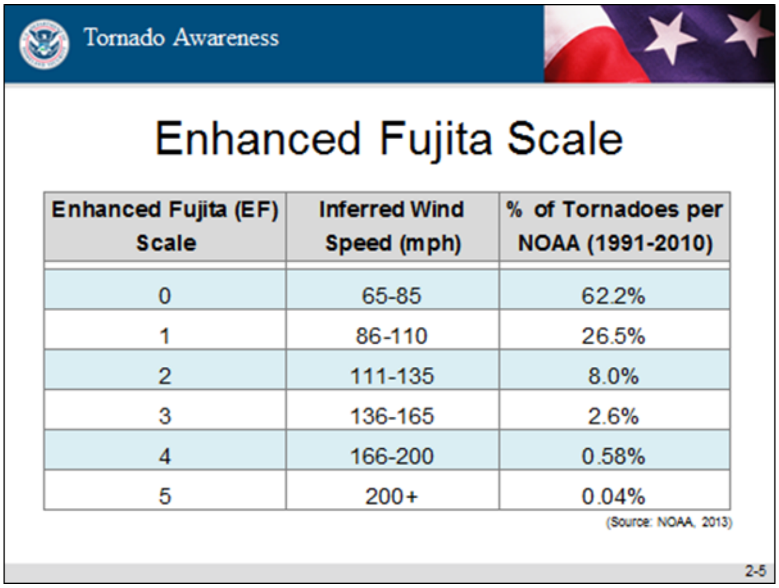
Slide 2-4. Official Tornado Definitions

Key Point: Even if a funnel cloud does not visibly touch the ground, a dust swirl rising from the ground below the visible funnel can indicate a tornado.

Two official tornado definitions are provided below:

- "A violently rotating column of air, usually pendant to a cumulonimbus, with circulation reaching the ground. It nearly always starts as a funnel cloud and may be accompanied by a loud roaring noise. On a local scale, it is the most destructive of all atmospheric phenomena." (National Weather Service Glossary, 2013)
- "A rotating column of air, in contact with the surface, pendant from a cumuliform cloud, and often visible as a funnel cloud and/or circulating debris/dust at the ground." (American Meteorological Society Glossary, 2013)

Participant Notes:



Enhanced Fujita Scale

Enhanced Fujita (EF) Scale	Inferred Wind Speed (mph)	% of Tornadoes per NOAA (1991-2010)
0	65-85	62.2%
1	86-110	26.5%
2	111-135	8.0%
3	136-165	2.6%
4	166-200	0.58%
5	200+	0.04%

(Source: NOAA, 2013)

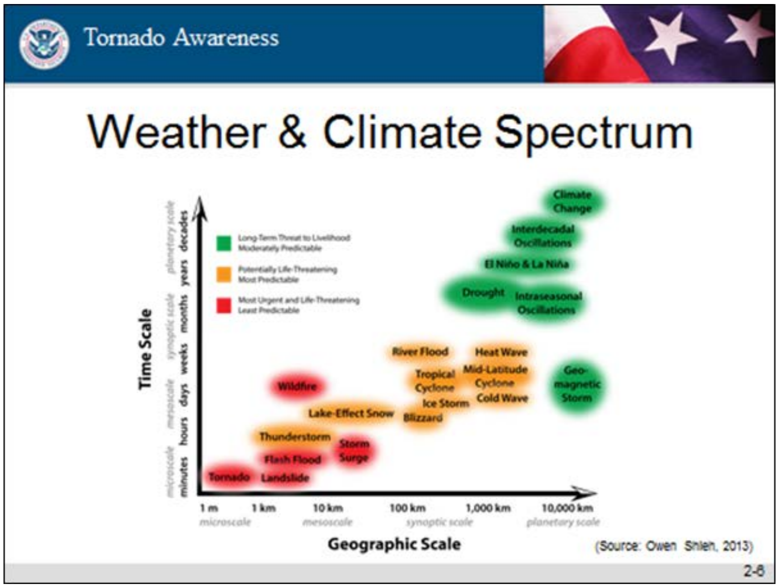
Slide 2-5. Enhanced Fujita Scale

The Enhanced Fujita (EF) Scale is the standard used in the United States to rate tornado damage. It was based on the original Fujita Scale, but was later revised in 2007 to better match recent studies on the different ranges of wind speeds and their associated damage potential.

The important thing to remember about this scale is that unlike the Saffir-Simpson Scale for hurricanes, tornado winds are not estimated in real-time. The EF number of a tornado is determined well after the tornado has dissipated and is inferred, purely on the observed structural damage that results from the tornado. The winds refer to the 3-second wind gust estimate.

Also, it is important to note that the vast majority of the most deadly and damaging tornadoes (EF 4/5) consist of less than 1% of the total number of reported tornadoes each year. This means that the survivability is high for the vast majority of tornadoes, if common sense actions are taken to properly shelter in place.

Participant Notes:



Slide 2-6. Weather & Climate Spectrum

Weather and climate phenomena span a vast spectrum of time and geographic scales. In order to fully understand the interplay between these very different scales, it is useful to plot the major weather and climate phenomena in a two-dimensional space, with geographic scales along the x-axis and time scales along the y-axis.

Using these scales, a semi-linear relationship between the spatial extent of a particular phenomenon and its temporal duration or cycle can be extracted. As illustrated above, each individual oval spans a small region of time and space showing the approximate variability of each type of hazard.

Highlights of the above graphic are outlined below:

- The microscale and mesoscale events at the bottom-left, such as tornadoes and flash floods, are considered the most urgent and life-threatening and therefore are highlighted in red.
- The synoptic scale events are in yellow because they are potentially life-threatening, but not necessarily urgent unless their downscale impacts are considered. The events on the synoptic scale, particularly tropical cyclones and mid-latitude cyclones, serve as parent storms to the more urgent and smaller scale events in red.
- At the top of the time scale is the planetary scale which leaves the realm of weather and enters the realm of climate variability and climate change.

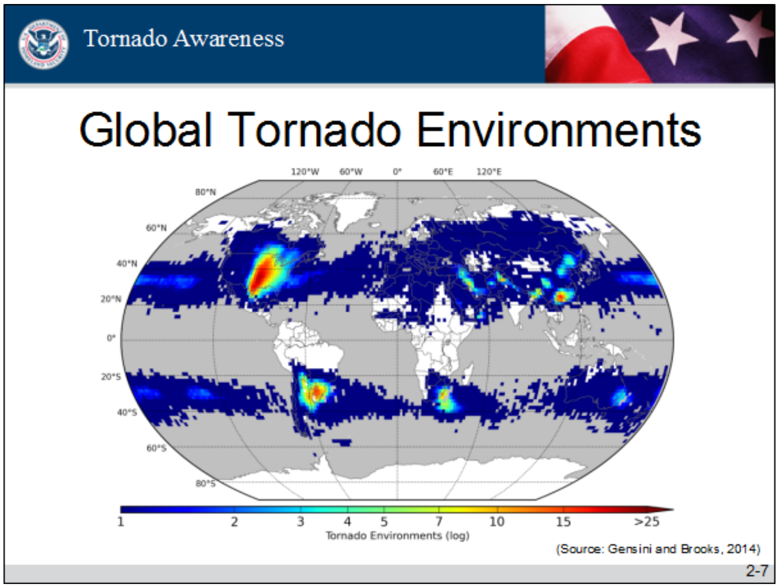
Participant Notes:

The only non-atmospheric phenomena in this figure are wildfires, landslides, and geomagnetic storms. They were included because they can be closely associated with other weather/climate phenomena. More information on these are provided below:

- Lightning from thunderstorms often spark wildfires.
- Flash floods can cause landslides.
- The source of geomagnetic storms is completely extraterrestrial in nature, but can affect telecommunications systems and electric grids on the planetary scale, all of which would impact the ability to observe and predict hazardous weather phenomena.

As the science of meteorology originated with a sparse network of observation stations co-located with airports, the synoptic scale was the first to be studied. This led to tremendous improvements in predictability over the last several decades. However, challenges still remain in the larger scale phenomena such as climate change, where numerous factors play a role over longer periods of time and are difficult to quantify. Similarly, phenomena at small scales are difficult to understand and resolve in numerical prediction models.

Participant Notes:

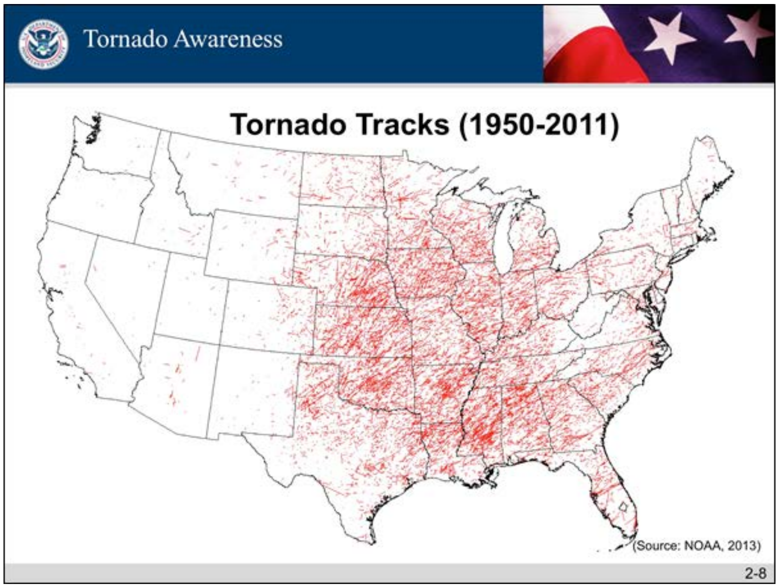


Slide 2-7. Global Tornado Environments

Tornadoes are found around the world, but predominately occur in the mid-latitudes where a seasonal clash of air masses is common. Furthermore, the presence of a warm body of water that supplies tropical moisture into the mid-latitudes increases the likelihood of severe thunderstorms that can generate tornadoes (e.g., Gulf of Mexico, South China Sea).

This figure shows the global distribution of environmental conditions that favor tornado development, plotted on a log scale with data from 1958 to 1999. This clearly shows that the central United States is a hotspot for tornado activity, with other localized maxima of favorable tornado conditions in other parts of the world such as south-central South America, South Africa, southeast Australia, and southeast China.

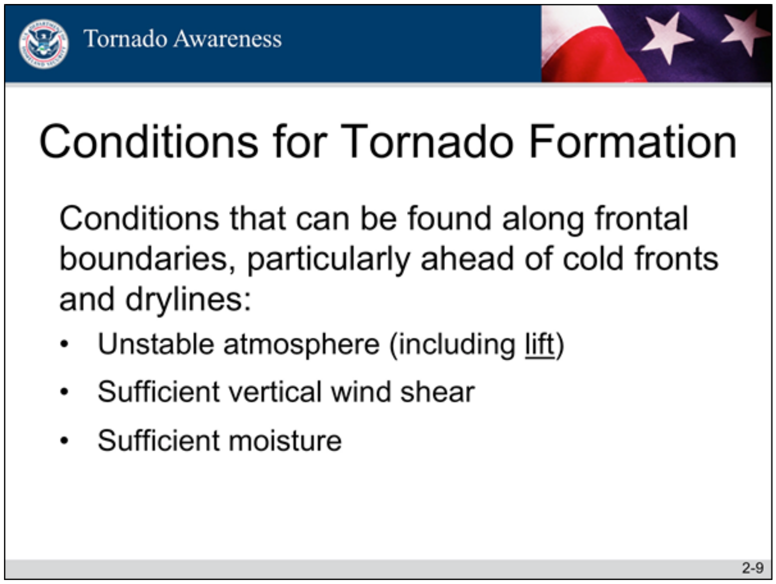
Participant Notes:



Slide 2-8. Tornado Tracks (1950 – 2011)

While tornadoes have been known to occur all over the world, the unique geography and climate of North America places the majority of tornado activity in the United States. The distribution of tornadoes across the continental United States reflects the unique convergence of tornado formation conditions across the central and southeastern part of the country. The Rocky Mountains serve as a barrier, separating cold/dry air to the West from the warm/moisture air to the East. Also, mid-latitude cyclones, parent storm systems of severe thunderstorms, can form on the lee side of the mountain range. These cyclones are discussed later in this module. Also notable is the predominant tornado tracks oriented from the southwest to the northeast. Although this represents a pattern, it should also be noted that many tracks do not follow a particular behavior. As such, assumptions should not be made about the direction of any particular tornado.

Participant Notes:



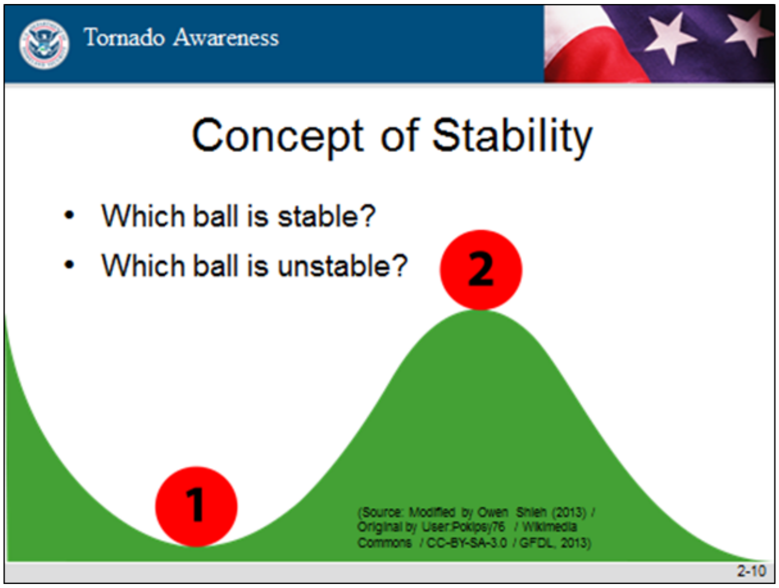
Slide 2-9. Conditions for Tornado Formation

Conditions that can be found along frontal boundaries, particularly ahead of cold fronts and drylines:

- Unstable atmosphere (including lift);
- Sufficient vertical wind shear; and
- Sufficient moisture.

A cold front is the boundary separating cold and warm air masses. A dryline is the boundary separating dry and moist air masses. Typical thunderstorms require an unstable atmosphere and a source of lift in order to sustain rising air motion in the updraft. Sufficient moisture is also necessary because it enhances instability and contributes to lower cloud bases and greater precipitation. In order for a thunderstorm to become more severe and long-lived, there must also be sufficient vertical wind shear to separate the updraft and downdraft of a storm and to initiate rotation in supercell thunderstorms (described later).

Participant Notes:



Slide 2-10. Concept of Stability

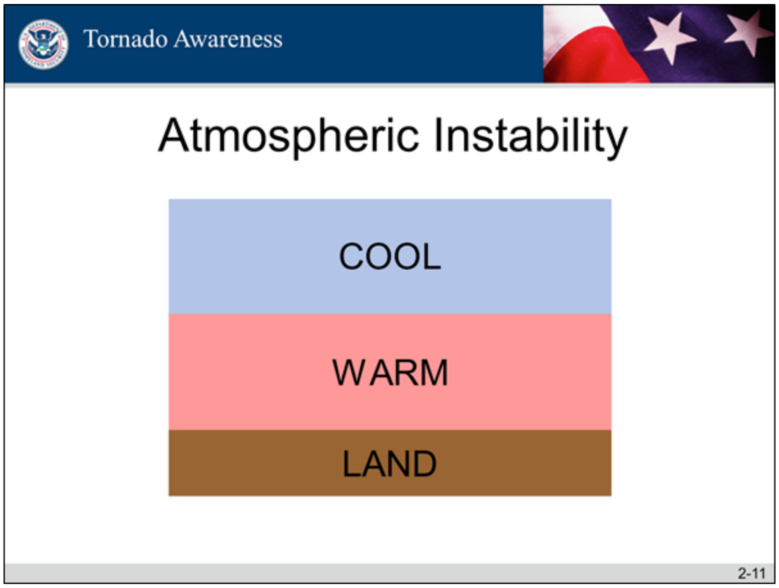
The concept of atmospheric stability is extremely important with respect to the development of storms. Although there are many different types of stabilities and instabilities, the general concept is as follows:

- A state of the atmosphere is “unstable” when a perturbation of an air parcel results in further displacement.
- An air parcel is “stable” when it returns to its original state after being displaced.

With respect to weather:

- Storms develop when the atmosphere is unstable.
- Storms weaken when the atmosphere becomes stable.

Participant Notes:

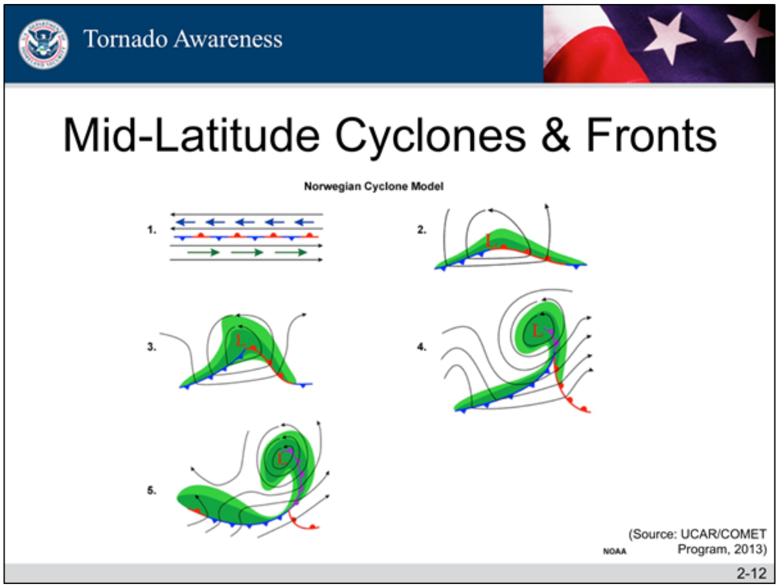


Slide 2-11. Atmospheric Instability

"Atmospheric instability" occurs when warm air is trapped beneath cooler air (with respect to their potential temperatures).

While the thermodynamic process is actually quite technical, the basic premise is that an unstable situation like this results in a warm air parcel that becomes less dense than the air above, thus causing it to rise rapidly. An analogy to this is a pot of boiling water that is heated from below or a hot air balloon rising.

Participant Notes:

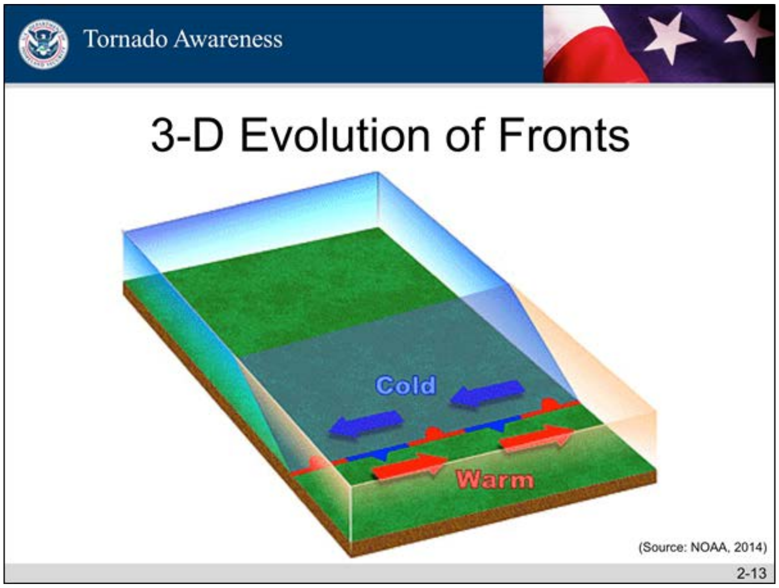


Slide 2-12. Mid-Latitude Cyclones & Fronts

In order for the atmosphere to realize, or “release” its instability, the air must be lifted. Cold fronts and warm fronts often generate this source of lift with cold fronts typically being the more severe of the two. These fronts are part of a larger storm system called a “mid-latitude cyclone,” which develops in response to instability resulting from horizontal temperature gradients.

On average, in the Northern Hemisphere, cold air exists to the north and warm air exists to the south. To correct this imbalance the atmosphere periodically spins up mid-latitude cyclones every few days to mix the air horizontally. A cold front marks the leading edge of the advancing cold air. A warm front marks the leading edge of the advancing warm air. Once the air is sufficiently mixed the mid-latitude cyclone dissipates. Mid-latitude cyclones are responsible for the day-to-day weather changes in the United States, but they may not always produce severe thunderstorms.

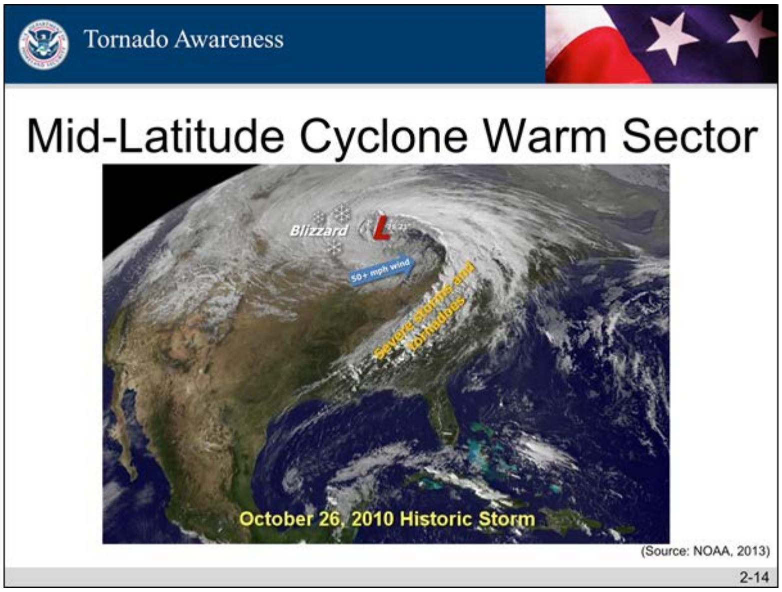
Participant Notes:



Slide 2-13. 3-D Evolution of Fronts

This animation shows a 3-dimensional perspective of the life cycle of a mid-latitude cyclone. As described on the previous slide, cold air to the north and warm air to the south collide along a frontal boundary. The cold air slopes backward with height because cold air is denser than warm air. As the cyclone develops, the cold air is brought southward and the warm air northward, rotating around the low-pressure system in a counterclockwise direction. Once the air is fully mixed, the cyclone weakens and dissipates.

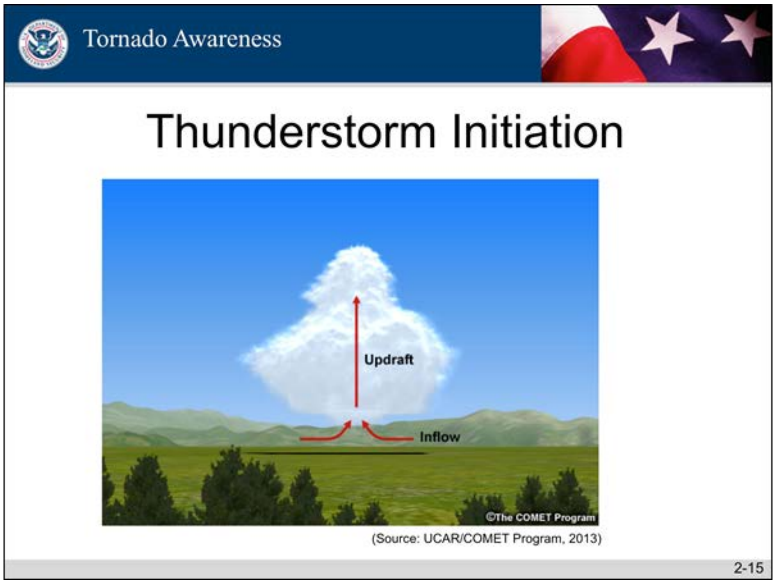
Participant Notes:



Slide 2-14. Mid-Latitude Cyclone Warm Sector

On October 26, 2010, an intense mid-latitude cyclone impacted the central United States. Given the large circulation and the division between the warm and cold sectors of the cyclone, the Midwest bore the brunt of heavy snows, and the Southeast suffered severe thunderstorms and tornadoes. This satellite image of the United States on that day shows the size and synoptic scale of this mid-latitude cyclone. The locations of the cold and warm sectors are typical of mid-latitude cyclones.

Participant Notes:

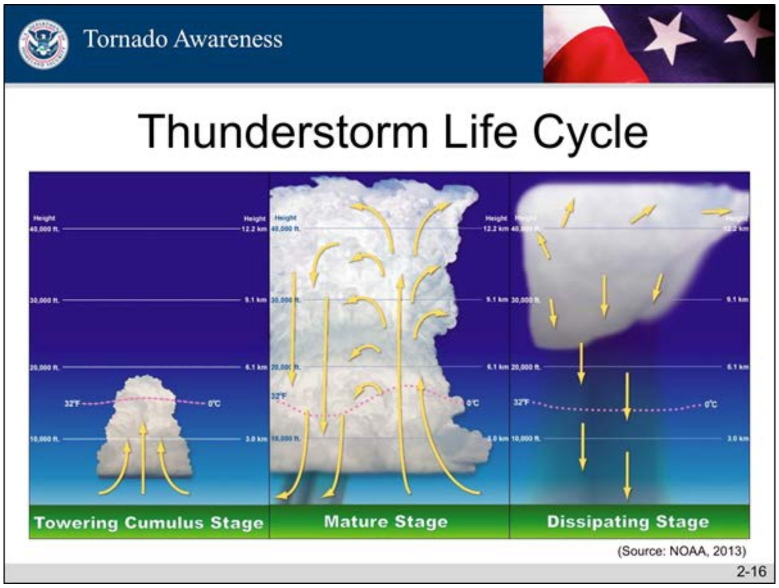


Slide 2-15. Thunderstorm Initiation

As the plume of warm, convectively unstable air rises, the air cools and the moisture condenses and turns into a cloud. This rising plume of air is called the "updraft." During this condensation process, the cloud can release latent heat, thus warming the column of air further. This positive feedback can lead to continuously rising updrafts that eventually cause the cloud to develop into a thunderstorm. Since the sun heats the land much quicker than the actual air itself, warm summer days can lead to thunderstorms because of atmospheric instability.

This process is analogous to boiling a pot of water. The stove heats the pot of water from below, causing water to become unstable and boil, with water rising in plumes.

Participant Notes:



Slide 2-16. Thunderstorm Life Cycle

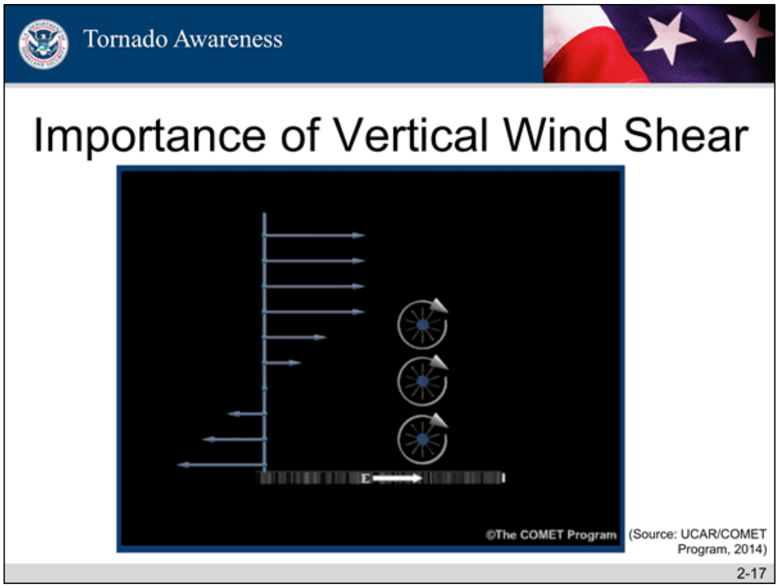
The life cycle of a single-cell thunderstorm can be described in three stages:

- Towering cumulus stage;
- Mature stage; and
- Dissipating stage.

During the towering cumulus stage an updraft develops in response to atmospheric instability and lift. The cloud grows taking on the appearance of a cauliflower. As the cloud matures a downdraft of rain and hail develops alongside the updraft. If the supply of warm and moist air runs out, the downdraft will eventually choke off the updraft, thus leading to the dissipating stage of a thunderstorm. An average summer thunderstorm can go through this cycle in a matter of an hour.

Under certain conditions, the downdraft can sometimes be intense, driving winds in all directions after hitting the surface. These “downbursts” can result in straight-line wind damage that can be as significant as tornado damage, except the winds in a downburst do not rotate in a vortex as in a tornado.

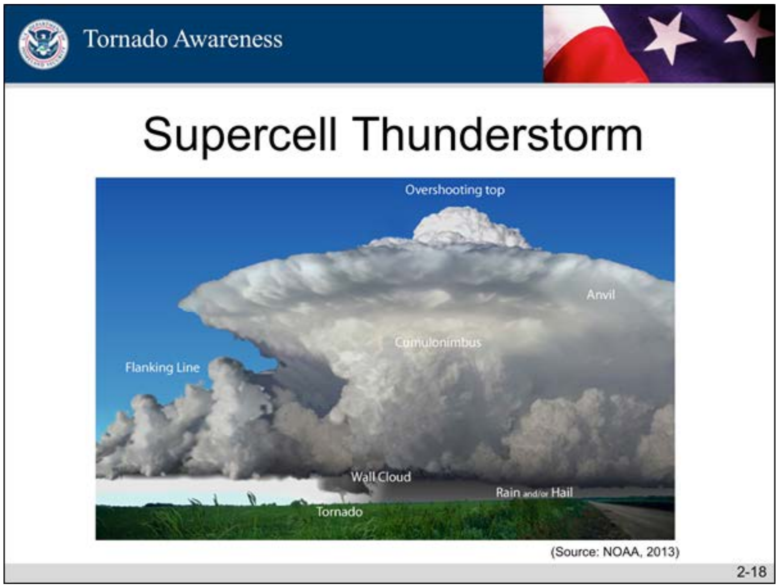
Participant Notes:



Slide 2-17. Importance of Vertical Wind Shear

This animation shows how vertical wind shear – a change in wind speed and direction with height – can result in a thunderstorm acquiring rotation in its updraft. Assuming winds from the east near the surface and winds from the west aloft, the shearing motion of the wind results in horizontal columns of rotating air oriented perpendicular to the wind. If these columns of air meet an updraft, the updraft can tilt and lift them into the thunderstorm. As this happens, the thunderstorm acquires a rotating updraft. In the United States, storm dynamics typically favor the counterclockwise-rotating updraft. Thus, a supercell thunderstorm is born.

Participant Notes:



Slide 2-18. Supercell Thunderstorm

In the presence of strong vertical wind shear a special class of thunderstorms can develop which is called the “supercell thunderstorm.” Supercells pose the most significant threat to communities because of their intensity and propensity to produce tornadoes.

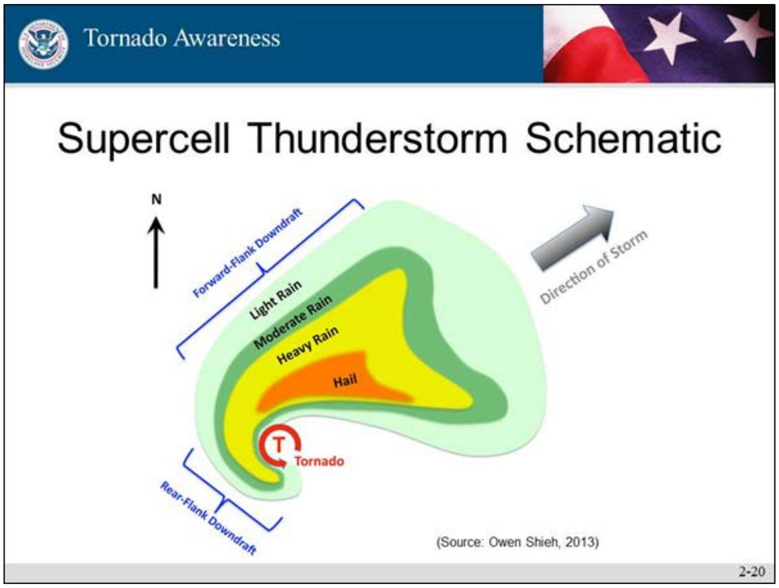
Unlike typical thunderstorms, supercell thunderstorms last much longer and are more severe, because the strong vertical wind shear can tilt the convective cloud in a way such that the downdraft will not choke off the updraft. Furthermore, horizontal rotation of the air due to the environmental wind shear can be tilted upward by the updraft leading to a rotating column of air called the “mesocyclone.” This rotating nature of the updraft is the defining characteristic of a supercell thunderstorm and can lead to the formation of a tornado.

Participant Notes:

Slide 2-19. Supercell Thunderstorm Timelapse

This video is a time lapse of a supercell thunderstorm showing the sculpted structure of the rotating updraft of a supercell thunderstorm. In addition to the rotation, note the separation of the updraft and downdraft, the latter indicated by the area of rain on the right side of the storm. The most likely region of a supercell for a tornado to form is within the rotating updraft.

Participant Notes:

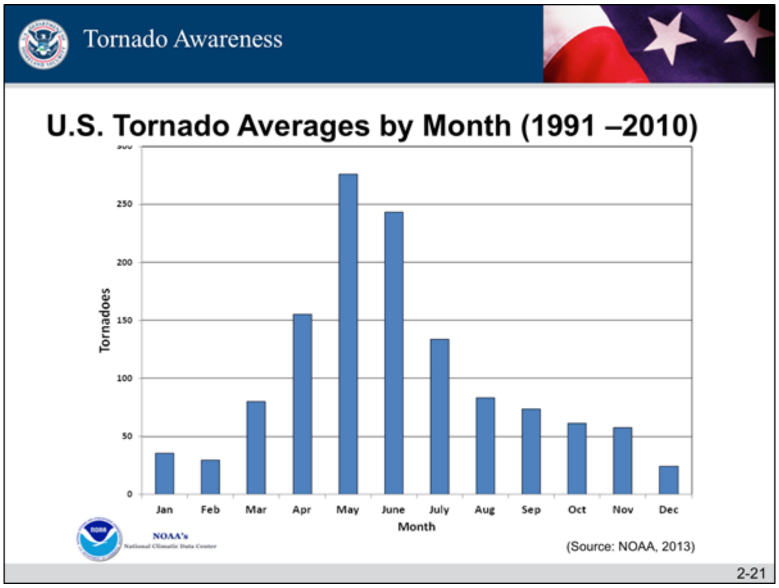


Slide 2-20. Supercell Thunderstorm Schematic

In the case of a classic supercell thunderstorm, the radar signature (top-down view) often resembles a “hook” (or “hook echo”). This pattern results from the rotation of the precipitation around the rotating updraft (or mesocyclone). The rear-flank downdraft (RFD) wraps around the back side of the tornado and the forward-flank downdraft (FFD) leads the tornado. The FFD is typically considered the region with the heavy rain and hail immediately ahead of the mesocyclone (Note: the blue bracket for the FFD was positioned to the top-left simply for legibility.). Hail often falls closer to the updraft because it is heavier than raindrops. In a classic supercell scenario, the typical direction of storm motion would result in an observer experiencing heavier rain, followed by hail, then an abrupt end to the precipitation just prior to the arrival of the tornado.

However, this classic depiction of a supercell can be rare in many parts of the country with some of the most dangerous tornadoes occurring in storms that do not exhibit this structure. Furthermore, radar images can be lagged in time by several minutes, along with other margins of error, so it is best not to make assumptions about the behavior of a particular storm when a Tornado Warning is issued for your location.

Participant Notes:



Slide 2-21. U.S. Tornado Averages by Month (1991 – 2010)

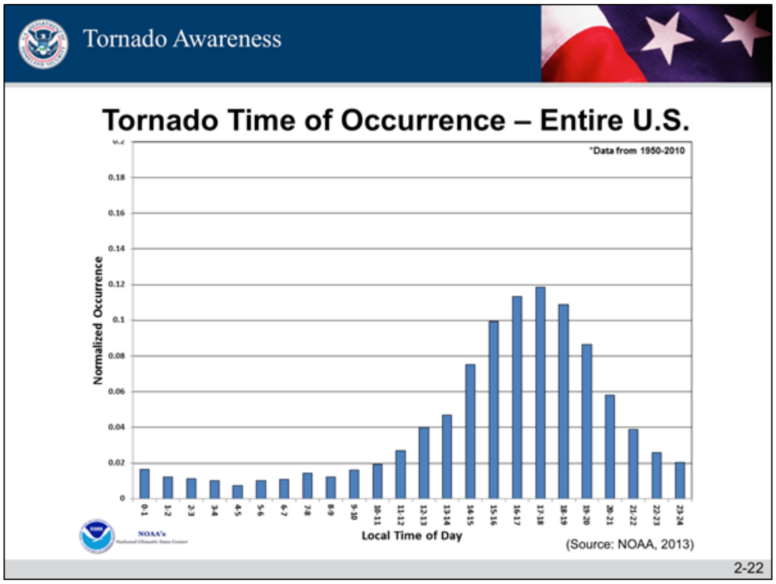
On average, the height of tornado occurrence in the country is in the spring season. However, there is no official "tornado season" because tornadoes can occur year-round with an annual peak frequency falling on different months depending on its geographic location:

- For the Great Plains, spring is the peak of tornado season because the clash of air masses is the greatest during that time. The upper-atmosphere is still cold during the spring season, whereas the lower-atmosphere is warmed by the surface due to the longer days, thereby contributing to atmospheric instability.
- In the southern Plains, the peak of the tornado season occurs in the early spring.
- Tornado frequency shifts toward the Northern Plains and central Canada in the summer. This is in response to the seasonal movement of the jetstream, an upper-level wind maximum that drives mid-latitude weather.

In general, the lower the latitude, the more the peak of the tornado season approaches the winter season. The higher the latitude, the more the peak of the tornado season approaches the summer season.

To determine the climatological severe weather threat for specific locations, participants can refer to the interactive website developed by the Storm Prediction Center: http://www.spc.noaa.gov/new/SVRclimo/climo.php?parm=anySvr

Participant Notes:

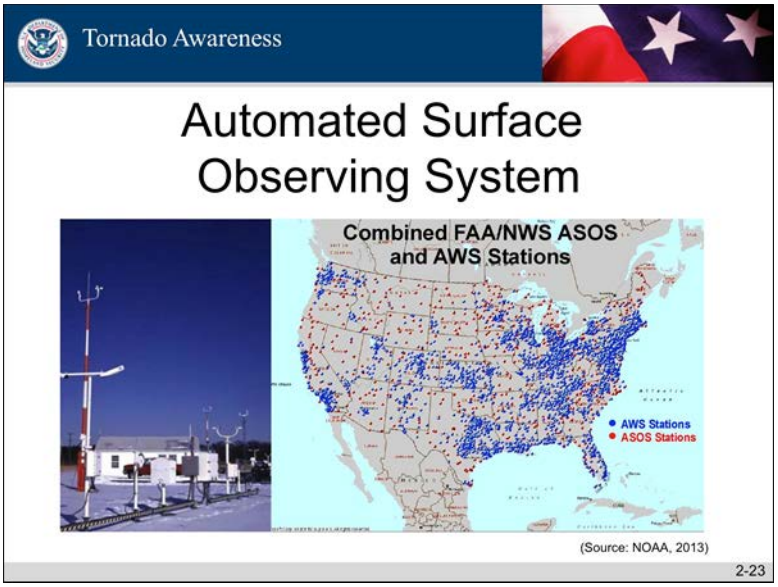


Slide 2-22. Tornado Time of Occurrence – Entire U.S.

Because tornadoes are associated with thunderstorms, they typically occur in the late afternoon and early evening hours when peak daytime heating and instability is at its maximum. It is important to note that evening tornadoes are particularly dangerous because they often occur in the cover of darkness.

As with the previous discussion about the peak of tornado season this graph should be used with caution because it is different for every location.

Participant Notes:



Slide 2-23. Automated Surface Observing System

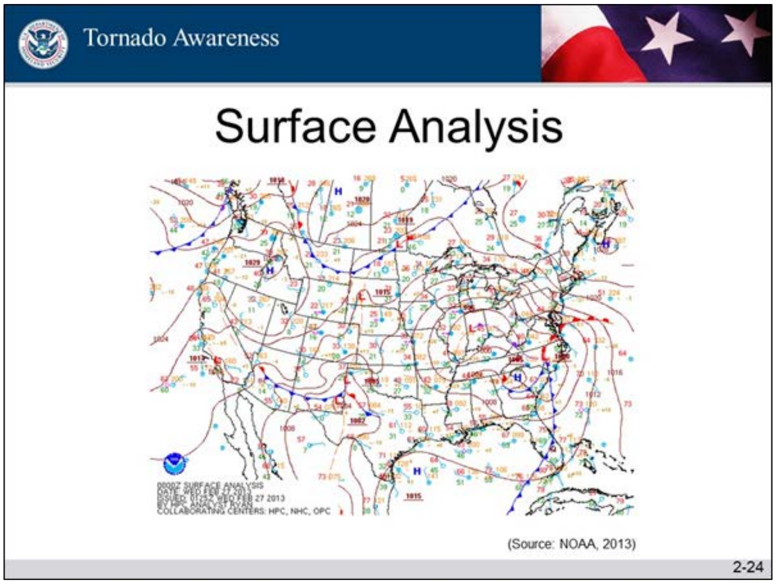
The Automated Surface Observing System (ASOS) is a collection of weather instruments installed at over 900 airports around the country. Supported by the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of the Defense (DOD), this network of automatic weather sensors collects important data on the changing weather conditions at the ground level around the country, up to 10 times each hour on every day of the year.

ASOS stations collect various types of data including the following:

- Sky conditions (cloud height/amount);
- Surface visibility and obstructions;
- Type of, intensity, and/or accummulated precipitation;
- Sea-level pressure;
- Temperature and dewpoint temperature;
- Wind direction and speed including gusts; and
- of significant weather changes.

Because of the limited point data that ASOS provides, human observations (e.g., sky conditions) can also be a useful supplement. Some states have also installed mesonets that provide greater spatial resolution of surface weather data. In addition to the land-based ASOS stations, the NOAA National Data Buoy Center (http://www.ndbc.noaa.gov/) also maintains a network of sea-based weather sensors (buoys), which collect crucial weather and ocean data along the U.S. coastlines including the Great Lakes.

Participant Notes:

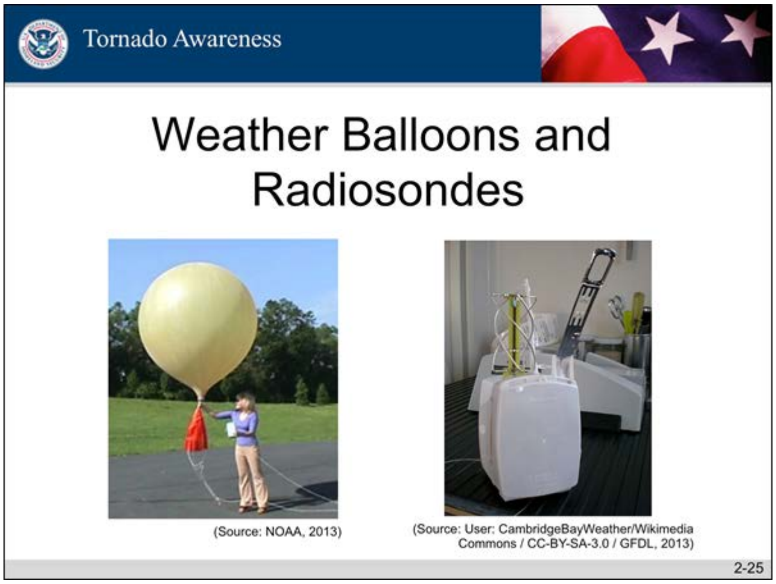


Slide 2-24. Surface Analysis

A series of ASOS observations collected at the same time can be mapped together using station plots. Doing this allows a meteorologist to analyze the weather systems that are occuring during that time (e.g., frontal zones, high/low pressure systems). In the United States, official surface analyses are performed by the Hydrometeorological Prediction Center of the National Weather Service.

A series of surface analyses can be put to animation showing the changes in weather patterns over time. In this animation, spanning from 0125Z to 1930Z on February 27, 2013, with each frame shown at approximately three-hour intervals, one is able to observe the changes of weather systems over time. From this, one can see that the two low pressure systems are slowly moving northeast, with the cold air over central Canada slowly progressing toward the southeast. Meanwhile, a weaker low pressure system is moving through the Gulf Coast states.

Participant Notes:

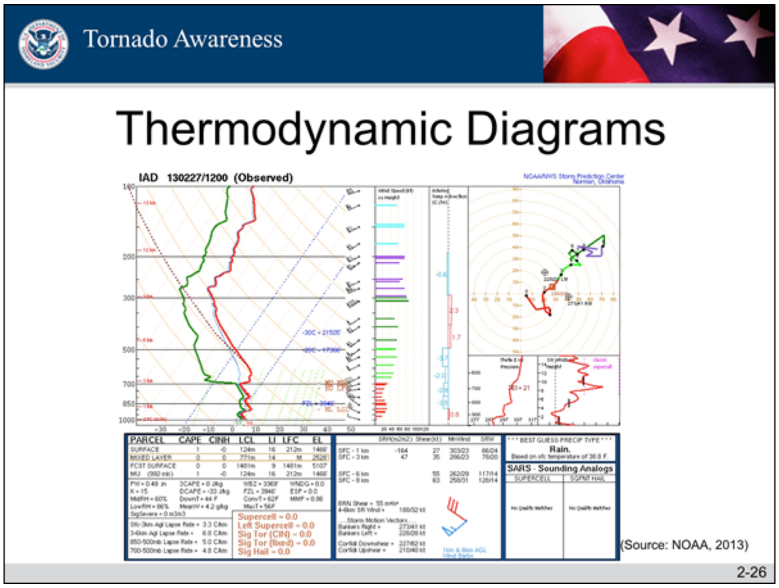


Slide 2-25. Weather Balloons and Radiosondes

Given that the atmosphere is three-dimensional, in addition to surface weather observations, it is also important to observe atmospheric variables in the upper-atmosphere. Meteorologists use weather balloons launched around the world at coordinated times (00Z and 12Z) to observe the state of the atmosphere above the ground. Data is collected via a radiosonde that is attached to the weather balloon, and transmitted back to the ground via a transmitter. Important data such as barometric pressure, altitude, position, wind direction/magnitude, air temperature, and relative humidity are collected by these systems.

Participant Note: "Z" time is in reference to "Zulu" time, also known as "Universal Time" (UTC) or "Greenwich Mean Time" (GMT). Four digits are used to express Zulu time (e.g., 1200Z), but at the top of the hour, the shorthand expression that drops the last two 00 digits can also be used (e.g., 12Z).

Participant Notes:

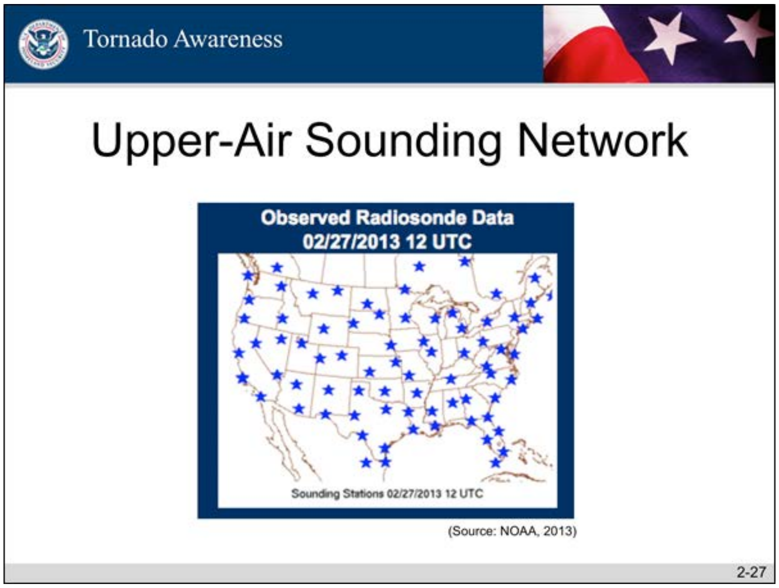


Slide 2-26. Thermodynamic Diagrams

Each weather balloon launch returns a vertical profile, or “sounding,” of atmospheric variables that is typically plotted as a “Skew-T Log-P” diagram in the United States. While this complicated diagram has numerous uses, most simply, it provides a vertical profile of wind (as shown by the wind barbs), temperature (as shown by the red curves), and dewpoint temperature (as shown by the green curves).

Depending on how these variables are manipulated the rest of the diagram can provide critical information such as atmospheric stability and wind shear, two important considerations when determining the likelihood of severe weather.

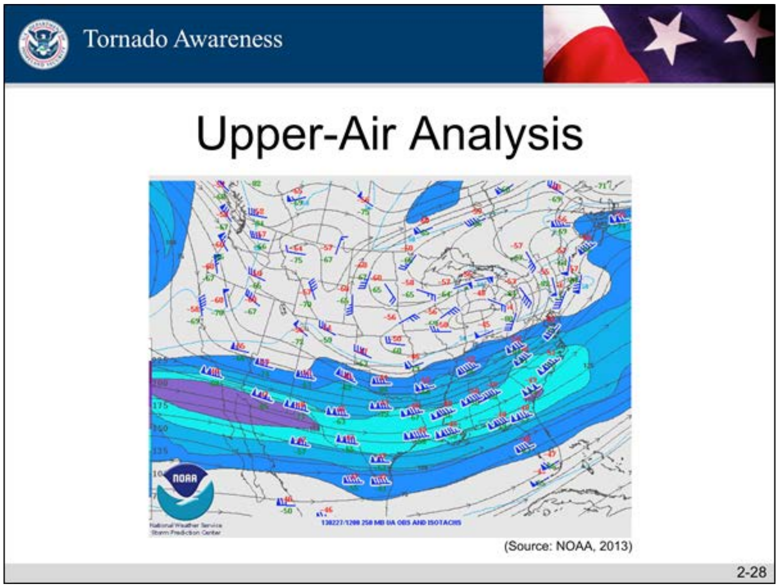
Participant Notes:



Slide 2-27. Upper-Air Sounding Network

The National Weather Service (NWS) operates over 90 radiosonde sites around North America and the Pacific Islands. Through international agreement, the 800+ radiosonde sites around the world launch weather balloons at 00Z and 12Z. These coordinated launch times provide a global snapshot of the atmosphere twice a day. This information is then assimilated into numerical weather models. Occasionally, imminent severe weather can prompt some radiosonde sites to launch special coordinated soundings at other times to get more data, such as was done across the eastern United States ahead of Hurricane Sandy.

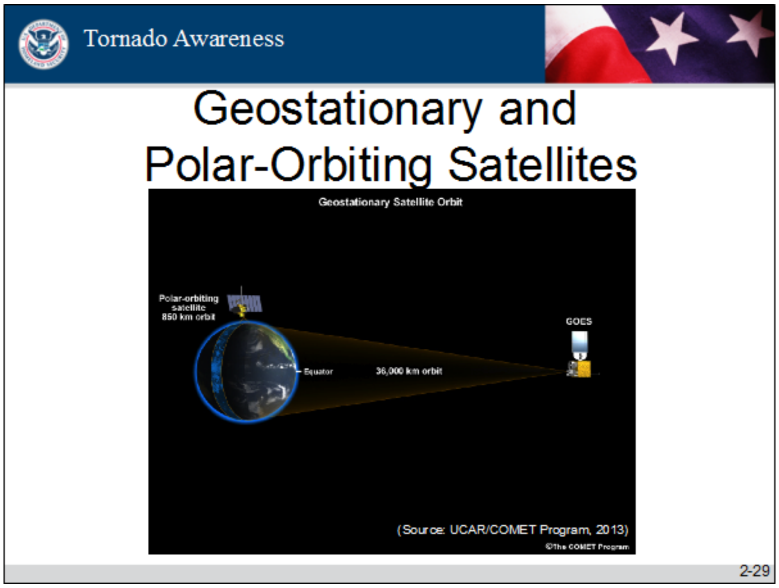
Participant Notes:



Slide 2-28. Upper-Air Analysis

As with surface observations, upper-air observations can be analyzed at a particular pressure level to convey dynamical features in the atmosphere. By shading in the upper-level wind magnitudes one can see that at 12Z on February 27, 2013, a strong jetstream extended from the eastern Pacific through the southern United States. The jetstream is a "river" of fast-moving winds often exceeding well above 100 mph. It contributes to the development of mid-latitude cyclones and provides the wind shear that is necessary for severe thunderstorms.

Participant Notes:



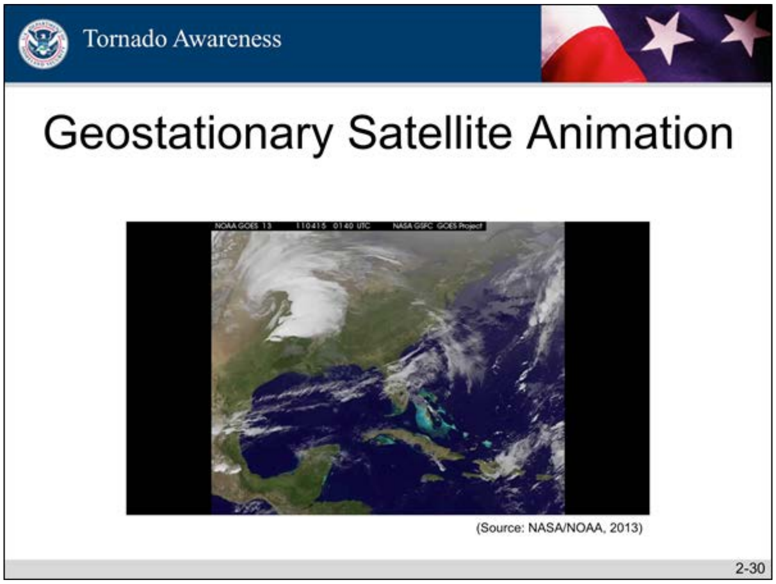
Slide 2-29. Geostationary and Polar-Orbiting Satellites

There are two primary types of satellites used for meteorological applications, classified by orbital patterns.

The first and most frequently used is known as the “geostationary satellite.” Orbitting at a high altitude of 35,786 km, this type of satellite is able to travel at the same radial velocity as the earth, completing one orbit at the same time as the planet. As a result, geostationary satellites remain fixed at a particular location above the earth’s equator, standing constant watch over half of the earth’s surface. Because the relative position is fixed, these satellites can take a snapshot of the cloud patterns every few minutes, which can be useful to understand the changing weather. The U.S. operates several Geostationary Operational Environmental Satellites (GOES).

“Polar-Orbiting Satellite” are the second type of satellites. These satellites orbit the earth at much lower latitude and typically travel on longitudinal paths. While the benefits of polar-orbiting satellites include much higher resolution images and better observation of the poles, it comes at the expense of a much smaller data collection area and the inability to continuously monitor the changing cloud patterns on an entire hemisphere like GOES. However, with the two types of satellites operating simultaneously, meteorologists can leverage the advantages of each.

Participant Notes:

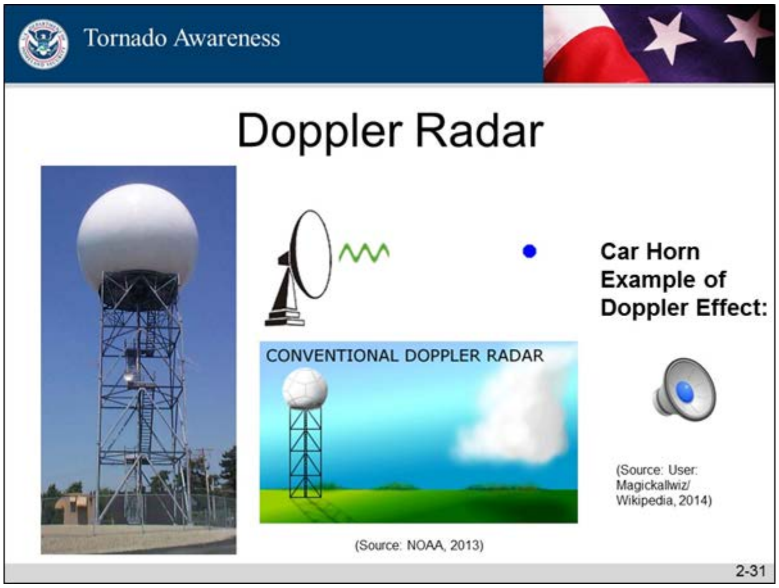


Slide 2-30. Geostationary Satellite Animation

This animation shows the comma-cloud structure of a mid-latitude cyclone as it sweeps across the U.S. Plains and southeast. Note the explosive development of thunderstorms just ahead of the cold front as it enters the southeast.

Example: This particular geostationary satellite animation shows the mid-latitude cyclone that resulted in the April 14-16, 2011 tornado outbreak that affected several states in the Southeast. While tornadoes are too small to see via satellite, the parent storm systems (mid-latitude cyclones) can be clearly tracked by satellite.

Participant Notes:



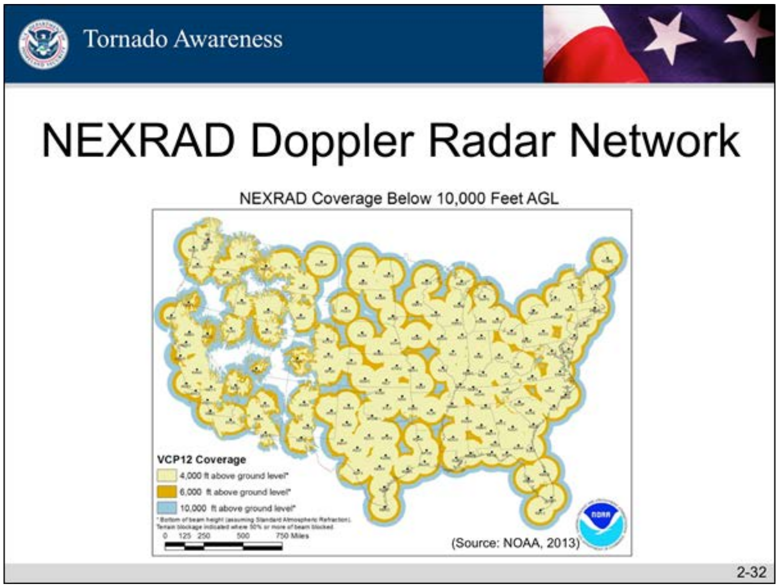
Slide 2-31. Doppler Radar

In addition to satellite-based imagers and sensors, another important type of remote sensing technology is the Doppler Radar. The basic principle of weather radar technology is the use of pulses of electromagnetic radiation emitted from an antenna to detect the presence of precipitation and wind. Mathematical algorithms are used to determine the intensity of precipitation based on the ratio of the power of the transmitted radiation to the power of the radiation scattered back from an object (e.g., collection of raindrops). The position of the object can be determined based on the time that lapses between transmission and reception of the radar pulse.

The term "Doppler" refers to the "Doppler Effect," which describes the frequency shift of waves (e.g., sound and light waves) that can occur when the observer is traveling with a velocity toward or away from the wave source. This is the principle behind the perceived change in the pitch of sirens as an ambulance speeds by. By leveraging the Doppler Effect associated with the microwaves of a weather radar pulse, meteorologists have developed techniques to observe precipitation and radial wind velocity (component of the wind along the radar beam).

The new dual-polarized Doppler Radar, currently being introduced operationally around the country, emits alternating vertical and a horizontal radar pulses (i.e., "polarized," as in "polarized sunglasses"), which is used to determine the shape and characteristics of the precipitation being observed. This results in more accurate assessments of rain/snow/sleet/hail and subsequent hazards. Some research radars such as the KOUN radar in Oklahoma can emit simultaneous vertical and horizonal pulses.

Participant Notes:

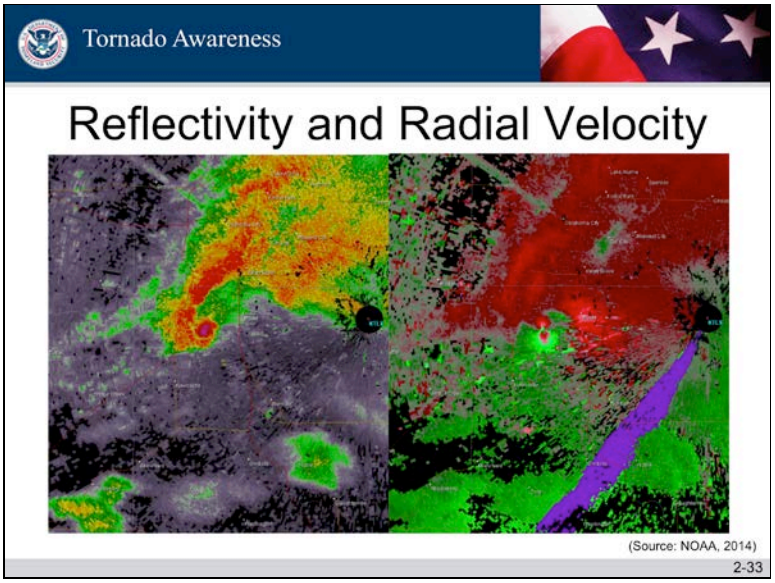


Slide 2-32. NEXRAD Doppler Radar Network

The National Weather Service currently operates a series of 159 WSR-88D Doppler Radar systems around the country. As these systems provide non-stop surveillance of the skies they have become instrumental for the detection of severe thunderstorms and associated weather. Timely tornado and flash flood warnings around the country depend on this network of Doppler Radars.

Even though radar is an indispensible tool in severe weather detection, it is not without its limitations. First of all, there are gaps in coverage, particularly in the mountainous regions of the western U.S. Furthermore, given that radar beams are angled slightly above the horizon, and the earth curves away from the radar site, it is difficult to detect the precipitation and wind occuring at the base of thunderstorms where tornadoes affect people. Finally, radar ranges do not extend far beyond the U.S. coastline, so storm systems such as tropical cyclones and hurricanes, are not detectable by radar until just before or near landfall.

Participant Notes:



Slide 2-33. Reflectivity and Radial Velocity

The above slide illustrates the type of valuable information that can be derived from Doppler radars. On the left is a radar reflectivity image showing the “hook” shaped pattern of heavy rain and hail, which was associated with the supercell thunderstorm that eventually became the deadly EF-5 tornado that struck Moore, Oklahoma, on May 20, 2013.

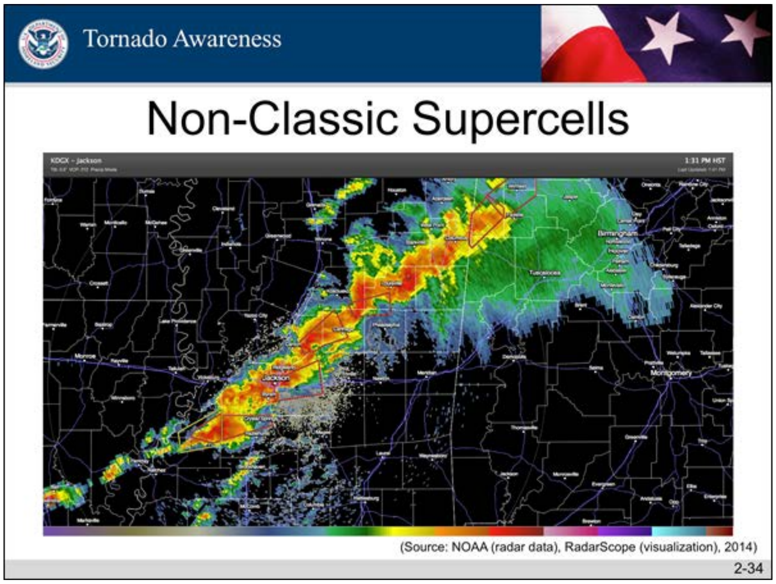
In this slide, the following should be noted:

- The storm-relative velocity figure is on the right. The term “storm-relative” is used to indicate a velocity figure that has been adjusted to account for the motion of the storm. In other words, the motion of the storm has been subtracted from the observed wind field.
- The green colors indicate winds rapidly approaching the radar (radar site is located at the center of the black circle to the right).
- The red colors indicate winds moving away from the radar.
- The green and red colors adjacent to each other suggest the presence of strong rotation.

Meteorologists were able to use these Doppler radar displays to issue tornado warnings to the residents of central Oklahoma on that fateful day.

Key Point: Even with the advances of radar technology, ground truth provided from storm spotters is still extremely valuable, enabling the meteorologist to validate what is being observed on radar.

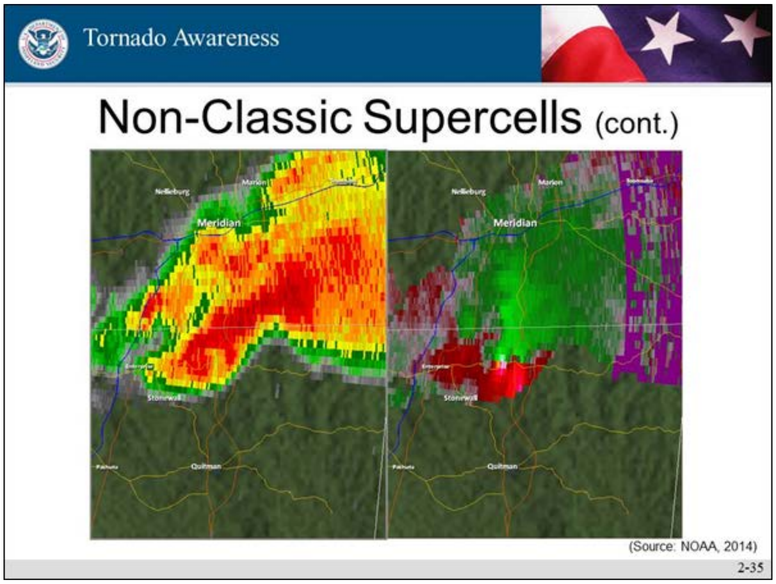
Participant Notes:



Slide 2-34. Non-Classic Supercells

Sometimes supercells can be joined together in an unbroken line of storms. These quasi-linear convective systems (QLCS) can pose a significant challenge for emergency managers and first responders, because tornadoes that form within them are often rain-wrapped, difficult to escape from with other tornadic storms developing to the southwest. These QLCSs are frequently found in the southeast U.S. and East Coast, often occuring ahead of cold fronts. Sometimes, the middle portion of the leading edge of the line of storms can accelerate forward in what is called a “bow echo”, which could be associated with rotation, and possible tornadoes at the ends, particularly the northern end.

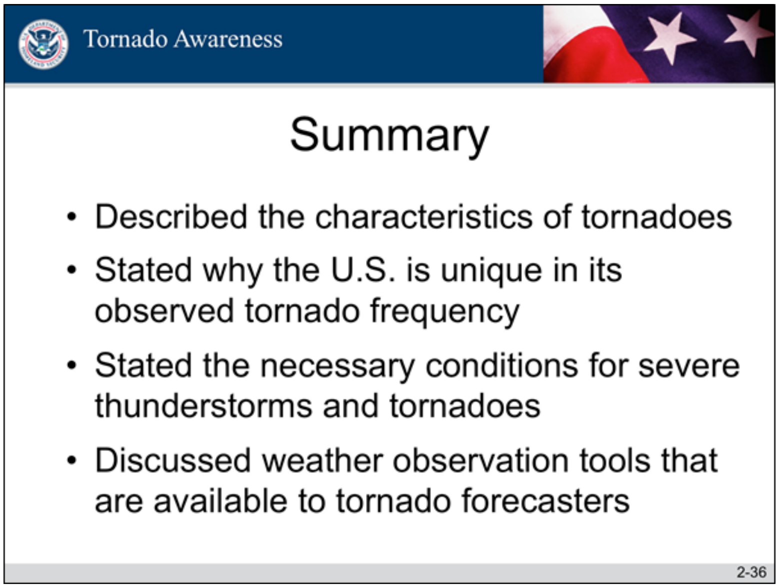
Participant Notes:



Slide 2-35. Non-Classic Supercells

This is another example of a non-classic supercell with a non-descript hook echo. While the tornado threat is somewhat difficult to identify on the reflectivity image, the storm-relative velocity shows the area of rotation clearly.

Participant Notes:



Slide 2-36. Summary

This module introduced participants to tornado characteristics, the reasons for the heightened frequency of tornadoes in the U.S., the necessary conditions for severe thunderstorms and tornadoes, and weather observation tools that are routinely used by forecasters.

Tornado Awareness

Participant Guide

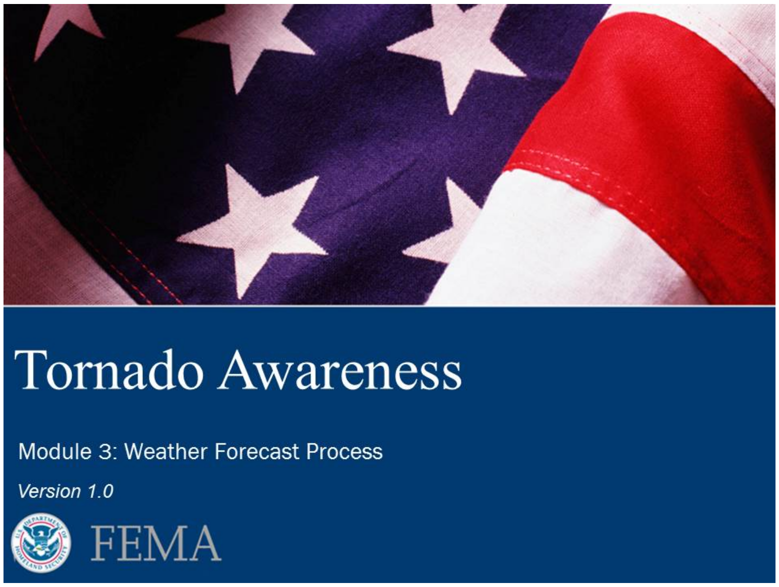
Module 3: Weather Forecast Process

Version 1.0

FEMA

This page is intentionally left blank.

Module 3: Weather Forecast Process – Administration Page



Slide 3-1. Weather Forecast Process

Duration

50 minutes

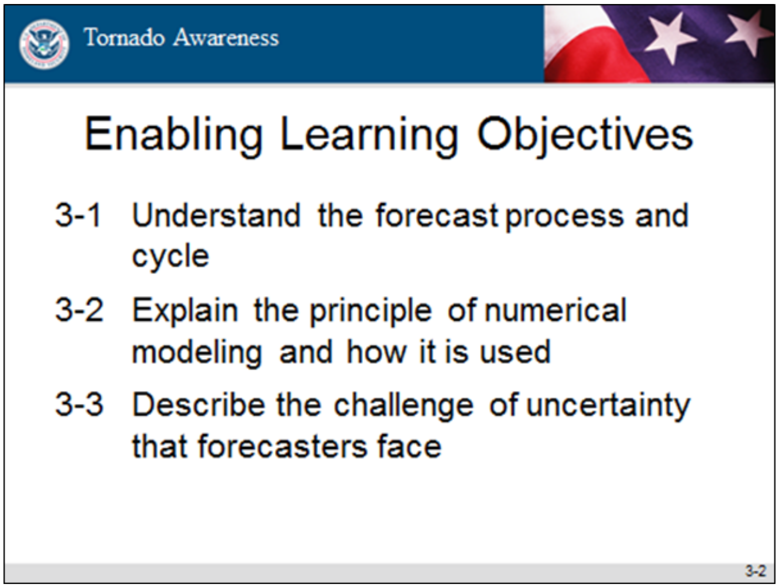
Scope Statement

In this module, the instructors will facilitate the discussion regarding weather forecasting as well as review the forecast process cycle. Special focus will be placed on the inherent challenges and uncertainties associated with forecasting and a general overview on numerical modeling will be provided. A group activity will provide participants with the opportunity to experience the challenges associated with tornado forecasting.

Terminal Learning Objective (TLO)

Participants will be able to describe the weather forecast process and appreciate its complexities while making decisions in the face of tornado hazards.

Enabling Learning Objectives (ELOs)



Slide 3-2. Enabling Learning Objectives

At the end of this module, participants will be able to:

3-1 Understand the forecast process and cycle.
3-2 Explain the principle of numerical modeling and how it is used.
3-3 Describe the challenge of uncertainty that forecasters face.

Resources

- Instructor Guide (IG)
- Module 3 presentation slides
- Laptop with presentation software installed and CD-ROM capability
- Audio-visual (A/V projection unit)
- Projector screen
- Chalkboard (and chalk), whiteboard (and dry erase markers), or easel and easel paper (and permanent markers)
- One of each of the following items per participant:
  - Participant Guide (PG) available for download from http://ndptc.hawaii.edu/
  - Participant Handout

Instructor-to-Participant Ratio

2:40

Reference List

Bluestein, H. B. 2009. "The formation and early evolution of the Greensburg, Kansas, Tornadic supercell on 4 May 2007." *Weather and Forecasting*, *24*, 899-920. doi: 10.1175/2009WAF2222206.1.

Cintineo, R.M. and D.J. Stensrud. 2013. "On the Predictability of Supercell Thunderstorm Evolution." *Journal of the Atmospheric Sciences*, 2013. 70(7): p. 1993-2011.

Mathis, Nancy. 2007. *Storm Warning: The Story of a Killer Tornado.* New York: Touchstone.

NWS: JetStream – Online School for Weather. 2013. Accessed 2013. http://www.srh.weather.gov/jetstream/

NWS: Storm Prediction Center. 2013. Frequently Asked Questions (FAQ). Accessed 2013. http://www.spc.noaa.gov/faq/

NWS Weather Forecast Office (WFO): Birmingham, AL. 2013. "Tuscaloosa-Birmingham Tornado – April 27, 2011." Accessed 2013. http://www.srh.noaa.gov/bmx/?n=event_04272011tuscbirm

NWS WFO: Norman, OK. 2013. "The May 31-June 1, 2013 Tornado and Flash Flooding Event." Accessed 2013. http://www.srh.noaa.gov/oun/?n=events-20130531

NWS WFO: Norman, OK. 2013. "The Tornado Outbreak of May 20, 2013." Accessed 2013. http://www.srh.noaa.gov/oun/?n=events-20130520

Rauber, R. M., J. E. Walsh, and D. J. Charlevoix. 2008. *Severe & Hazardous Weather: An Introduction to High Impact Meteorology*. Dubuque: Kendall/Hunt

Simmons, K. M., and D. Sutter. 2012. *Deadly Season: Analysis of the 2011 Tornado Outbreaks.* Boston: American Meteorological Society.

Practical Exercise Statement

This exercise allows participants to work in groups in a role-playing activity that is intended to demonstrate the challenges of tornado forecasting. Participants will be provided with simplified weather maps for use in generating a basic tornado forecast, based on their knowledge gained in the course thus far. After presenting the results of their forecast, the instructors will critique each group's analysis. The purpose of this activity is not to train participants to become amateur forecasters, but rather, for the participants to appreciate the challenges behind the forecast process so that they are aware of the steps involved prior to the issuance of a tornado warning.

Assessment Strategy

- Instructors observation of participant involvement in classroom discussion
- Instructor-led discussion to gauge participant grasp of the subject matter
- Instructors engagement of participant involvement with requests for local examples and experiences
- Instructors observation of individual participation during group activity

Tornado Awareness

Icon Map

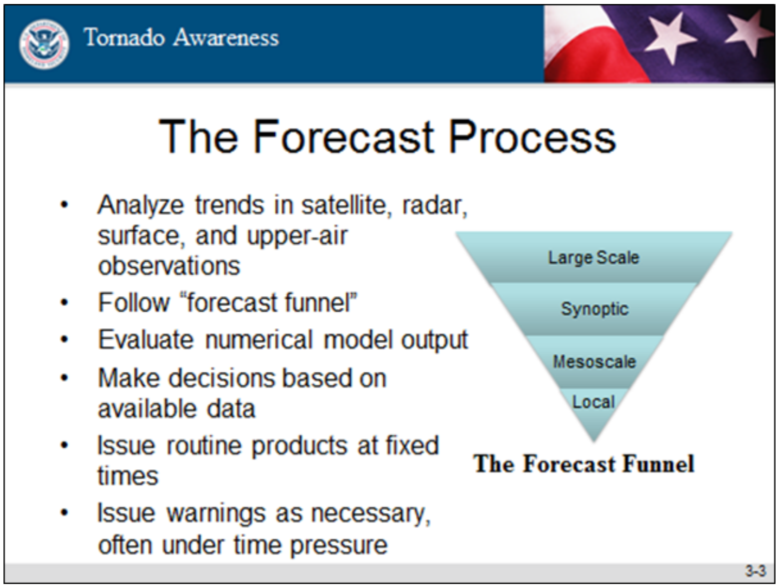
Knowledge Check: Used when it is time to assess participant understanding.

Example: Used when there is a descriptive illustration to show or explain.

Key Points: Used to convey essential learning concepts, discussions and introduction of supplemental material.

Participant Note: Used to indicate text that has been included as additional information for the participant. The text may not be directly addressed in the slide presentation or during class discussion.

Participant Notes:

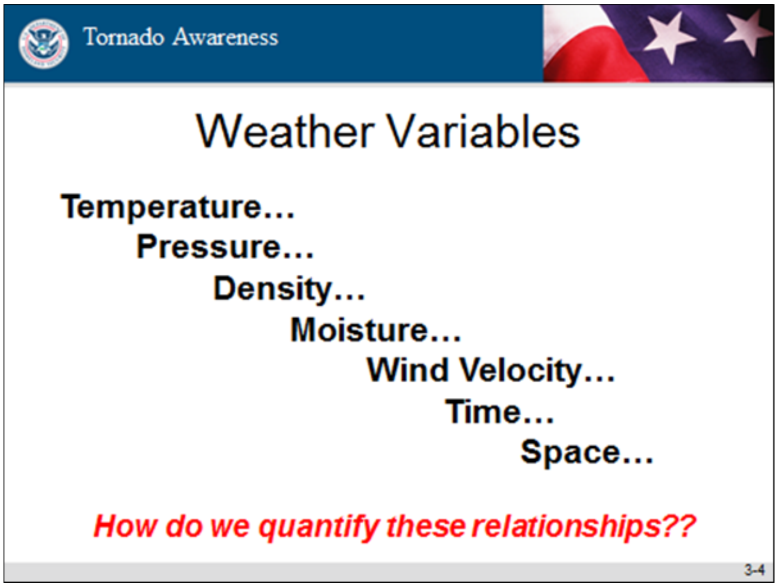


Slide 3-3. The Forecast Process

The forecast process is based on the concept known as the "forecast funnel." Forecasters typically start by analyzing the large-scale weather patterns around the globe followed by analyzing the subsequently smaller scales (synoptic, mesoscale, then local).

Forecasters analyze trends in satellite, radar, surface, and upper-air observations, and then evaluate numerical model output. They make decisions based on available data and must issue routine products at fixed times. Warnings are issued as necessary often under time pressure.

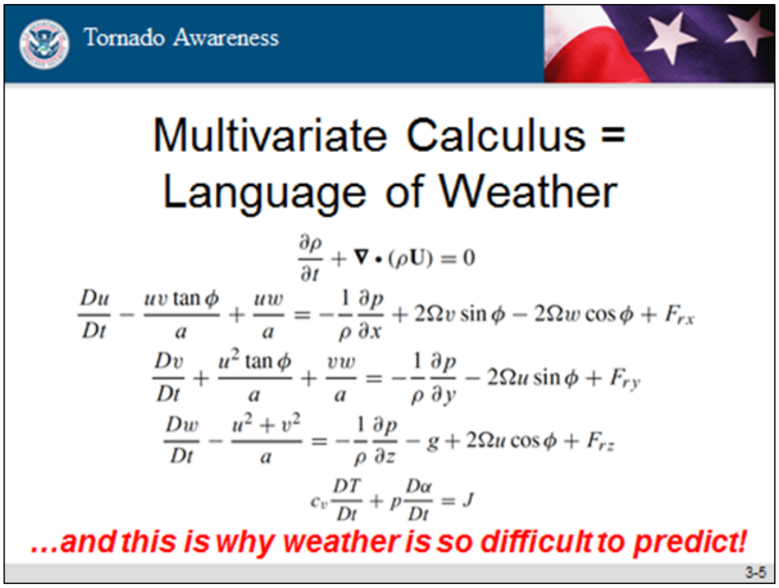
Participant Notes:



Slide 3-4. Weather Variables

The diverse types of weather observing technologies provide a variety of information about all the atmospheric variables. These include, but not limited to, temperature, pressure, density, moisture, wind velocity, time, and space.

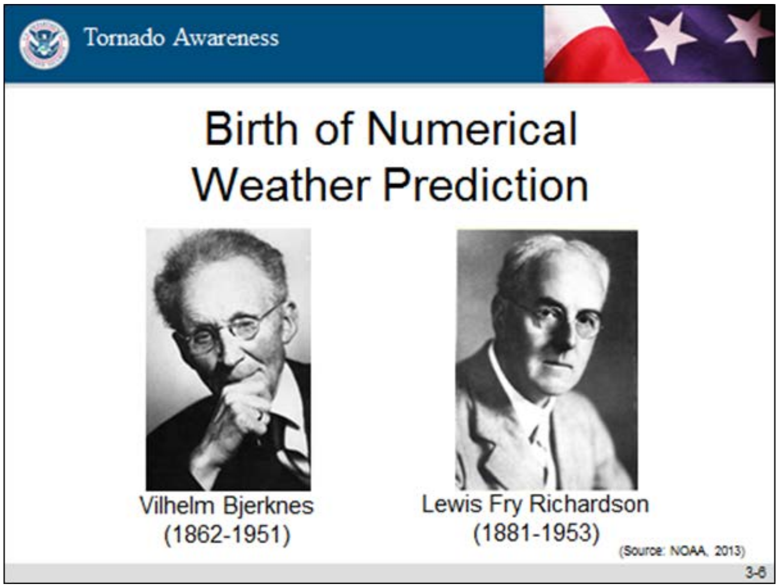
Participant Notes:



Slide 3-5. Multivariate Calculus = Language of Weather

Mathematics is the language of science, and calculus is a way to express the relationships between changing variables as they relate to space and time. Because weather is always changing and involves multiple variables, meteorologists use multivariate calculus to express the dynamics of the the sky. Without calculus, the weather would be even more difficult to predict! These particular equations form the foundation of numerical weather prediction expressing the forces that govern the motion of a single air parcel.

Participant Notes:

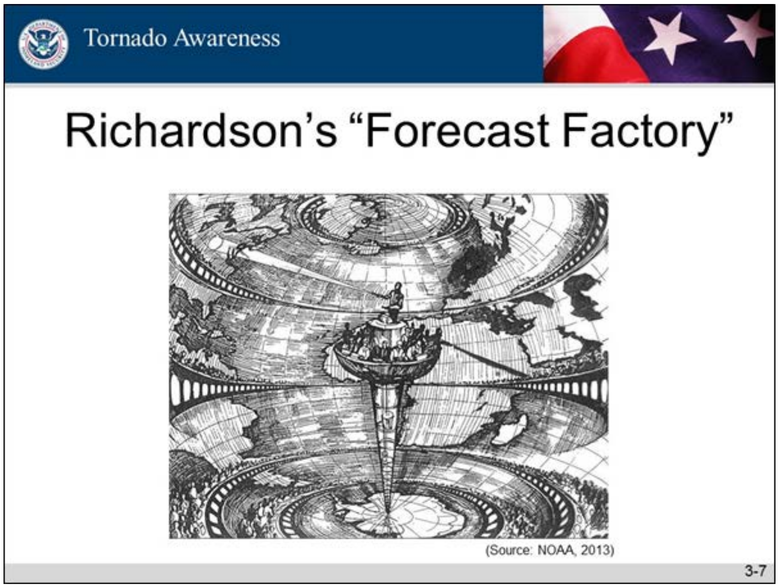


Slide 3-6. Birth of Numerical Weather Prediction

Vilhelm Bjerknes: In 1904, Norwegian physicist Vilhelm Bjerknes suggested that the atmosphere could be modeled using a series of partial differential equations. Solving these equations could result in the ability to predict the behavior of weather systems.

Lewis Fry Richardson: Not long after that, British mathematician Lewis Fry Richardson attempted to calculate the change in pressure at a location using nothing more than a slide rule. During World War I, it took him 6 weeks to make a 6-hour pressure forecast – and the result was completely incorrect. However, this first attempt at “numerical integration” of differential equations to predict atmospheric variables set the stage for modern numerical weather prediction.

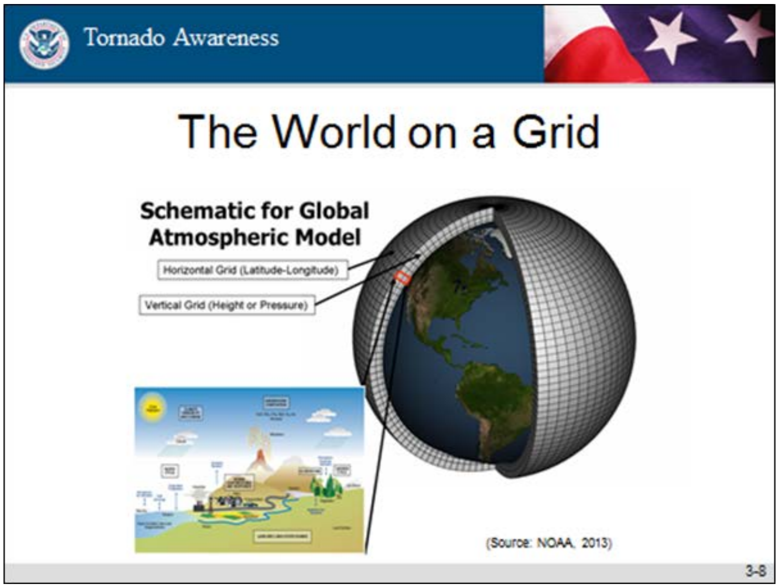
Participant Notes:



Slide 3-7. Richardson's "Forecast Factory"

Lewis Fry Richardson envisioned the use of a "forecast factory," filled with 64,000 mathematicians in a theater-like hall, each making calculations for a particular area of the globe. With a conductor at the center coordinating the calculations with different colored lights, this "forecast factory" would allow weather to be predicted at a sufficient pace. In reality, this experiment was never performed, thanks to the advent of computer technology.

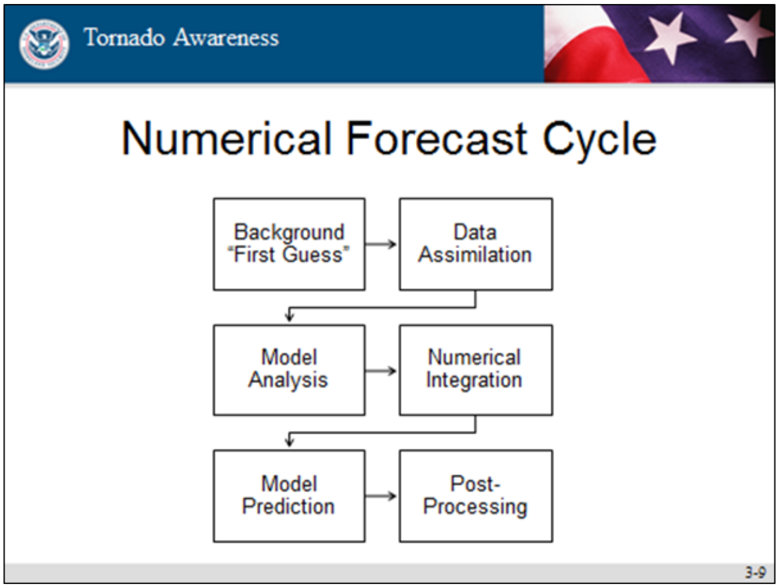
Participant Notes:



Slide 3-8. The World on a Grid

Today, numerical weather prediction is performed using some of the world's most powerful computers. These computers consist of hundreds and thousands of parallel processors, each sharing the task of performing numerous calculations based on the differential equations that describe the atmosphere. In order to do this, continuous equations must be broken into discrete steps using finite difference schemes that are set to a three-dimensional grid. This grid forms the foundation of the computer calculations where variables are calculated and passed through each gridpoint. Presently, the National Oceanic and Atmospheric Administration (NOAA) supercomputers can make approximately 213 trillion calculations per second!

Participant Notes:



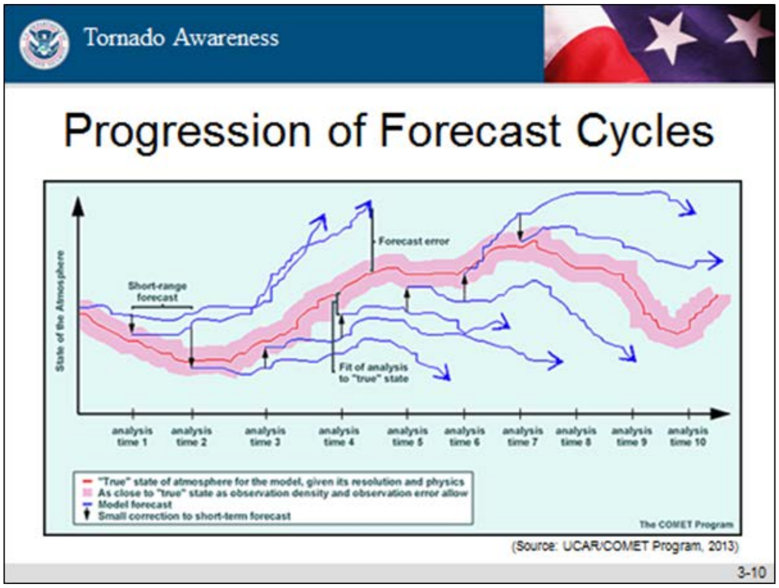
Slide 3-9. Numerical Forecast Cycle

The National Centers for Environmental Prediction of the National Weather Service is tasked with providing operational numerical model forecasts for the United States. Basically, each numerical weather prediction model's forecast cycles consist of the following steps:

- The "first guess" of the initial field of atmospheric variables is based on the forecast in the previous forecast cycle. This sets up the "background" field of wind, temperature, pressure, and other variables.
- Through data assimilation, information such as observations from ASOS stations, radiosondes, and other measures are incorporated into the model.
- By modifying the "background" environment based on the data assimilation process, the model uses this analysis to initialize its forecast.
- Starting with the initial analysis, the model integrates the atmospheric variables according to the governing equations of the atmosphere.
- During the integration process, the model predicts the state of the atmosphere at certain time steps.

These predictions are then "post-processed" to reveal the important atmospheric variables that meteorologists can interpret graphically.

Participant Notes:



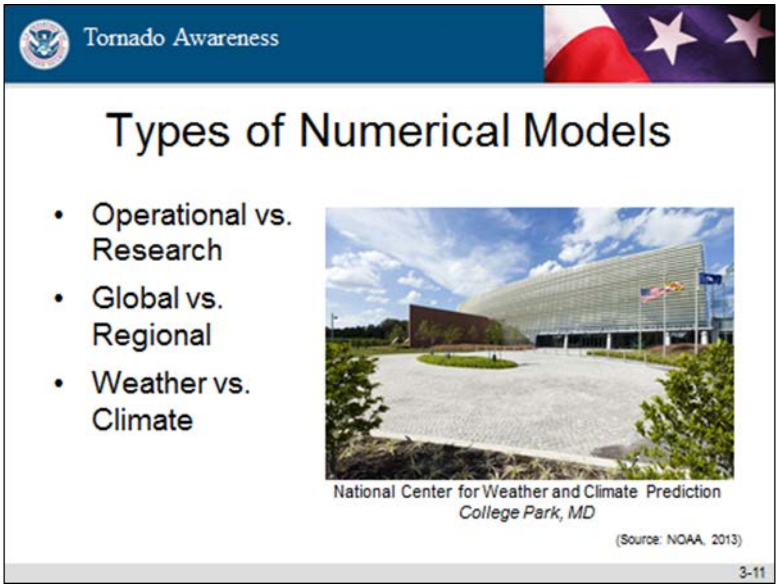
Slide 3-10. Progression of Forecast Cycles

For numerical weather prediction models used in operational forecasts, each forecast cycle is repeated at a given time interval. For example, the Global Forecasting System (GFS) model of the United States is run every six hours. The “true” state of the atmosphere is plotted in red with the model predictions in blue. Model predictions often diverge from “truth” at longer integration times. Thus, it is more difficult to predict weather five days from now than one day from now. This is due to the chaotic nature of the atmosphere and will be explained in more detail in the next slide.

The difference between the model prediction and the actual state of the atmosphere is considered the “forecast error.” This figure clearly depicts the “first guess” process of using the short-range forecast of the previous forecast cycle as the “background” to initialize the current forecast cycle. This process includes a small correction (black arrow) based on observed data that is assimilated.

Key Point: The numerical model forecast cycle illustrates the fact that forecasts are imperfect and errors grow as forecast lead time increases.

Participant Notes:



Slide 3-11. Types of Numerical Models

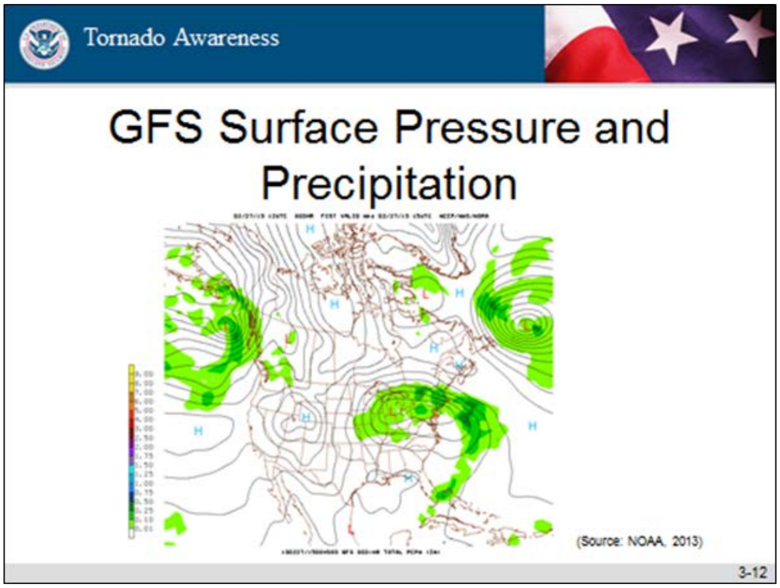
There are many types of numerical weather prediction models and a comprehensive discussion of each would be well beyond the scope of this course. Therefore, in general, the models can be classified as follows:

- Operational vs. Research;
- Global vs. Regional; and
- Weather vs. Climate.

Definitions of each type is provided below:

- "Operational models" are those that are run on a fixed forecast cycle and are used by meteorologists to construct real-time weather forecasts.
- "Research models" are used predominately for research purposes only and are used to test model physics and parameters or to perform scientific experiments.
- "Global operational models" are some of the most well-known models and are run by multiple government agencies around the world. As an example, NOAA runs the GFS and the data is available worldwide.
- "Regional models" are typically initiated based on boundary conditions supplied by global models with an inner "nested" domain that is at a higher resolution.
- "Global climate models" differ from numerical weather prediction models in temporal and spatial scales, given the need for climate models to integrate months and years into the future. Climate models also usually include coupled ocean/land/ice feedbacks that may not be present in purely atmospheric models.

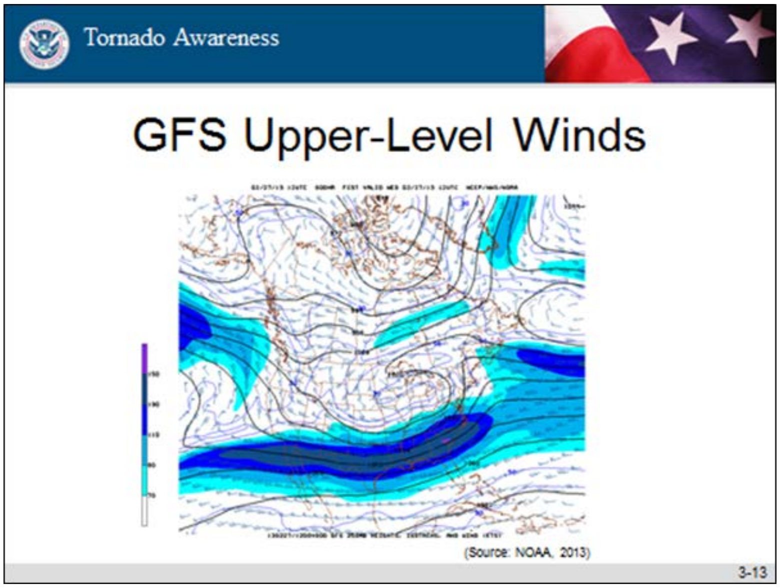
Participant Notes:



Slide 3-12. GFS Surface Pressure and Precipitation

This is an example of the GFS model output/prediction for surface pressure and total precipitation at three-hour intervals. This run was initialized at 12 UTC on February 27, 2013. At this time, the model predicted that the low pressure systems over the northeast would gradually slide into the North Atlantic, with development of a new mid-latitude cyclone over the Pacific Northwest and northern Great Plains toward the end of the forecast period (120 hours from initialization).

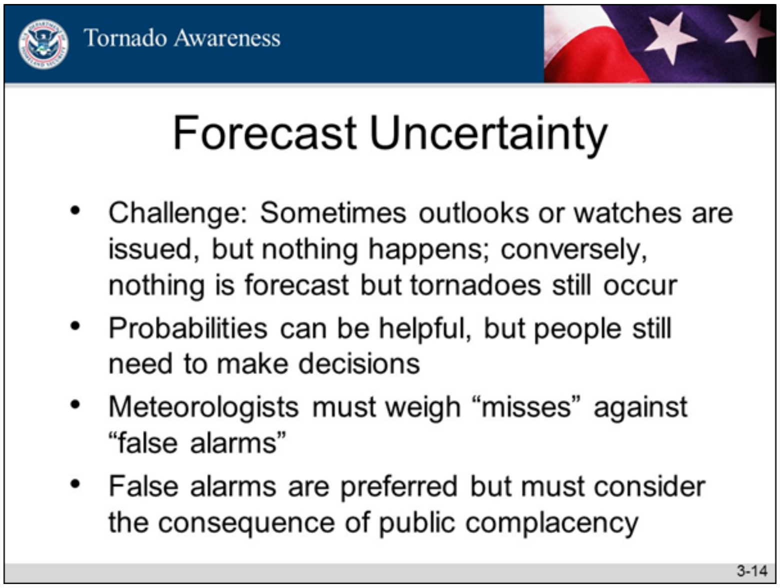
Participant Notes:



Slide 3-13. GFS Upper-Level Winds

The same model run can also be analyzed for upper-air conditions showing the jetstream patterns across the United States near the altitude of commerical airline flights. Looking at this model, it is easy to see that the air flow patterns follow a wave-like motion, and the passage of the troughs and ridges dictate the changing weather patterns in the mid-latitudes.

Participant Notes:

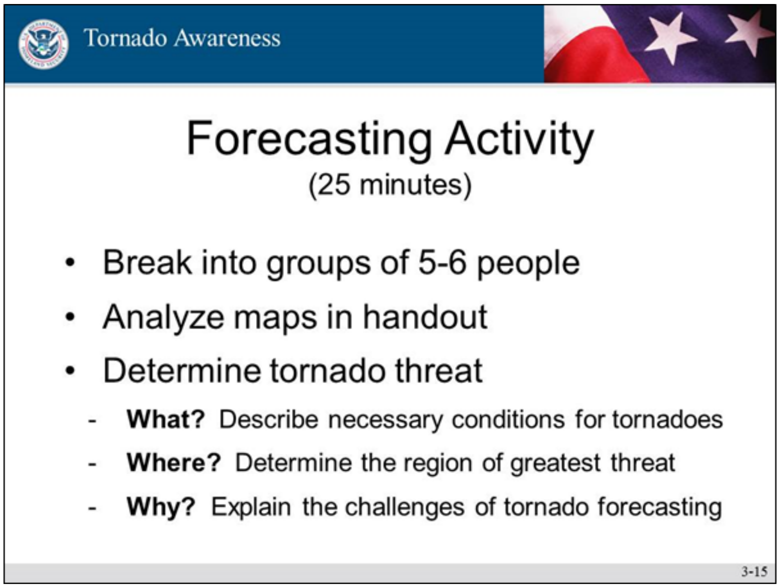


Slide 3-14. Forecast Uncertainty

The primary implication and challenge of forecast uncertainty is that sometimes outlooks or watches are issued, but nothing happens, or conversely, nothing is forecast, but tornadoes still occur.

Expressing forecasts as probabilities can be helpful, but people still need to make decisions, so different levels of acceptable risk must be taken into consideration. Meteorologists must weigh "misses" against "false alarms." Relatively speaking, while the latter is preferred, the consequences such as an increase in public complacency must be carefully considered.

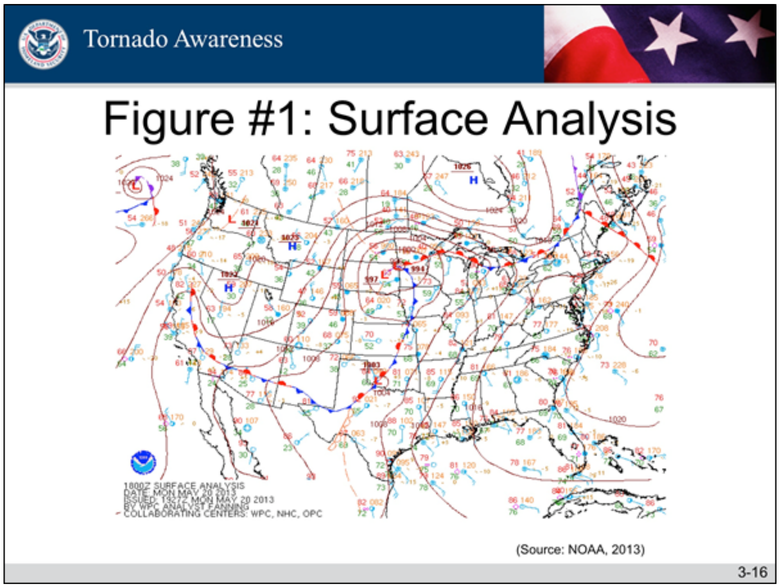
Participant Notes:



Slide 3-15. Forecasting Activity

This exercise allows participants to work together to understand the challenges of tornado forecasting by exploring Storm Prediction Center (SPC) mesoanalysis maps that are freely available online, describe necessary conditions for tornadoes, and determine the region of greatest threat, The total time for this exercise is estimated at 25 minutes.

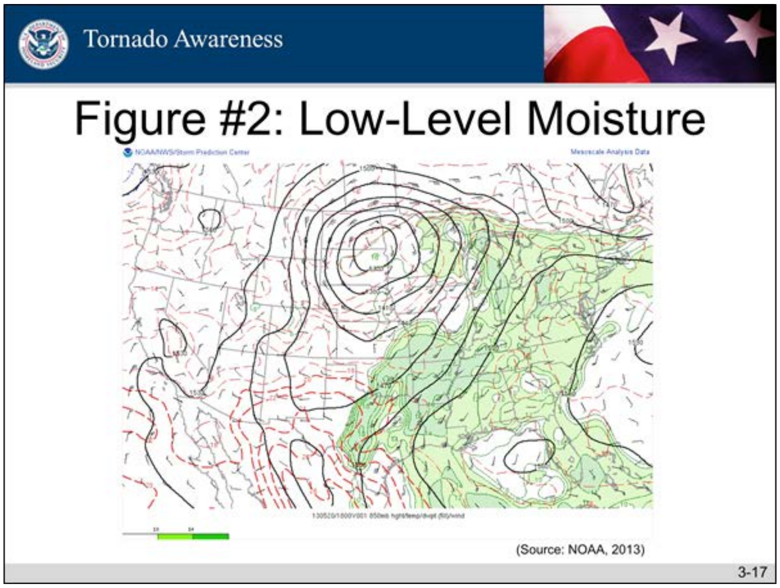
Participant Notes:



Slide 3-16. Figure #1: Surface Analysis

This surface analysis map depicts the weather systems that were in place across the continental United States at 18Z on May 20, 2013. Note the mid-latitude cyclone over the northern Plains, with a frontal boundary draped through Iowa, Kansas, Oklahoma, and Texas. Another low-pressure system is located over southwest Oklahoma. Think about where severe weather is most likely in relation to these weather features.

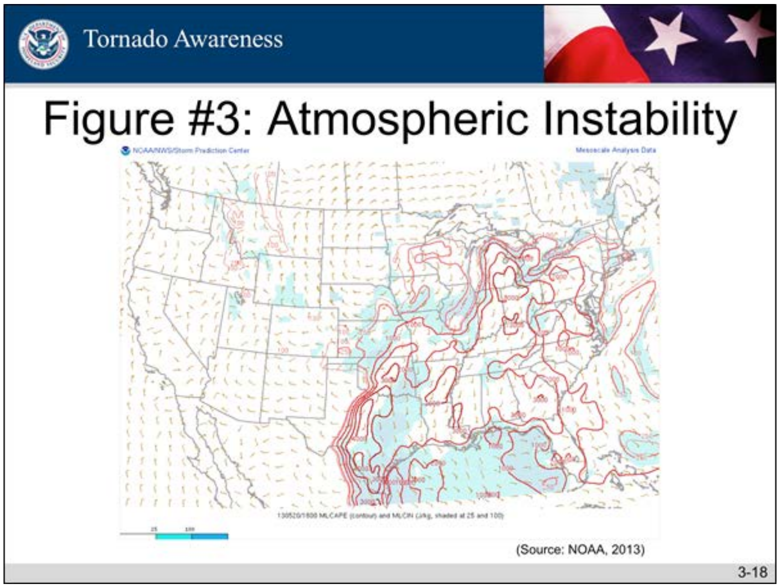
Participant Notes:



Slide 3-17. Figure #2: Low-Level Moisture

This is a map of low-level moisture, expressed as dewpoint temperature, valid at the same time as the surface map. For the purposes of this simplified exercise, the numerical values are not as important as the relative magnitude of the moisture: the darker the shade of green, the higher the moisture content of the air. Pay attention to areas of enhanced low-level moisture when considering severe weather risk.

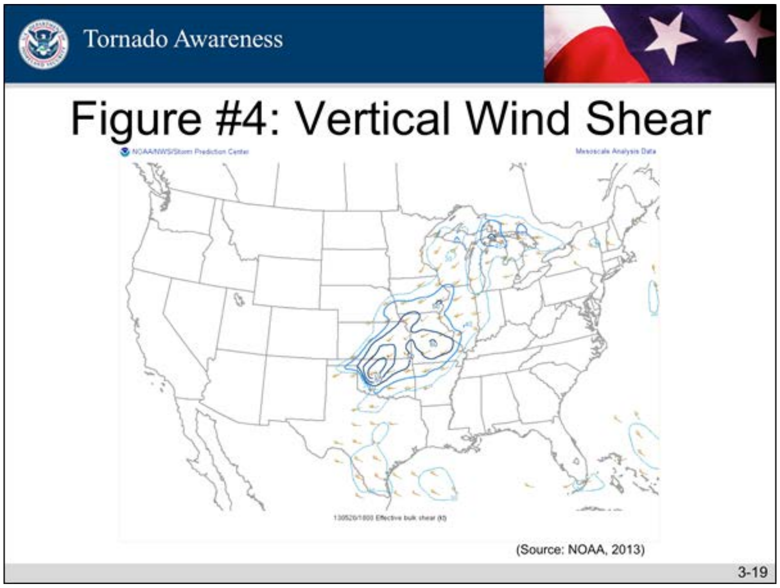
Participant Notes:



Slide 3-18. Figure #3: Atmospheric Instability

This is a map of instability, valid at the same time as the surface map, depicted by the red contours. For the purposes of this simplified exercise, the numerical values are not as important as the relative magnitude of the instability: the greater the contour value, the greater the instability. Pay attention to areas of enhanced instability when considering severe weather risk.

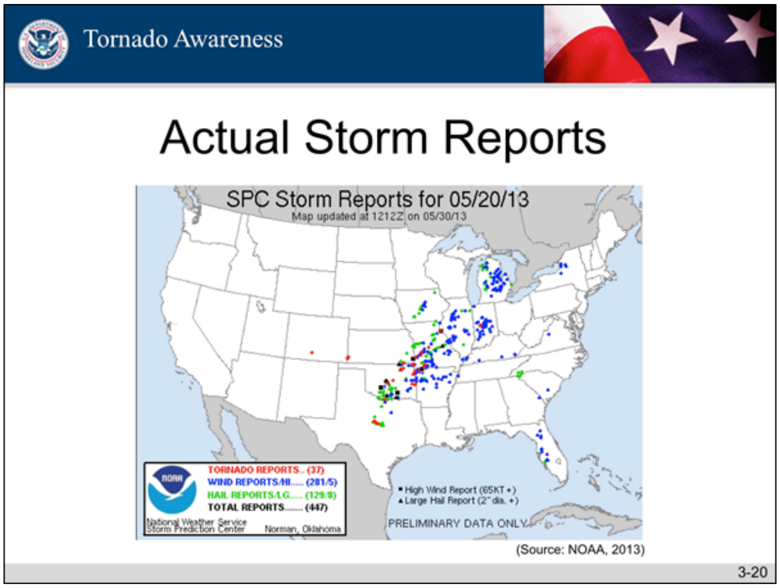
Participant Notes:



Slide 3-19. Figure #4: Vertical Wind Shear

This is a map of effective bulk shear, which is an expression of wind shear, depicted by blue contours and valid at the same time as the surface map. For the purposes of this simplified exercise, the numerical values are not as important as the relative magnitude of the shear: the greater the contour value, the greater the shear. Pay attention to areas of enhanced shear when considering severe weather risk.

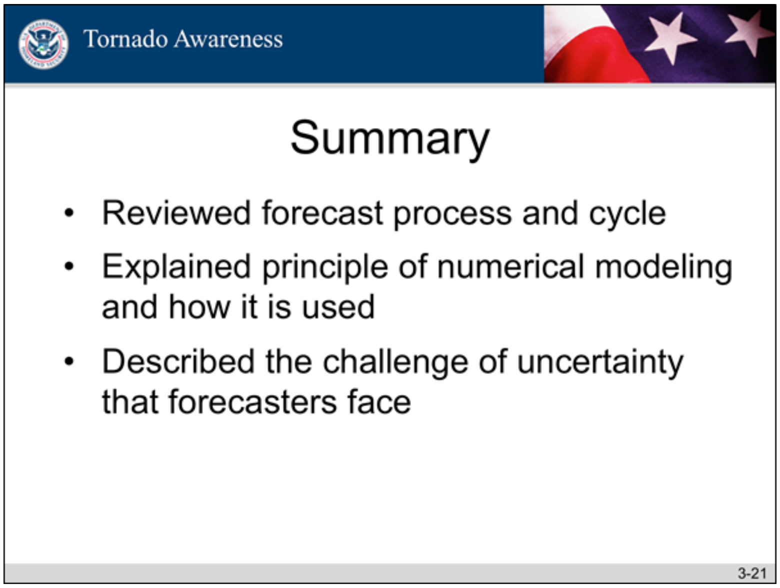
Participant Notes:



Slide 3-20. Actual Storm Reports

These were the actual storm reports from the severe weather outbreak that occurred on May 20, 2013. This day was notable due to the EF-5 tornado that tore through the city of Moore, Oklahoma. Tornadoes were observed across the southern Plains and into the Midwest, along with severe hail and straight-line winds.

Participant Notes:



Slide 3-21. Summary

This module provided an overview of the forecast process and cycle, with an emphasis on numerical modeling as a primary tool. The challenges associated with forecast uncertainty were also described.

This page is intentionally left blank.

Tornado Awareness

Participant Guide

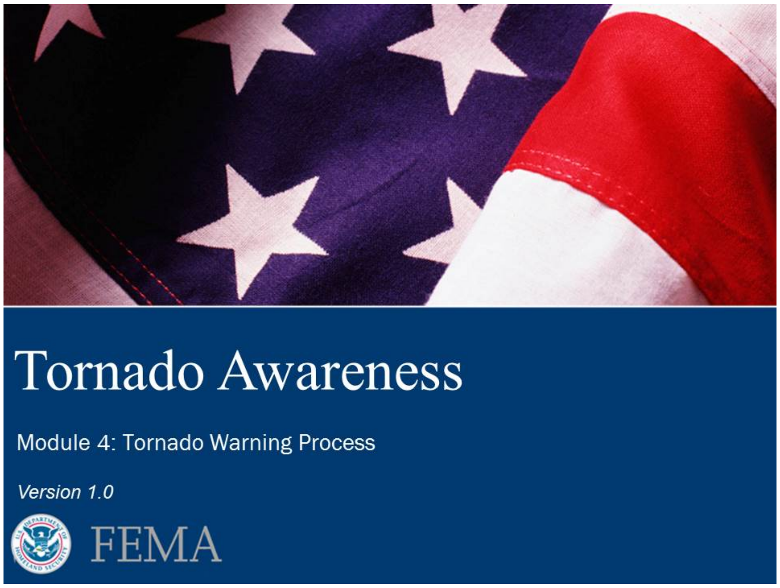
Module 4: Tornado Warning Process

Version 1.0

FEMA

This page is intentionally left blank.

Module 4: Tornado Warning Process – Administration Page



Slide 4-1. Tornado Warning Process

Duration

55 minutes

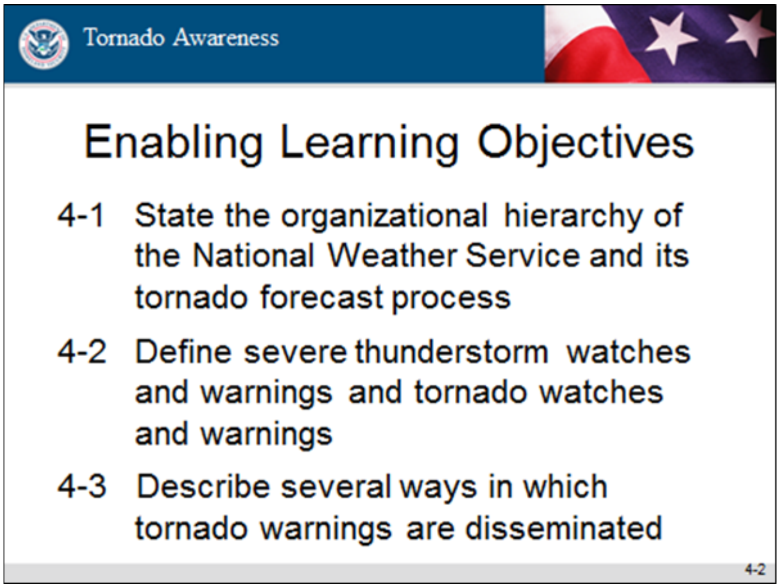
Scope Statement

In this module, the instructors will describe and explain the organizational hierarchy of the National Weather Service (NWS) as well as the various components of the warning dissemination system. In addition, participants will learn the definitions for severe thunderstorm and tornado watches and warnings.

Terminal Learning Objective (TLO)

Participants will be able to understand the tornado warning process and associated definitions.

Enabling Learning Objectives (ELOs)



Slide 4-2. Enabling Learning Objectives

At the end of this module, participants will be able to:

4-1 State the organizational hierarchy of the National Weather Service and its tornado forecast process.

4-2 Define severe thunderstorm watches and warnings and tornado watches and warnings.

4-3 Describe several ways in which tornado warnings are disseminated.

Resources

- Instructor Guide (IG)
- Module 4 presentation slides
- Laptop with presentation software installed and CD-ROM capability
- Audio-visual (A/V projection unit)
- Projector screen
- Chalkboard (and chalk), whiteboard (and dry erase markers), or easel and easel paper (and permanent markers)
- One of each of the following items per participant:
  - Participant Guide (PG) available for download from http://ndptc.hawaii.edu/
  - Participant Handout

Instructor-to-Participant Ratio

2:40

Reference List

Brotzge, J., W. Donner, 2013: The Tornado Warning Process: A Review of Current Research, Challenges, and Opportunities. Bulletin of American Meteorological Society, 94, 1715–1733. doi: http://dx.doi.org.eres.library.manoa.hawaii.edu/10.1175/BAMS-D-12-00147.1

Federal Emergency Management Association (FEMA). 2013. “Tornadoes.” Accessed 2013. http://www.ready.gov/tornadoes

Rauber, R. M., J. E. Walsh, and D. J. Charlevoix. 2008. *Severe & Hazardous Weather: An Introduction to High Impact Meteorology*. Dubuque: Kendall/Hunt.

NOAA’s National Weather Service: Storm Prediction Center. 2013. Frequently Asked Questions (FAQ). Accessed 2013. http://www.spc.noaa.gov/faq/

Schneider, B. 2012*. Extreme weather: A guide to surviving flash floods, tornadoes, hurricanes, heat waves, snowstorms, tsunamis and other natural disasters.* New York: Palgrave Macmillan.

SKYWARN National: Current Radar, Convective Outlooks & Watches. 2013. Accessed 2013. http://skywarn.org/

SKYWARN Storm Spotter Guides Online Version 2.0. 2011. Accessed 2013. http://spotterguides.us/

Assessment Strategy

- Instructors observation of participant involvement in classroom discussion
- Instructor-led discussion to gauge participant grasp of the subject matter

Tornado Awareness

Icon Map

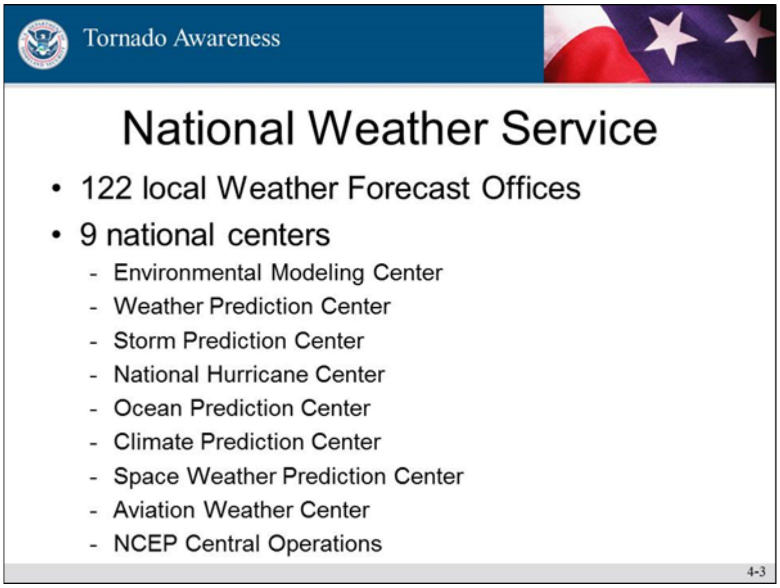
Knowledge Check: Used when it is time to assess participant understanding.

Example: Used when there is a descriptive illustration to show or explain.

Key Points: Used to convey essential learning concepts, discussions and introduction of supplemental material.

Participant Note: Used to indicate text that has been included as additional information for the participant. The text may not be directly addressed in the slide presentation or during class discussion.

Participant Notes:

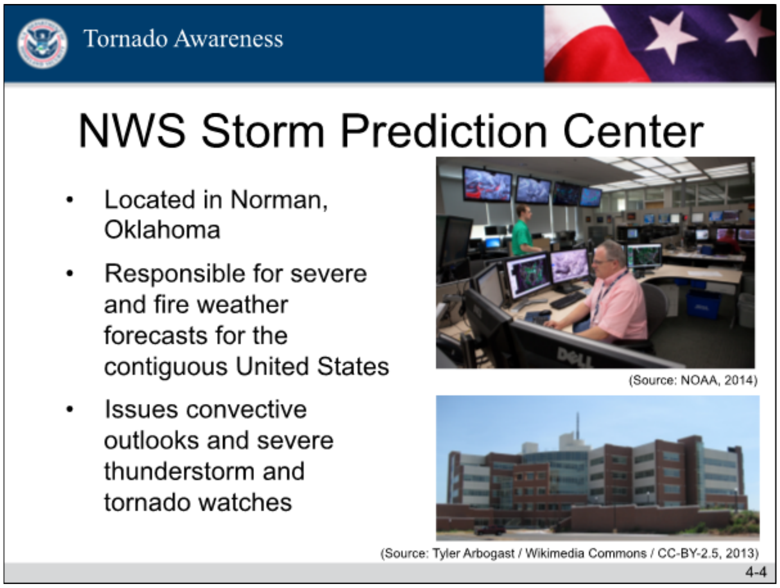


Slide 4-3. National Weather Service

Founded in 1870 as the Weather Bureau, today the National Weather Service (NWS) is part of the National Oceanic and Atmospheric Administration (NOAA), which is located within the U.S. Department of Commerce. By law, the NWS is tasked to provide official weather forecasts and warnings:

> "**Sec. 313. Duties of Secretary of Commerce**
> The Secretary of Commerce shall have charge of the forecasting of weather, issue of storm warnings, display of weather and flood signals for the benefit of agriculture, commerce, and navigation, gauging and reporting of rivers, maintenance and operation of seacoast telegraph lines and collection and transmission of marine intelligence for the benefit of commerce and navigation, reporting of temperature and rain-fall conditions for the cotton interests, display of frost and cold-wave signals, distribution of meteorological information in the interests of agriculture and commerce, and taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States, or as are essential for the proper execution of the foregoing duties."
> **~ excerpt from 15 USC 313 "The Organic Act"**

Participant Notes:



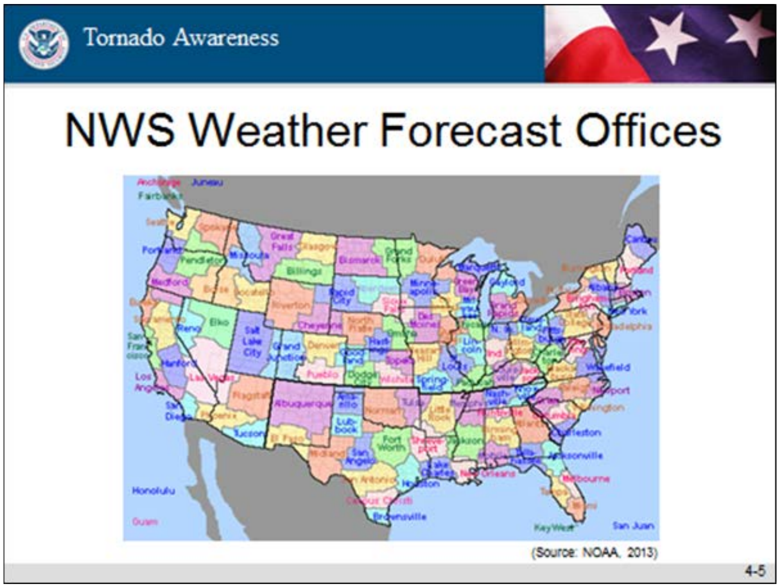
Slide 4-4. NWS Storm Prediction Center

Example: In the above slide, the top photo shows an example of a "high risk" convective outlook issued by the Storm Prediction Center (SPC). The bottom photo shows the National Weather Center (NWC) in Norman, Oklahoma, within which the SPC is located.

The SPC is the national center tasked with issuing severe weather outlooks and watches. The SPC which is located in the NWC on the University of Oklahoma campus in Oklahoma:

- Issues severe thunderstorm and tornado watches for this nation's 48 contiguous states;
- Issues mesoscale weather discussions and fire weather forecasts;
- Coordinates with local NWS Weather Forecast Offices during the issuance of severe weather watches; and
- Maintains 24-hour forecasting operations.

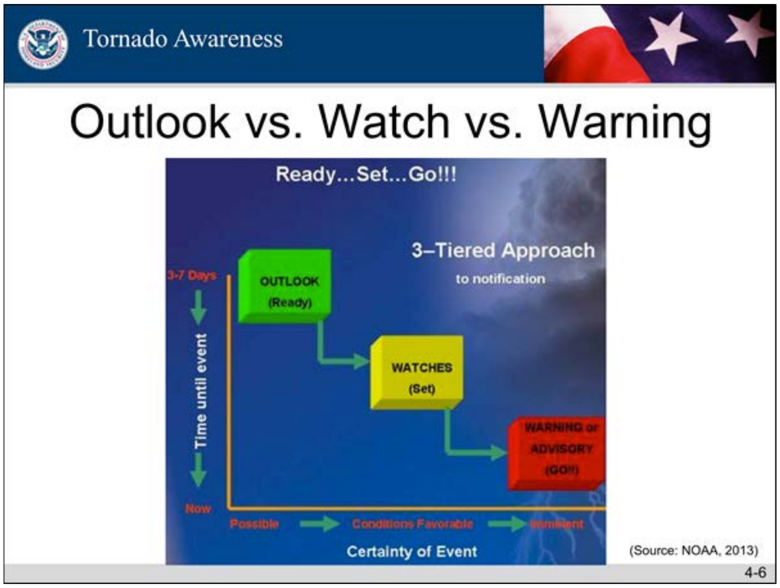
Participant Notes:



Slide 4-5. NWS Weather Forecast Offices

The NWS operates 122 Weather Forecast Offices (WFOs) around the country which serve as the front lines for day-to-day weather forecasting. While WFOs receive guidance from the NWS national centers, they also can and do utilize their local expertise when issuing routine forecasts for their respective county warning areas (CWA). Local WFOs are also responsible for issuing warnings of high-impact weather hazards such as tornadoes and flash floods.

Participant Notes:



Slide 4-6. Outlook vs. Watch vs. Warning

The NWS Glossary provides the following definitions:

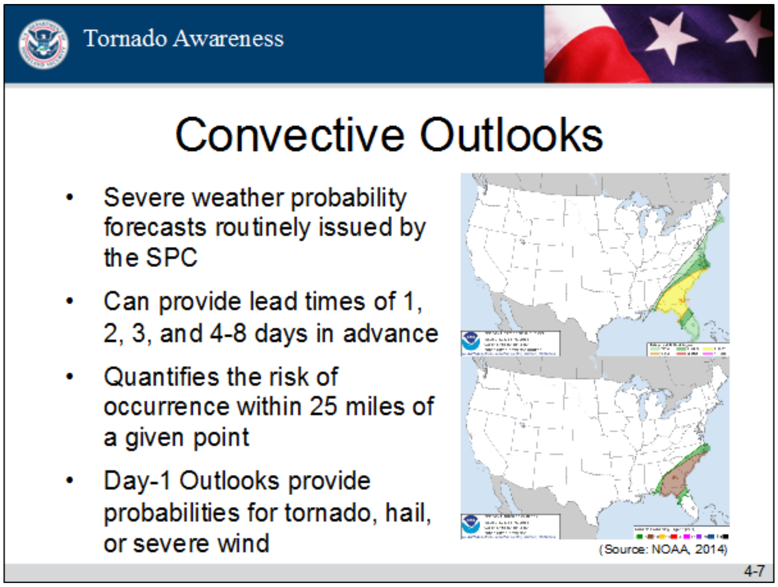
"Outlook" indicates a hazardous weather or hydrologic event may develop. It's used to provide info to those needing considerable lead time to prepare for the event."

"Watch" indicates the risk of a hazardous weather or hydrologic event has increased significantly, but its timing, occurrence, and/or location is uncertain. It's used to provide enough lead time for those needing to set plans in motion."

"Warning" is issued when a hazardous weather or hydrologic event is occurring, is imminent, or has a high probability of occurring. It's used for conditions posing a threat to life or property."

"Advisory" highlights special weather conditions that are less serious than a warning. They are for events that may cause significant inconvenience, and if caution is not exercised, it could lead to situations that may threaten life and/or property."

Participant Notes:



Slide 4-7. Convective Outlooks

Convective outlooks issued by the SPC are the first line of defense against severe weather threats and provide information regarding the potential for severe weather conditions (e.g., hail, damaging winds and tornado) for up to several days in advance. They are usually written in technical meteorological language and are intended to provide guidance to forecasters in the affected areas. The outlooks also include categorical risk (marginal/slight/enhanced slight/medium/high) maps and probability of occurrence maps which are helpful to:

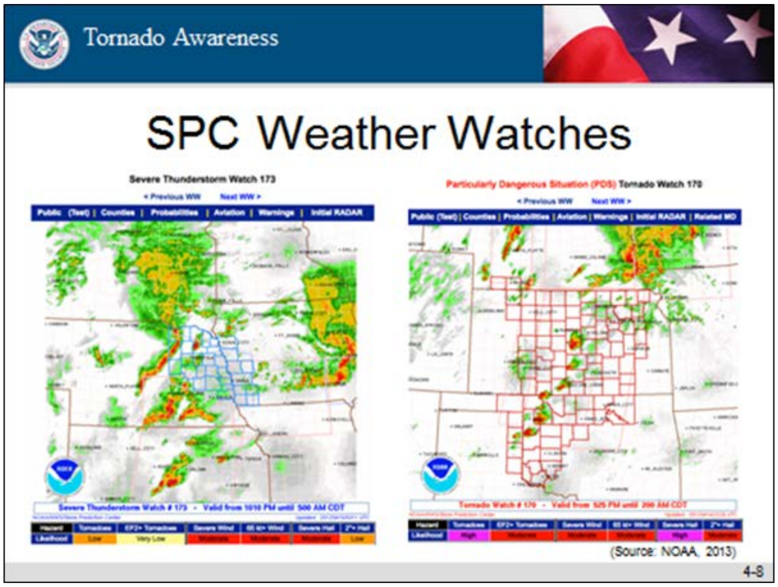
- Decision makers who need to quantify the risk of a particular type of severe weather hazard; and
- All members of the community.

At a lead time of 1 day (i.e., Day 1 Outlook), the probabilities are given for each type of hazard (e.g., hail, damaging wind and tornado). The categorical outlook is shown in the top figure, and the probabilistic outlook for tornadoes is shown in the bottom figure. For the Day 2 and Day 3 products, probabilities for all hazards are considered together. At longer lead times, only a discussion about the general region of concern is given.

On October 22, 2014, SPC updated the convective outlook risk categories. For a summary of the changes, please see Appendix D.

For more information about SPC products, including issuance/valid times, please visit: http://www.spc.noaa.gov/misc/about.html and http://www.spc.noaa.gov/faq/

Participant Notes:



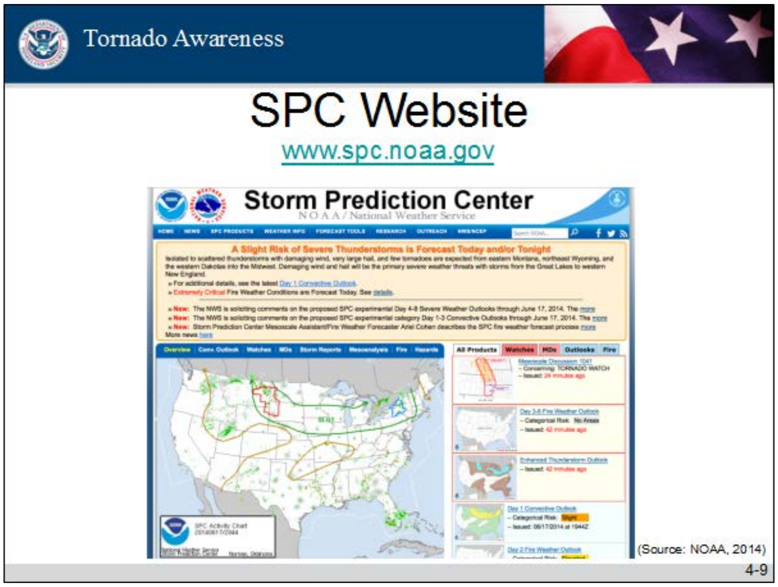
Slide 4-8. SPC Weather Watches

Within this nation's 48 contiguous states, severe thunderstorm and tornado "watches" are issued by the SPC (in coordination with local WFOs) typically on the day of the severe weather event and several hours before its onset. A "watch" signals the need for preparedness actions – both in and near the watch area – such as alerting communities to maintain an eye to the skies and to be within reach of public communication sources in case the weather rapidly deteriorates. Tornadoes can still occur outside a tornado watch area or within a severe thunderstorm watch (or none could form at all).

On rare occasions, watches are labeled as a "Particularly Dangerous Situation" (PDS). Although there is no objective threshold for the issuance of PDS watches, they are typically reserved for when the most volatile atmospheric conditions are set to produce the most violent weather.

For additional information about SPC products, visit:
http://www.spc.noaa.gov/misc/about.html and
http://www.spc.noaa.gov/faq/

Participant Notes:



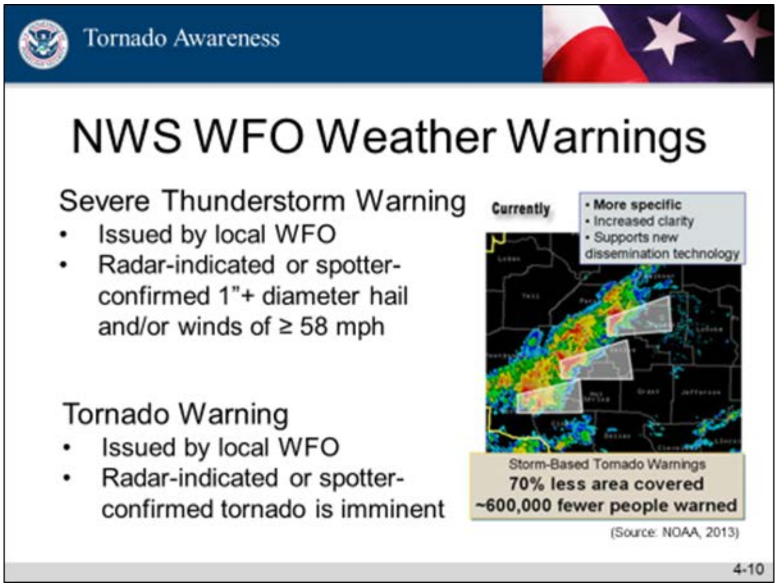
Slide 4-9. SPC Website

The SPC website is a comprehensive source of information for ongoing and forecast severe thunderstorm, tornado, and fire hazards. While much of the information is technical with meteorological details beyond the scope of immediate concern to emergency managers, the relevant tools and products for situational awareness are located in the tabs above the map of the United States.

The overview map shows the current Doppler radar animation with overlays of the Day 1 Convective Outlook and active severe thunderstorm (blue) and tornado watches (red). Of particular interest to decision makers are some of the tabs above the map that lead to separate pages showing active convective outlooks, watches, mesoscale discussions, storm reports, and fire weather outlooks.

SPC website: http://www.spc.noaa.gov

Participant Notes:



Slide 4-10. NWS WFO Weather Warnings

Severe thunderstorm and tornado warnings are issued by local NWS offices and are the most urgent alerts issued for imminent threats. Immediate action must be taken to ensure safety and security.

Since 2007, the NWS has implemented storm-based warnings. Rather than issuing warnings by county, storm-based warnings using polygons allow a reduction in warning area, which increases the accuracy of the warnings. However, although warnings are now storm-based, some methods of dissemination in certain locations are still county-based.

This is an important distinction that could affect public awareness and understanding of the warning process.

For more information about storm-based warnings, visit: http://www.nws.noaa.gov/sbwarnings/

From the NWS Glossary (http://w1.weather.gov/glossary/):

> ***Severe Thunderstorm Warning***
> This is issued when either a severe thunderstorm is indicated by the WSR-88D radar, or a spotter reports a thunderstorm producing hail one inch or larger in diameter and/or winds equal or exceed 58 miles an hour; therefore, people in the affected area should seek safe shelter immediately. Severe thunderstorms can produce tornadoes with little or no advance warning. Lightning frequency is not a criterion for issuing a severe thunderstorm

Participant Notes:

warning. They are usually issued for a duration of one hour. They can be issued without a Severe Thunderstorm Watch being already in effect.

Like a Tornado Warning, the Severe Thunderstorm Warning is issued by your National Weather Service Forecast Office (NWFO). Severe Thunderstorm Warnings will include where the storm was located, what towns will be affected by the severe thunderstorm, and the primary threat associated with the severe thunderstorm warning. If the severe thunderstorm will affect the near shore or coastal waters it will be issued as the combined product--Severe Thunderstorm Warning and Special Marine Warning. If the severe thunderstorm is causing torrential rains, this warning may also be combined with a Flash Flood Warning. If there is an ampersand (&) symbol at the bottom of the warning, it indicates that the warning was issued as a result of a severe weather report.

After it has been issued, the affected NWFO will follow it up periodically with Severe Weather Statements. These statements will contain updated information on the severe thunderstorm and they will also let the public know when the warning is no longer in effect.

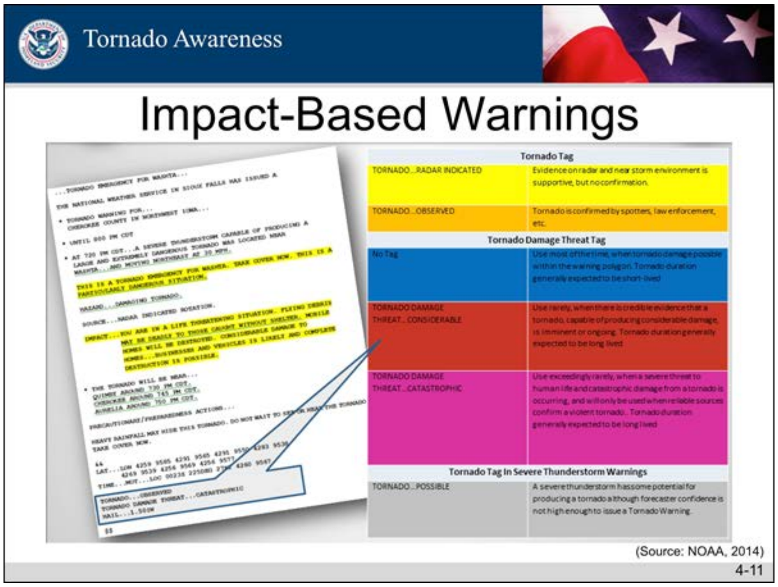
Tornado Warning

This is issued when a tornado is indicated by the WSR-88D radar, or sighted by spotters; therefore, people in the affected area should seek safe shelter immediately. They can be issued without a Tornado Watch being already in effect. They are usually issued for a duration of around 30 minutes.

A Tornado Warning is issued by your local National Weather Service Office (NWFO). It will include where the tornado was located and what towns will be in its path. If the tornado will affect the near shore or coastal waters, it will be issued as the combined product--Tornado Warning and Special Marine Warning. If the thunderstorm which is causing the tornado is also producing torrential rains, this warning may also be combined with a Flash Flood Warning. If there is an ampersand (&) symbol at the bottom of the warning, it indicates that the warning was issued as a result of a severe weather report.

After it has been issued, the affected NWFO will be followed up periodically with Severe Weather Statements. These statements will contain updated information on the tornado, and they will also let the public know when warning is no longer in effect.

Participant Notes:



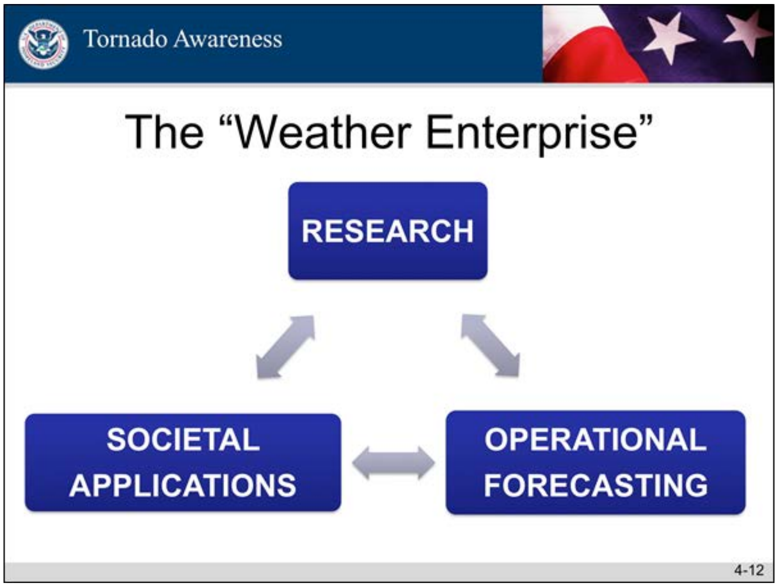
Slide 4-11. Impact-Based Warnings

The National Weather Service is currently testing its impact-based warning products. The program began in 2012 to better communicate risk by emphasizing the likely level of severe thunderstorm and tornado impacts. They are intended to be easier to read and to facilitate the identification of important information about a storm.

In the spring of 2013, 38 offices in NWS Central Region adopted these warnings. The warnings continue to be expanded to offices in other regions for testing. This multi-tiered approach to tornado warnings is targeted at emergency managers, first responders, and the media to allow them to make better decisions and to better inform the public.

For more information: http://www.weather.gov/impacts

Participant Notes:



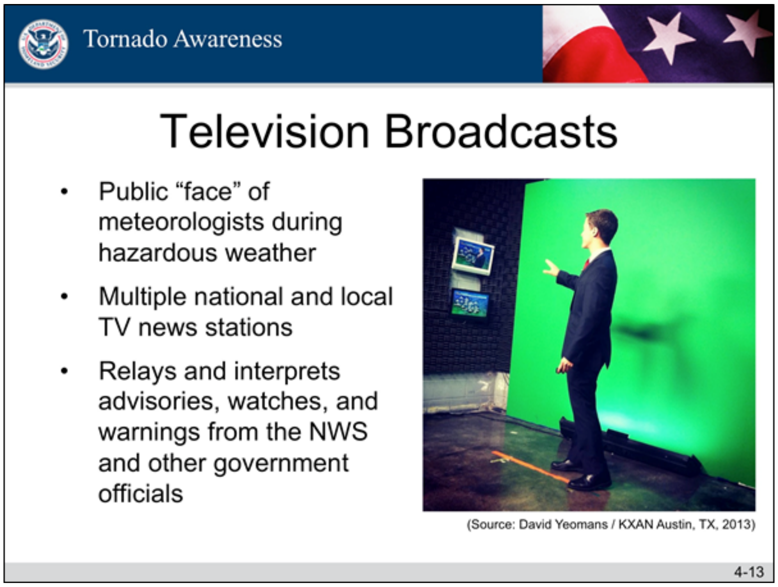
Slide 4-12. The "Weather Enterprise"

The ability to understand and forecast hazardous weather is dependent on all parts of the "Weather Enterprise," which is comprised of the following sectors:

- Research:
  - Academia
  - Government laboratories
  - Private sector R&D
- Societal Applications:
  - Private sector consulting
  - Energy, insurance, agriculture, forensics
  - Emergency management, security, policy
- Operational Forecasting:
  - Civilian and military government forecasting
  - Private sector forecasting
  - Broadcast meteorologists

The above chart is not meant to be all-inclusive as weather has countless applications in today's society. However, as this slide shows, all sectors within meteorology must work together to respond to the various impacts of hazardous weather. For example, research provides for advances in the science of understanding the weather while operational forecasting enables society to benefit from research. Applications of forecasting and research include energy, insurance, agriculture, forensics, emergency response, security, and policy.

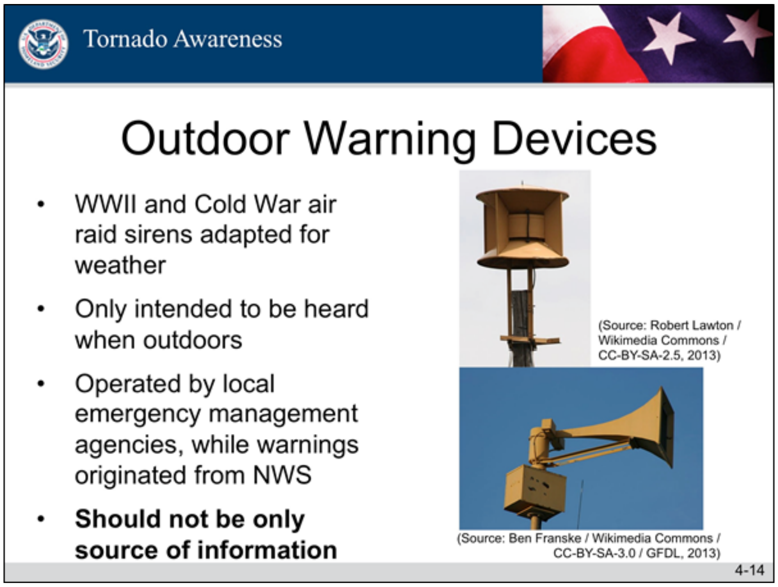
Participant Notes:



Slide 4-13. Television Broadcasts

Television is one of the primary methods in which the public receives weather warnings. Most national and local news stations employ meteorologists on their staff whose sole purpose is to watch and broadcast the weather. While news stations are required to relay NWS alerts, they are also able to add value to the forecasts by providing their own interpretations that make the complex weather situations more easily understandable to the public.

Participant Notes:

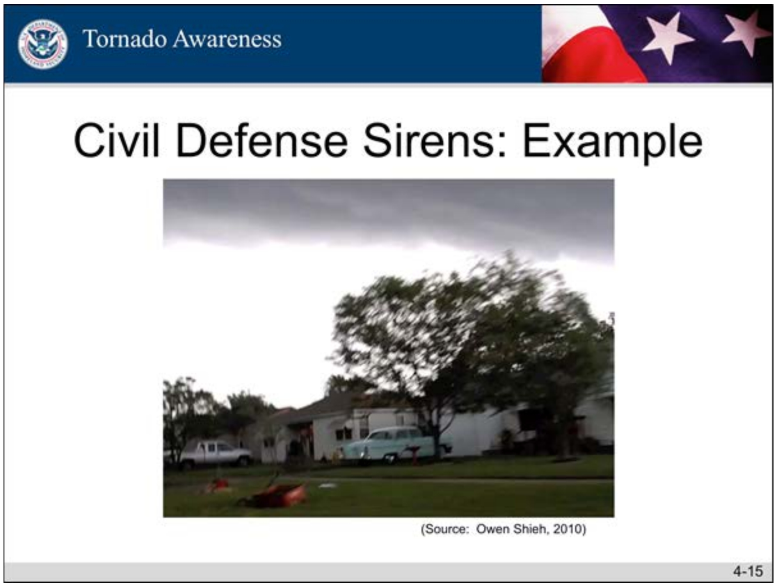


Slide 4-14. Outdoor Warning Devices

Civil defense sirens (as shown in the above photo) from the Cold War era are frequently used as outdoor warning devices in areas that are susceptible to tornado threats. However, no nationwide policy governs all details of siren operations. As such, local emergency management agencies may differ in how they run their local siren system. Furthermore, sirens can be sounded for multiple different community threats that are non-weather related. Each member of the community is encouraged to study the local siren policies in their county.

Key Point: It is critical to remember that sirens are only intended to be heard while outdoors. One should NEVER depend on sirens as a means of receiving tornado warnings while inside a building or a vehicle. Also, be sure to seek more information to clarify why the sirens are sounding.

Participant Notes:



Slide 4-15. Civil Defense Sirens: Example

This example illustrates the multiple, simultaneous pitches present in tornado sirens. This distinctive, haunting sound signals an imminent threat and is very familiar to those who live in the Plains. However, these types of sirens are intended to be useful only while outdoors as they are often not heard while indoors. For this reason, it is best to have another source of weather information when severe weather is possible.

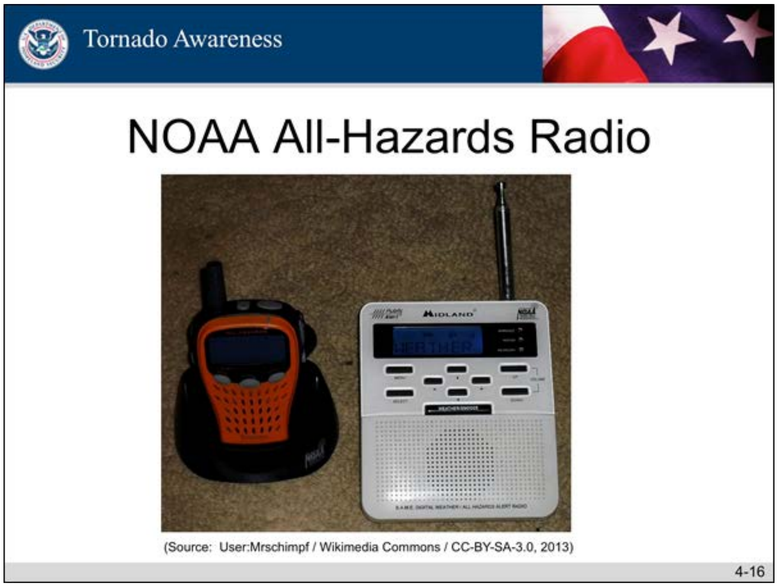
This video clip was filmed during an official, government-funded field project to collect data to study tornadoes in the Great Plains. The video is approximately 56 seconds in length.

Unofficial Video Transcript

The sirens have started… About time. Alright, a quarter of a mile, make a right turn onto 152.

Deliberately intercepting tornadic thunderstorms is NOT recommended and should only be done with proper training!

Participant Notes:

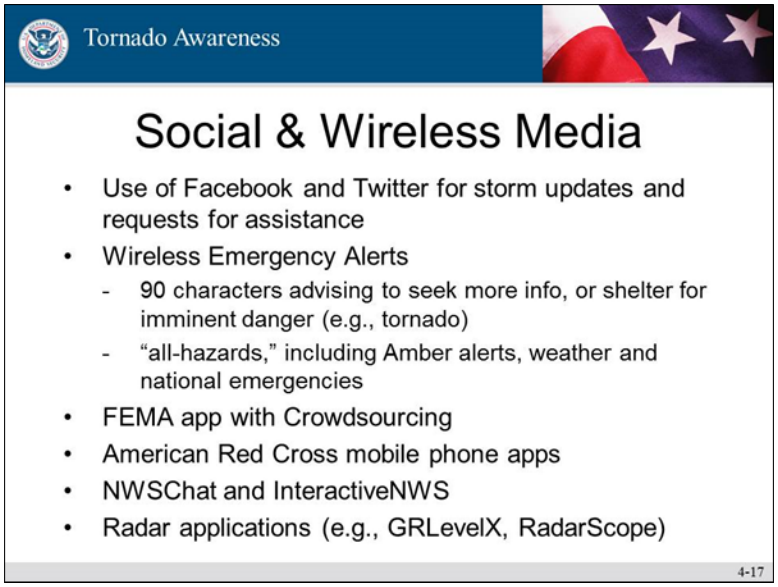


Slide 4-16. NOAA All-Hazards Radio

The “NOAA Weather Radio” is a continuous broadcast of weather forecasts and advisories originating from local NWS offices. Newer radios offer Specific Area Message Encoding (SAME) capability, which allow users to filter alerts based on the most relevant geographic area of interest. The weather radio is designed to play a continuous broadcast of the latest weather forecasts, or to be set on standby and to activate when an alert is received. It can be a life-saving tool.

Non-weather emergencies can also be broadcast via the “Emergency Alert System” (EAS). Implemented in 1997, the EAS was designed to allow the President to reach the public within 10 minutes in the event of an emergency. The EAS is a part of the FEMA Integrated Public Alert and Warning System and is coordinated by the Federal Communications Commission.

Participant Notes:



Slide 4-17. Social & Wireless Media

Social media applications, such as Facebook and Twitter, have become useful communication tools as weather events unfold and the Internet is still available. Both requests for assistance and reports of damage can be relayed to officials via these platforms, taking the burden off of traditional telephone and cell service, which can sometimes slow down during a crisis. However, caution must be exercised when relaying reports via social media. As an example, during Hurricane Sandy, there were numerous fraudulent and unverified reports as well as altered photos that were circulated and posted as legitimate news.

"Wireless Emergency Alerts (WEA)," also known as "Commercial Mobile Alert System" or "Personal Localized Alerting Network," are a free service for wireless customers developed in 2012 through a partnership between the Federal Communications Commission, the wireless industry, and FEMA. A special text message-like alert with audible alarm is delivered to WEA-capable cell phones when there is an imminent threat nearby, including "Presidential Alerts," "Imminent Threat Alerts," and "AMBER Alerts." These alerts are delivered separately from text messages and are location dependent.

The weather-related alerts are based on National Weather Service warnings but are limited to the most dangerous threats.

Participant Notes:

The 90 character messages are meant to advise customers to seek more information about the threat, but if the threat is imminent, they will ask customers to seek shelter immediately. Individuals should not rely purely on these alerts for weather warnings as not all phones are currently WEA-capable. However, this service could potentially save lives when a person is threatened with hazardous weather while on the road or away from other forms of communication. For more information on this, visit:

http://www.fema.gov/commercial-mobile-alert-system

The FEMA app has a disaster reporter function with crowdsourcing. For more information on this, visit:

http://www.fema.gov/smartphone-app

The American Red Cross also offers useful smart phone applications that can be used during different types of hazardous weather conditions. For more information on these applications, visit:
http://www.redcross.org/prepare/mobile-apps

NWSChat is an instant messaging, decision support tool available for NWS partners, such as emergency managers and media:

https://nwschat.weather.gov/

InteractiveNWS (iNWS) is the NWS' mobile alerting platform available for NWS partners:

http://inws.wrh.noaa.gov/

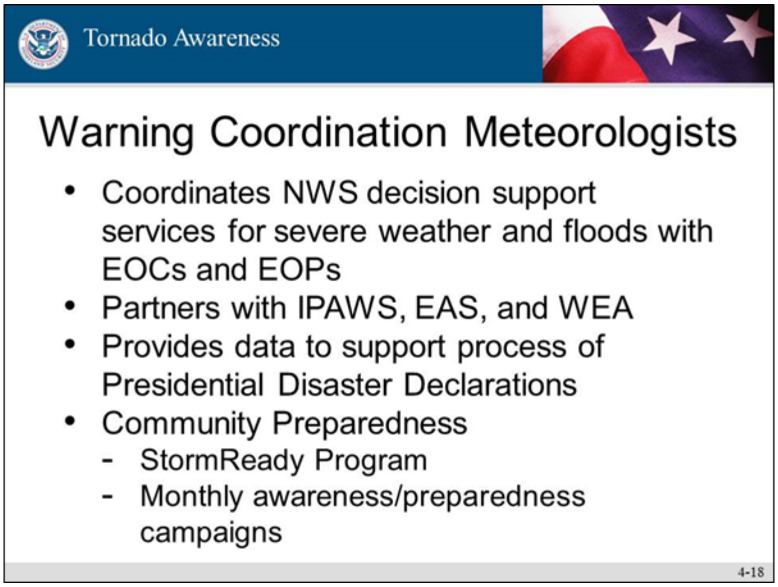
For information on the Integrated Public Alert & Warning System, visit:

http://www.fema.gov/integrated-public-alert-warning-system

Some private applications can provide useful platforms for visualizing NWS radar data. Some of these include GRLevelX (Windows) and RadarScope (Apple and Android).

For more about social media, please refer to the National Disaster Preparedness Training Center's FEMA-certified PER-304 course, "Social Media for Natural Disaster Response and Recovery."

Participant Notes:



Slide 4-18. Warning Coordination Meteorologists

- Coordinates NWS decision support services for severe weather and floods with EOCs and EOPs
- Partners with IPAWS, EAS, and WEA
- Provides data to support process of Presidential Disaster Declarations
- Community Preparedness
    - StormReady Program
    - Monthly awareness/preparedness campaigns

The Warning Coordination Meteorologist (WCM) is the meteorologist at a local NWS office that is tasked with serving as the liaison between NWS and emergency management.

Participant Notes:

Slide 4-19. SKYWARN Spotter Program

- National network of 290,000 volunteer storm spotters who report severe weather to NWS
- Locally-organized groups
- Public safety personnel
- Emergency managers
- Amateur radio operators
- Administered by WCM
- Local training hosted by WFO
- Spotter Network

As discussed earlier in the course, limitations in radar technology result in a need for observers to report near-surface storm behavior and impacts. The SKYWARN spotter training program serves to fill the need for trained observers to relay information to the NWS from the field. Although holding an amateur radio license would be beneficial, it is not required to become a SKYWARN spotter.

Participants are encouraged to contact their local NWS office and to take a SKYWARN spotter training course. This would further their knowledge of tornadoes to include a more detailed analysis of storm structure, behavior, and safety tips. This current “Tornado Awareness” course is intended to supplement (not replace) the lessons learned during spotter training by providing a broader and more general understanding of the tornado hazard and the forecast/warning process.

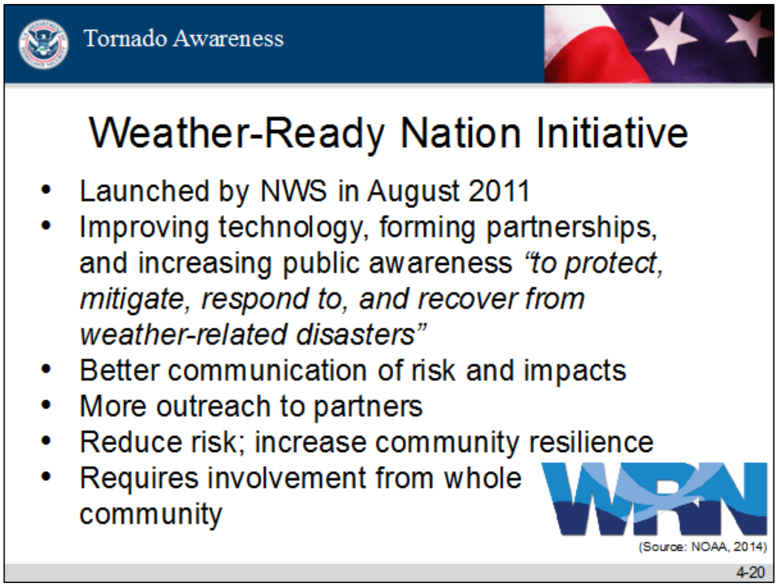
Participant Notes:

For more information on SKYWARN, visit: http://skywarn.org/

Online SKYWARN training can also be found here:
https://www.meted.ucar.edu/training_course.php?id=23

Since April 2006, a tool that has facilitated communication between SKYWARN spotters and the NWS has been Spotter Network, which provides position data tagged with storm reports for spotters who log into the system while on the road. NWS forecasters can use this information in real-time during an unfolding severe weather event as a way to monitor the "ground truth" from a particular storm. For more information on Spotter Network, visit: http://www.spotternetwork.org.

Participant Notes:



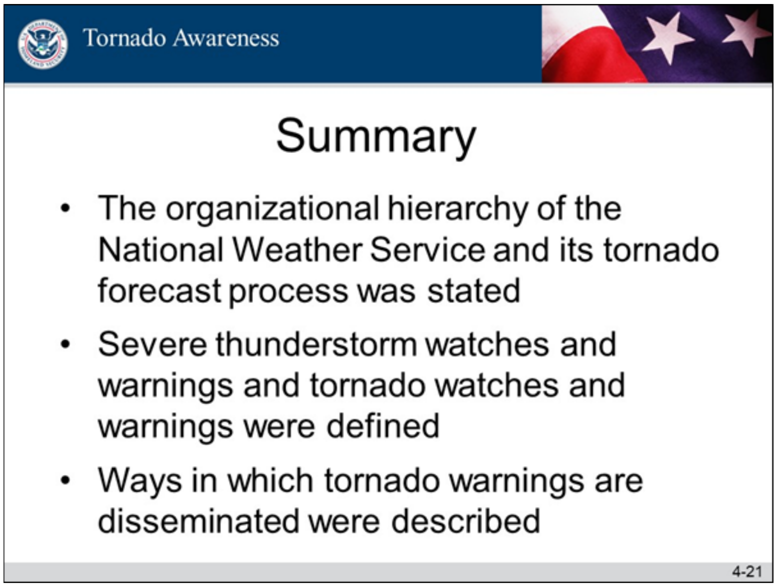
Slide 4-20. Weather-Ready Nation Initiative

- Launched by NWS in August 2011
- Improving technology, forming partnerships, and increasing public awareness "to protect, mitigate, respond to, and recover from weather-related disasters"
- Better communication of risk and impacts
- More outreach to partners
- risk and increase community resilience
- Requires involvement from whole community

As part of this initiative, individual WFO websites have gradually been increasing their number of graphical weather briefings that complement official warnings and products. This effort is meant to increase the efficiency of communicating with emergency management and the general public. More research efforts are now being supported to integrate the social sciences to better understand how the public interprets different warning messages and graphics.

The meteorology community is gravitating toward the use of more probabilistic weather forecasts, but the public often thinks deterministically without a clear understanding of different probabilities. This challenge needs to be addressed through a better integration between the research, operational, and societal communities. Weather-Ready Nation seeks to build partnerships through workshops and symposiums around the country to engage all sectors. For more on this initiative, please visit: http://www.nws.noaa.gov/com/weatherreadynation/.

Participant Notes:



Slide 4-21. Summary

This module illustrated that the “Weather Enterprise” is a large and complicated system and that most of the components are often not visible in the media. It also confirmed that the National Weather Service is the government agency that is tasked with providing official severe weather forecasts and warnings although there are other sectors that are crucial for their role in disseminating the severe weather watches and warnings.

Tornado Awareness

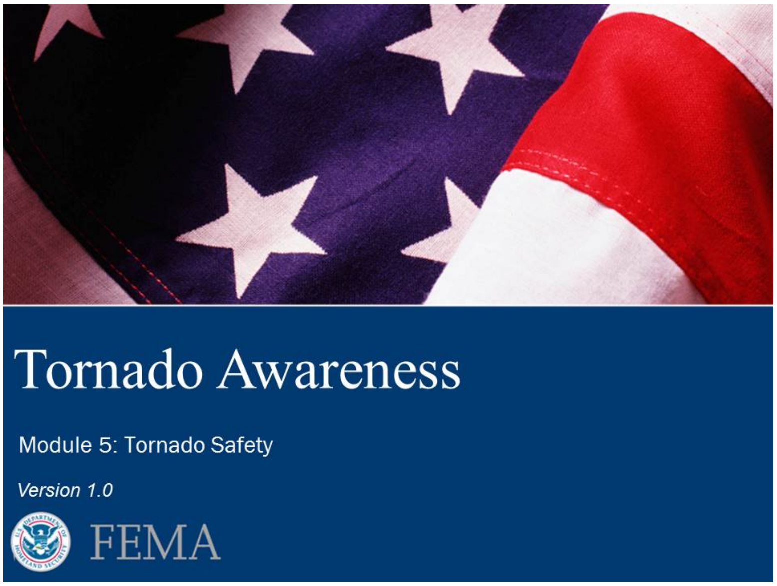
Participant Guide

Module 5: Tornado Safety *Version 1.0*

FEMA

This page is intentionally left blank.

Module 5: Tornado Safety – Administration Page



Slide 5-1. Tornado Safety

Duration

120 minutes

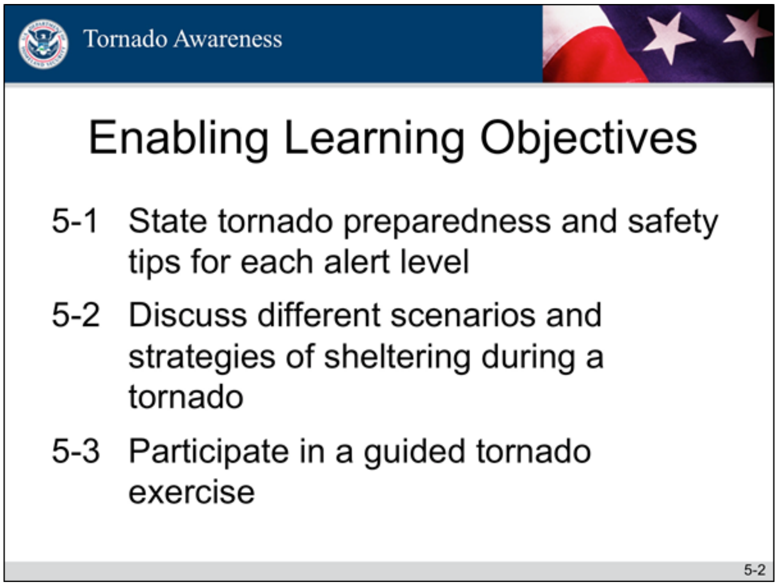
Scope Statement

In this module, the instructors will facilitate the discussion of different strategies to prepare for and mitigate the threats associated with tornadoes in different settings. Participants will integrate all of the knowledge obtained in this course through a group activity consisting of an actual tornado event scenario.

Terminal Learning Objective (TLO)

Participants will be able to review procedures to maximize the safety of themselves, their families, and their organizations during a tornado.

Enabling Learning Objectives (ELOs)



Slide 5-2. Enabling Learning Objectives

At the end of this module, participants will be able to:

5-1 State tornado preparedness and safety tips for each alert level.

5-2 Discuss different scenarios and strategies of sheltering during a tornado.

5-3 Participate in a guided tornado exercise.

Resources

- Instructor Guide (IG)
- Module 5 presentation slides
- Laptop with presentation software installed and CD-ROM capability
- Audio-visual (A/V projection unit)
- Projector screen
- Chalkboard (and chalk), whiteboard (and dry erase markers), or easel and easel paper (and permanent markers)
- One of each of the following items per participant:
  - Participant Guide (PG) available for download from http://ndptc.hawaii.edu/
  - Participant Handout

Instructor-to-Participant Ratio

2:40

Reference List

National Institute of Standards and Technology (NIST) Technical Investigation of the May 22, 2011, Tornado in Joplin, Missouri (NIST NCSTAR 3). 2011. Accessed 2013. http://www.nist.gov/manuscript-publication-search.cfm?pub_id=914787

National Weather Service (NWS) WFO: Springfield, MO. 2011. Joplin Tornado Event Summary, May 22, 2011. Accessed 2013. www.crh.noaa.gov/sgf/?n=event_2011may22_summary

Rohr, Mark. 2012. *Joplin: The Miracle of the Human Spirit.* Mustang: Tate Publishing.

Turner, Randy and John Hacker. 2011. *5:41 – Stories from the Joplin Tornado.* Accessed 2013.

U.S. Department of Commerce. 2011. *NWS Central Region Service Assessment Joplin, Missouri Tornado – May 22, 2011.* July 22. Accessed 2013. www.weather.gov/os/assessments/pdfs/Joplin_tornado.pdf

Practical Exercise (PE) Statement

This exercise provides an opportunity for participants to work together in groups to role-play in a difficult, messy, non-ideal tornado situation. Participants will consider the different decisions and courses of action that should be made during a tornado. The objective of this activity is to use the knowledge and understanding gained from this course to maximize safety in different settings during a tornado situation.

Assessment Strategy

- Instructors observation of participant involvement in classroom discussion
- Instructor-led discussion to gauge participant grasp of the subject matter
- Instructors engagement of participant involvement with requests for local examples and experiences
- Instructors observation of individual participation during group activity

Tornado Awareness

Icon Map

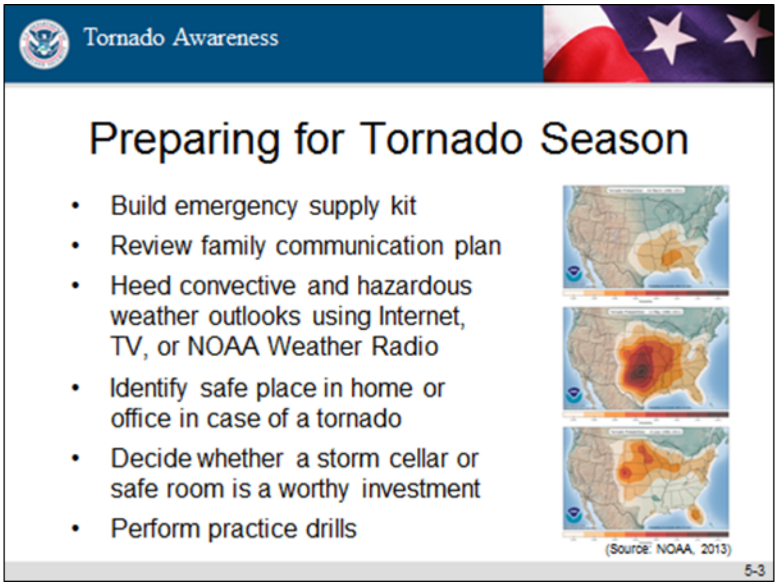
Knowledge Check: Used when it is time to assess participant understanding.

Example: Used when there is a descriptive illustration to show or explain.

Key Points: Used to convey essential learning concepts, discussions and introduction of supplemental material.

Participant Note: Used to indicate text that has been included as additional information for the participant. The text may not be directly addressed in the slide presentation or during class discussion.

Participant Notes:



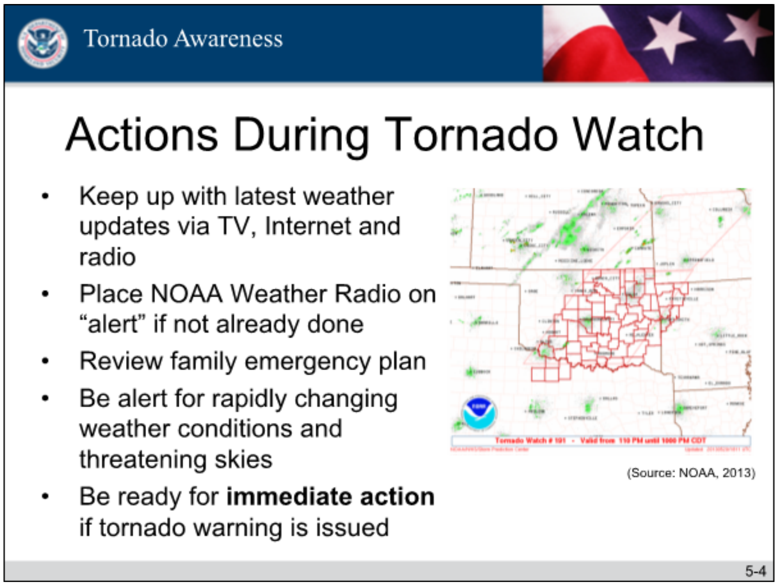
Slide 5-3. Preparing for Tornado Season

Tornado preparedness must be a year-round endeavor. Although certain parts of the country have climatological tornado seasons, it is important to remember that tornadoes can happen at any time of the year. In addition, participants should take note of the following points:

- If a safe room is installed, ensure that it is registered and from a reputable source;
- Keep an emergency supply kit handy at all times;
- Have a plan in place for sheltering family members in the event of a heightened tornado threat; and
- Be sure to monitor NWS outlooks routinely for tornadoes and other hazards, if thunderstorms are in the forecast.

The figures on the right show that tornado frequencies shift from the Southeast to the northern tier of the country as the spring season transitions into the summer season. This is because of the northward migration of the jet stream and associated mid-latitude cyclone tracks. This is why tornado seasons are different in different parts of the country.

Participant Notes:

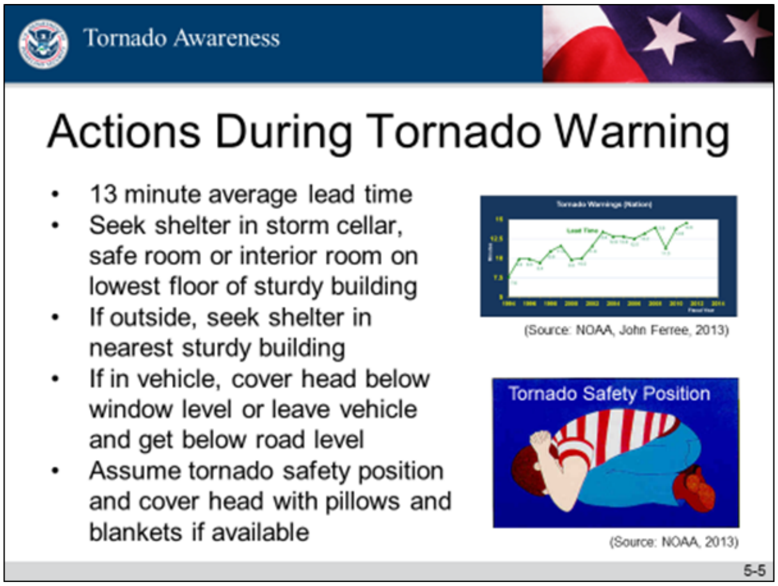


Slide 5-4. Actions During Tornado Watch

When a tornado watch is issued for a particular area, the following actions should be taken:

- Be on the lookout for threatening and rapidly-changing weather;
- Think about where each of the family members are and where they will be later in the afternoon and/or evening; and
- Discuss with family members a contingency plan, in the event that the daily routine is disrupted. Issues to discuss may include the following:
  - How will pets at home be cared for and by whom?
  - What types of communication devices are available to ensure the family members can stay updated regarding developing weather situation?

Participant Notes:



Slide 5-5. Actions During Tornado Warning

The average tornado warning lead time is 13 minutes. However, this can vary greatly depending on how "classic" the structure of a supercell thunderstorm is. Non-classic cases can result in much less lead time. When a tornado warning is issued for a particular area, individuals should follow the actions listed below:

- Seek shelter in storm cellar, safe room or interior room on lowest floor of sturdy building;
- If outside, seek shelter in nearest sturdy building;
- If in vehicle, cover head below window level or leave vehicle and get below road level; and
- Assume tornado safety position and cover head with pillows and blankets if available.

Do not seek shelter under an overpass! Despite some scenes depicted in movies and videos, sheltering under an overpass can result in exposure to winds and debris that may accelerate as they pass through.

Knowledge Check: What is the definition of a tornado warning?

Participant Notes:

Slide 5-6. Best Options for Tornado Safety

The National Weather Service Office in Norman, Oklahoma, prepared the following tornado safety tips for when a tornado occurs, which were posted by social media on the day of the El Reno tornado of May 31, 2013, an unfortunate event where people died in vehicles. These tips include the real-world complexities of residents not feeling safe at home and possibly considering travel to a safer location. Sheltering in place is preferable in most cases, but if traveling to a safer location is required, it is important to do so with plenty of lead time.

Best Options for Tornado Safety:

1. First, take shelter in an underground storm shelter, basement, cellar, or engineered safe room designed to withstand a tornado.
2. If that option is not available, take shelter on the lowest floor of a sturdy building. In addition,
   - Stay away from doors, windows and outside walls;
   - Put as many walls between you and the tornado as you can;
   - Use pillows, couch cushions, sleeping bags, a mattress or blankets to cover up;
   - If you or your children have helmets, wear them; and
   - If you have an infant, put them in their car seat or carrier.

Participant Notes:

Other important sheltering reminders:

- Wear long pants, a long sleeve shirt, and real shoes (not flip flops or sandals!);
- Charge and take cell phones to the shelter; and
- Make a plan for your pets including finding their leashes and carriers.

You can survive almost every tornado if you follow these guidelines!

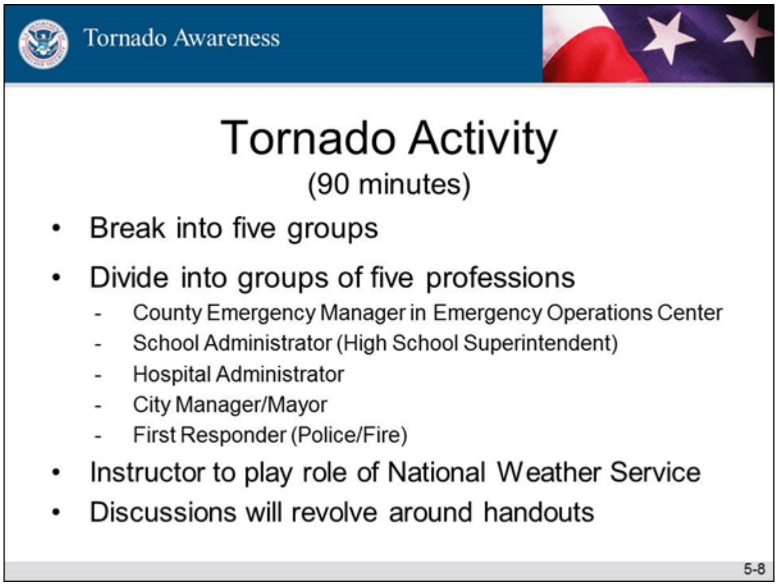
Participant Notes:

Slide 5-7. Other Options for Tornado Safety

Additional Tornado Safety Tips

1. If you do not feel safe from a tornado where you are, and you feel the need to drive somewhere else to find better shelter, it's important that you do not wait too late to make that critical decision.
2. If you wait until the tornado warning is in effect for your location, it is probably too late for you to be able to drive away safely!
3. If you choose to leave in your vehicle, be sure you know where you are going before you start the car. Try to let someone know you are not at home and where you are going.
4. Do not assume that public buildings are tornado shelters. Check with your local community while the sun is still shining and before storms ever develop!
5. Be sure that you are not putting yourself in more danger by driving into another storm.

Participant Notes:

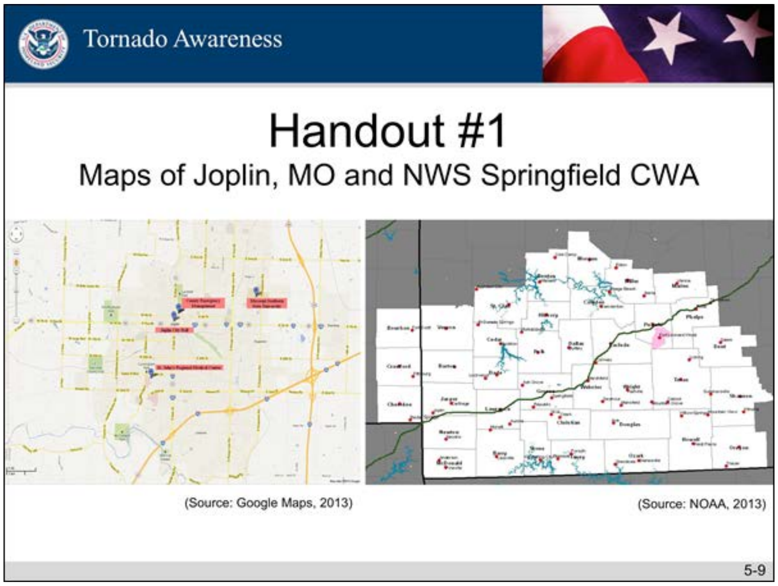


Slide 5-8. Tornado Activity

This exercise provides an opportunity for participants to work together in groups to understand and appreciate the different decisions and course of action that they may need to make in a tornado situation.

The total time for this exercise is estimated at 90 minutes.

Participant Notes:



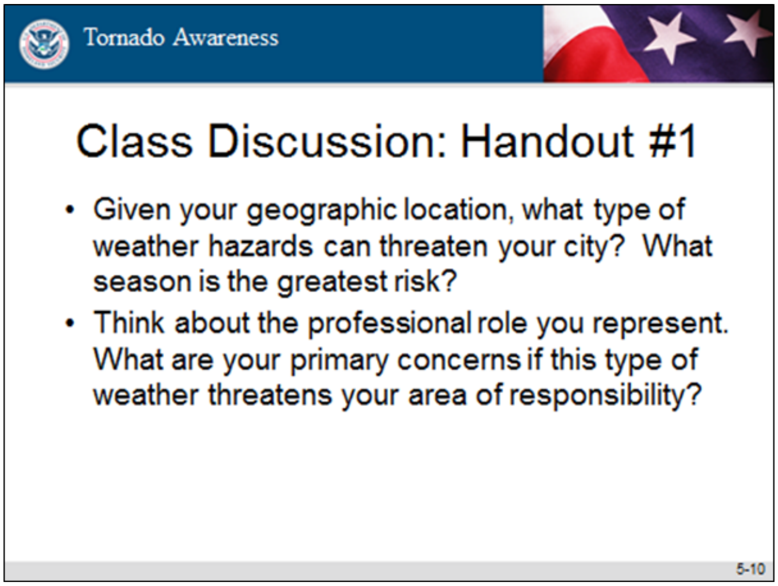
Slide 5-9. Handout #1, Maps of Joplin, MO

Module 5: Handout #1 (page 1 of 5) is a map of Joplin, MO with important landmarks labeled. The map of Joplin (left) shows that Joplin City Hall and the County Emergency Management are located near the center of town with St. John's Regional Medical Center located toward the southwest. Missouri Southern State University, toward the northeast side of town, was the site of Joplin High School's graduation ceremony, to be held at 3:00 pm CDT.

Module 5: Handout #1 (page 3 of 5) is a map of the NWS Springfield CWA (right). The green line cutting across the image from southwest to northeast is I-44, the major interstate highway in the region. Note that Joplin is located toward the extreme southwestern portion of the CWA.

These handouts will be used to set the stage for the rest of the activity.

Participant Notes:

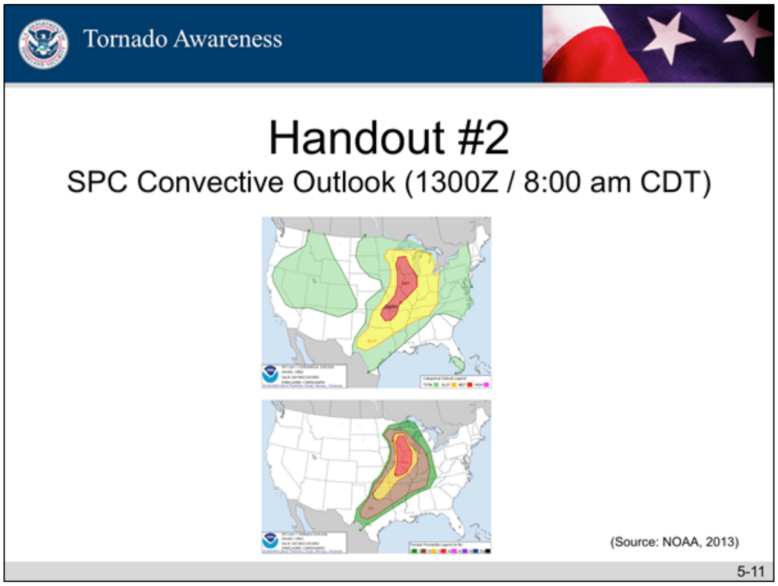


Slide 5-10. Class Discussion: Handout #1

Given your geographic location, what type of weather hazards can threaten your city? What season is the greatest risk?

Participants should think about the professional role they represent. What are your primary concerns if this type of weather threatens your area of responsibility?

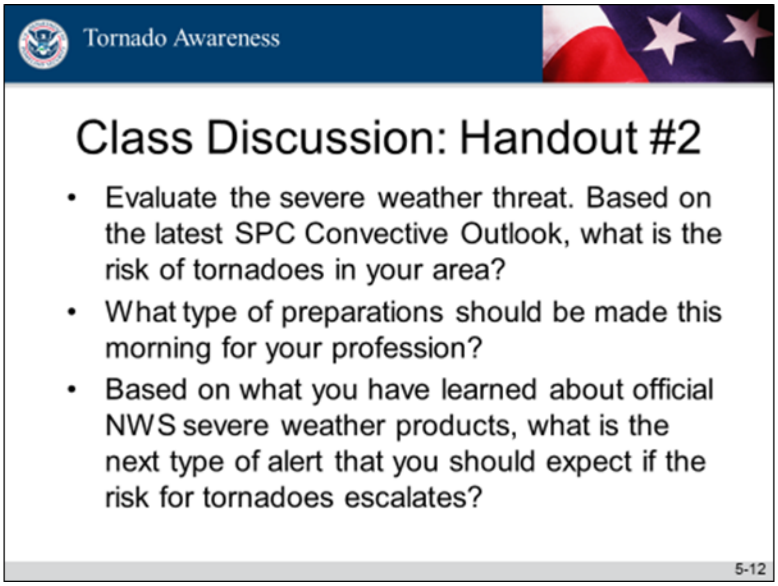
Participant Notes:



Slide 5-11. Handout #2, SPC Convective Outlook (1300Z / 8:00 am CDT)

Module 5: Handout #2 (page 1 of 4) includes the SPC Convective Outlook issued at 1300Z / 8:00 am CDT. The top figure shows the categorical outlook, with a slight severe weather risk (yellow) extending from Texas northeastward toward the upper Midwest. A moderate severe weather risk (red) extends from northeastern Oklahoma through Wisconsin.

Participant Notes:



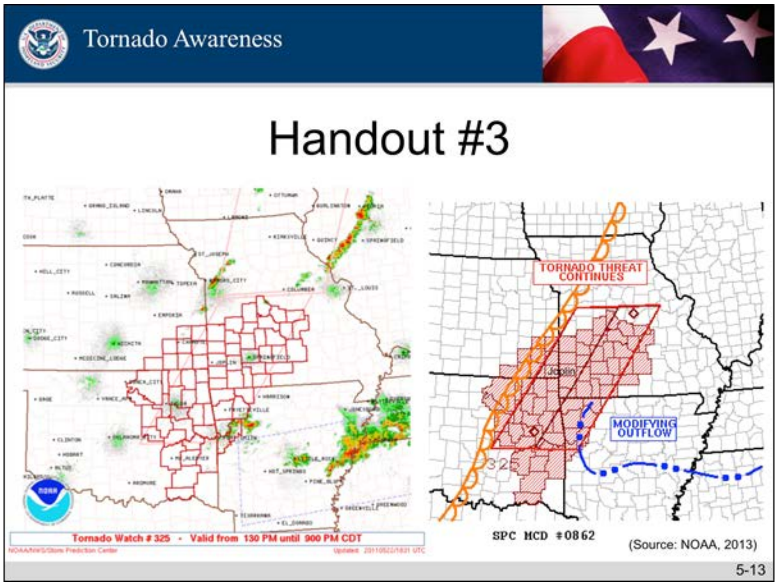
Slide 5-12. Class Discussion: Handout #2

Evaluate the severe weather threat. Based on the latest SPC Convective Outlook, what is the risk of tornadoes in your area?

What type of preparations should be made this morning for your profession?

Based on what you have learned about official NWS severe weather products, what is the next type of alert that you should expect if the risk for tornadoes escalates?

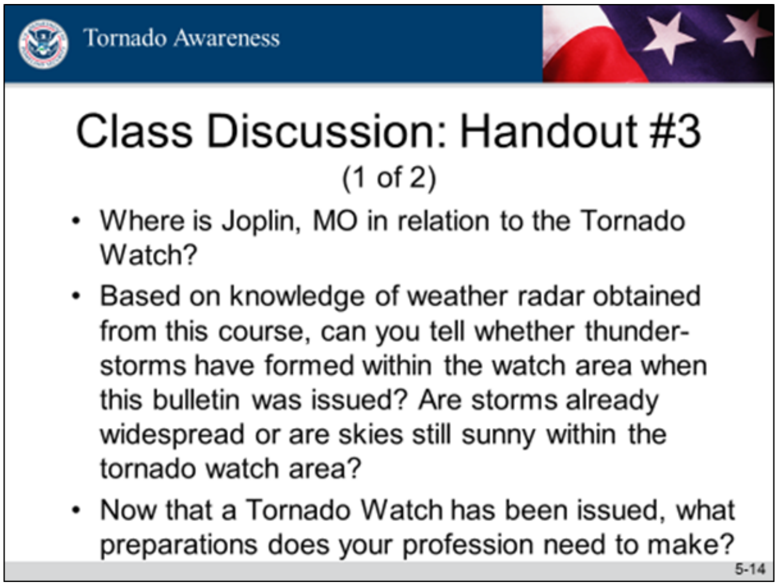
Participant Notes:



Slide 5-13. Handout #3

Module 5: Handout #3 (page 1 of 3) includes the tornado watch graphic and initial radar image at the time of watch issuance (left), and an update to the watch issued by the SPC (right) (Module 5: Handout #3 (page 2 of 3). The text associated with each product is also included. At this time, the tornado watch includes eastern Oklahoma, southwestern Missouri, and extreme northwestern Arkansas. The dryline (scalloped orange line) is located just west of the watch area, indicating the leading boundary of dry air to the west with moist air to the east.

Participant Notes:



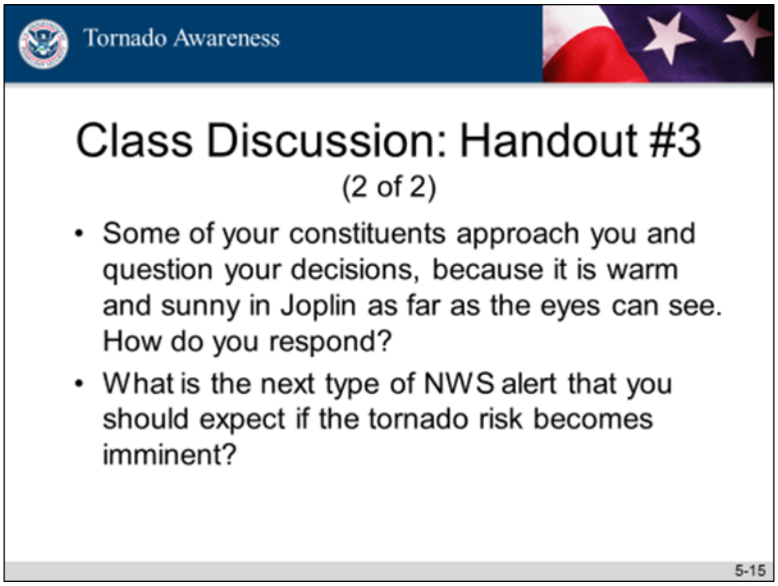
Slide 5-14. Class Discussion: Handout #3 (1 of 2)

Where is Joplin, MO in relation to this Tornado Watch?

Based on knowledge of weather radar obtained from this course, can you tell whether thunderstorms have formed within the watch area when this bulletin was issued? Are storms already widespread or are skies still sunny within the tornado watch area?

Now that a Tornado Watch has been issued, what preparations does your profession need to make?

Participant Notes:

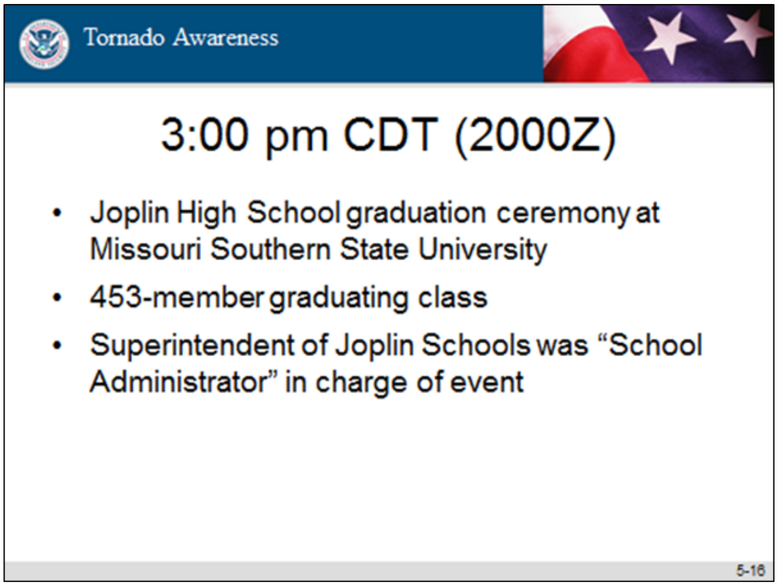


Slide 5-15. Class Discussion: Handout #3 (2 of 2)

Some of your constituents approach you and question your decisions, because it is warm and sunny in Joplin as far as the eyes can see. How do you respond?

What is the next type of NWS alert that you should expect if the tornado risk becomes imminent?

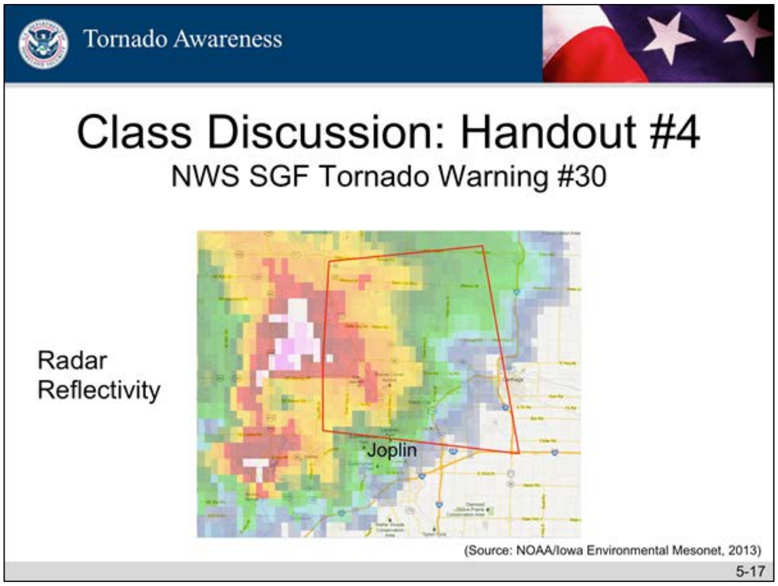
Participant Notes:



Slide 5-16. 3:00 pm CDT (2000Z)

At 3:00 pm CDT (2000Z), the Joplin High School graduation ceremony was held at Missouri Southern State University. The Superintendent of Joplin Schools was the "school administrator" in charge of the event with a 453-member graduating class.

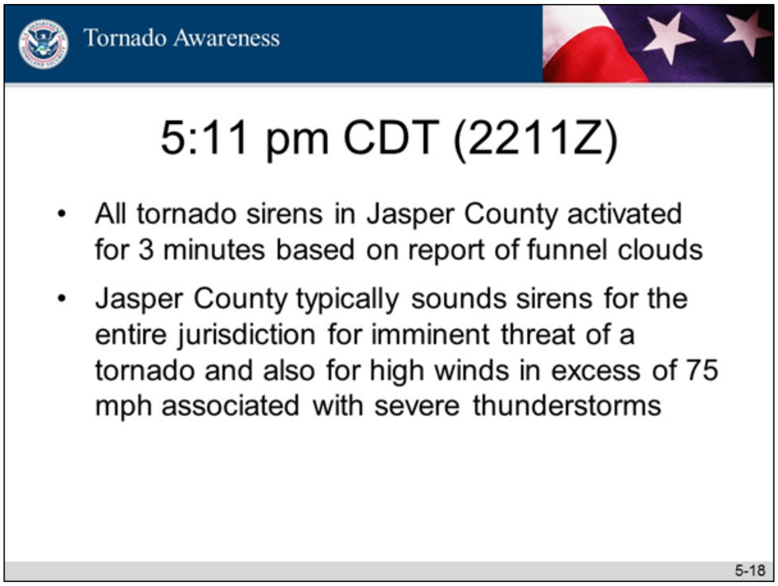
Participant Notes:



Slide 5-17. Class Discussion: Handout #4

Module 5: Handout #4 (page1 of 3) illustrates a tornado warning issuance by the National Weather Service. The warning polygon is located ahead of the supercell hook echo which was expected to pass to the north of the city of Joplin.

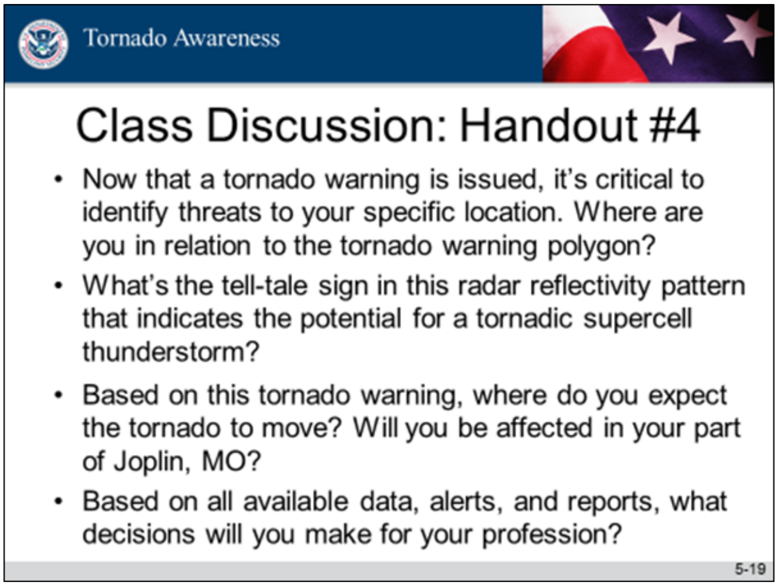
Participant Notes:



Slide 5-18. 5:11 pm CDT (2211Z)

At 5:11 pm CDT (2211Z), all tornado sirens in Jasper County were activated for 3 minutes based on a report of funnel clouds. Jasper County typically sounds sirens for the entire jurisdiction for an imminent threat of a tornado and also for high winds in excess of 75 mph associated with severe thunderstorms.

Participant Notes:



Slide 5-19. Class Discussion: Handout #4

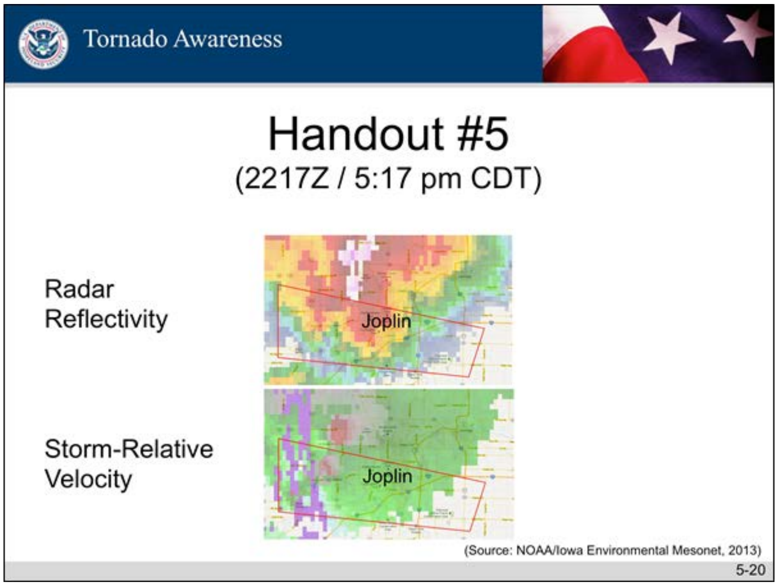
Now that a tornado threat is issued, it's critical to identify threats to your specific location. Where are you in relation to the tornado warning polygon?

What's the tell-tale sign in this radar reflectivity pattern that indicates the potential for a tornadic supercell thunderstorm?

Based on this tornado warning, where do you expect the tornado to move? Will you be affected in your part of Joplin, MO?

Based on all the available data, alerts, and reports, what decisions will you make at this time for your profession?

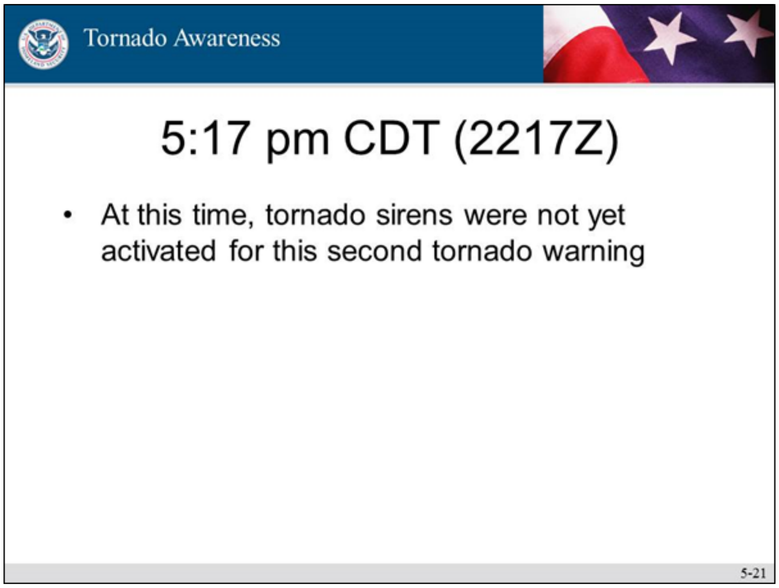
Participant Notes:



Slide 5-20. Handout #5

Module 5: Handout #5 (page 1 of 5) depicts a new tornado warning that was issued at 5:17 pm CDT (2217Z). This time, the warning includes Joplin. The reflectivity shows a new hook echo developing to the southwest of the initial storm. This is confirmed by the velocity couplet in the radial velocity figure. Oftentimes, new updrafts and storms will develop to the southwest previous storms, because that is where fresh, warm, moist air and greater instability can often be found. This is an important behavior of storms to keep in mind when concerned with rapidly-evolving classic supercells during a tornado outbreak.

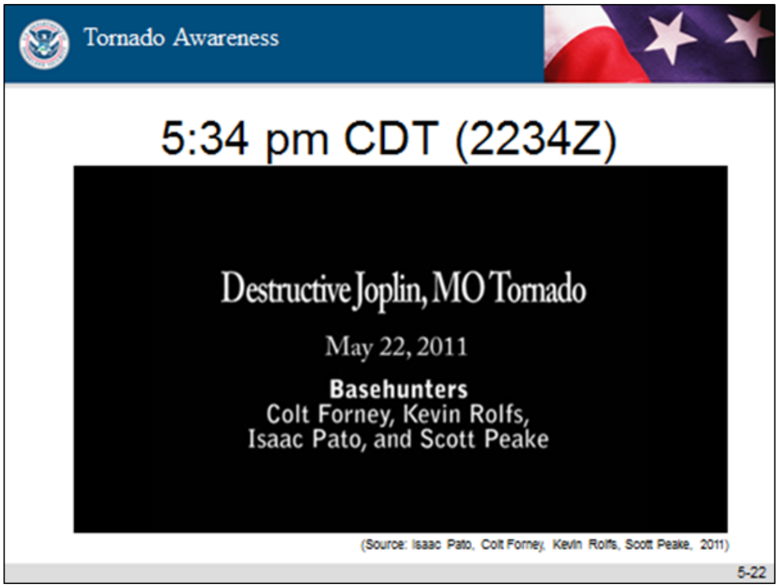
Participant Notes:



Slide 5-21. 5:17 pm CDT (2217Z)

At 5:17 pm CDT (2217Z), tornado sirens were not yet activated for this second tornado warning.

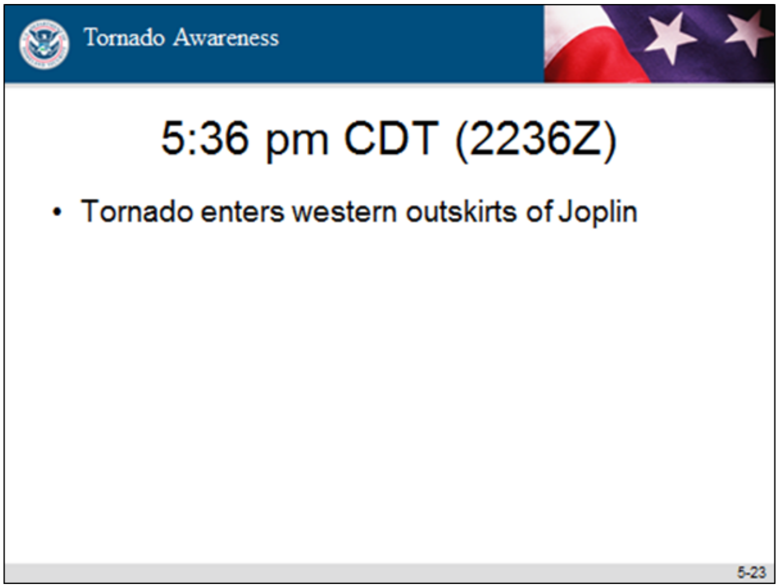
Participant Notes:



Slide 5-22. 5:34 pm CDT (2234Z)

This video shows the moment that the Joplin tornado developed into a large wedge tornado on the western side of town. It multiplied in size within a matter of seconds, eventually reaching a width of approximately one mile in diameter.

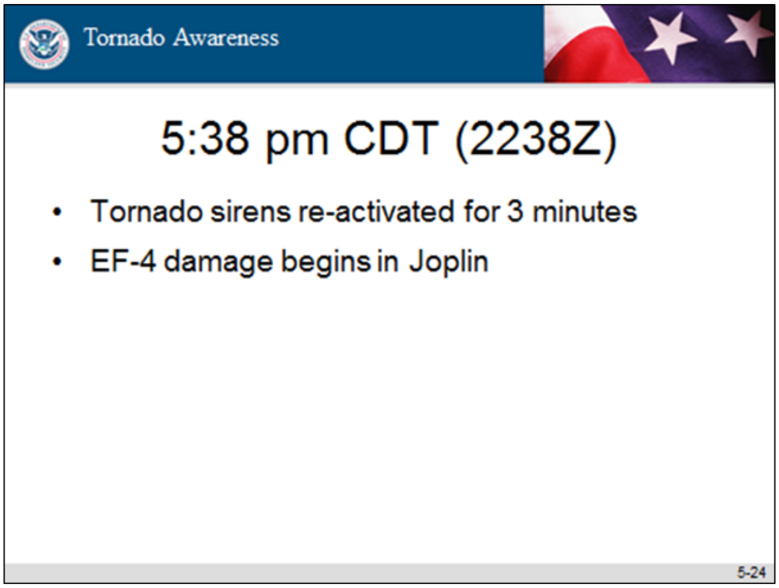
Participant Notes:



Slide 5-23. 5:36 pm CDT (2236Z)

At 5:36 pm CDT (2236Z), the tornado enters the western outskirts of Joplin.

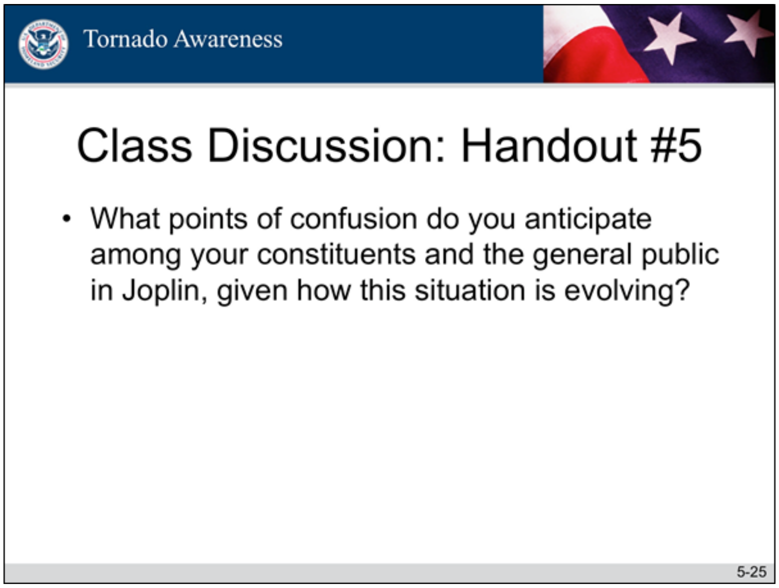
Participant Notes:



Slide 5-24. 5:38 pm CDT (2238Z)

At 5:38 pm CDT (2238Z), tornado sirens were re-activated for 3 minutes, and EF-4 damage begins in Joplin.

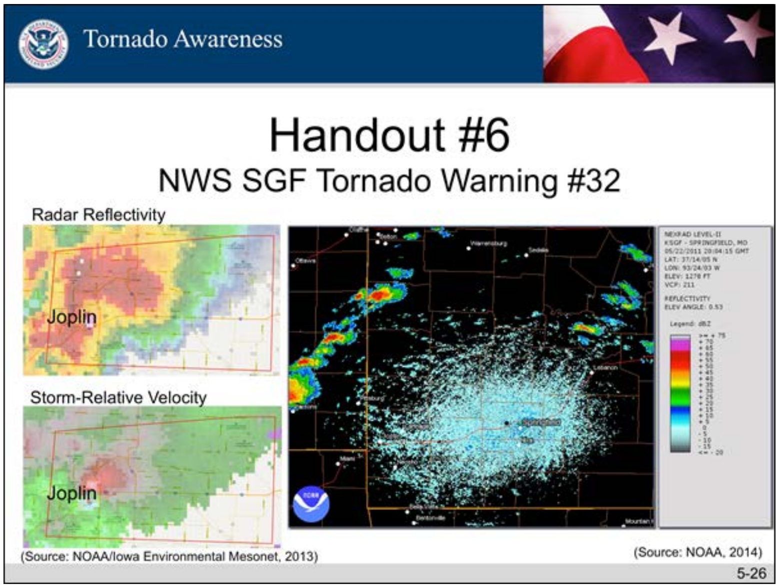
Participant Notes:



Slide 5-25. Class Discussion: Handout #5

What points of confusion do you anticipate among your constituents and the general public in Joplin, given how this situation is evolving?

Participant Notes:

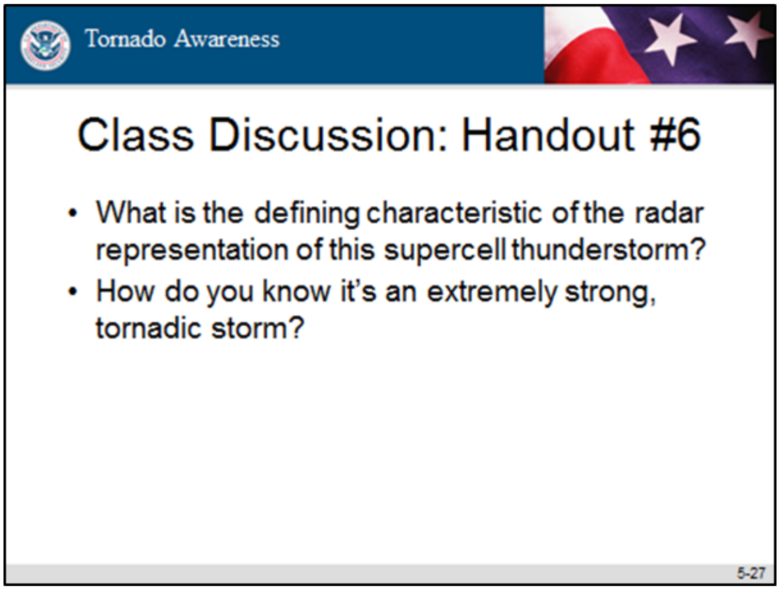


Slide 5-26. Handout #6: NWS SGF Tornado Warning #32

The final handout (Module 5: Handout #6 (page 1 of 4)) shows an expanded tornado warning that encompasses the extremely intense circulation of the EF-5 tornado that eventually leveled the south side of Joplin.

A base reflectivity radar animation of the entire storm event shows the progression of storms from west to east on that day. Supercell thunderstorms with hook echoes could be seen developing to the west of Joplin and passing over, with the storms congealing into a quasi-linear convective system to the south and southeast of the image.

Participant Notes:

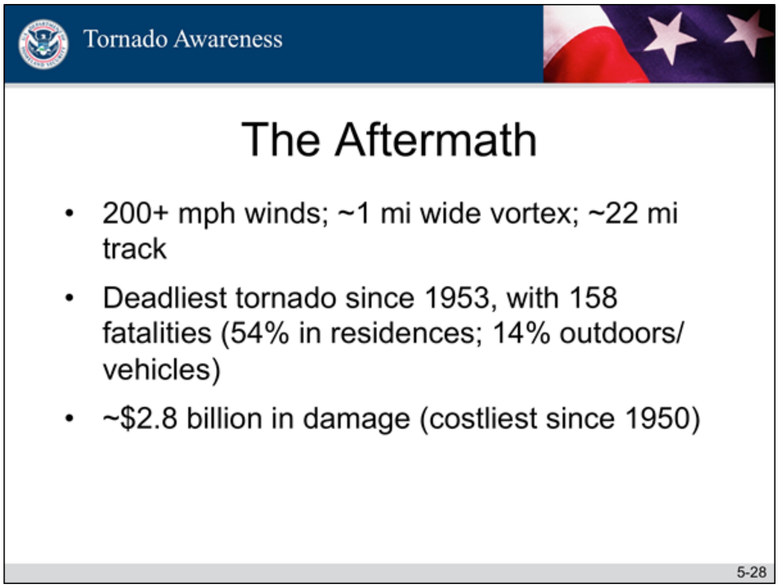


Slide 5-27. Class Discussion: Handout #6

Within a matter of seconds, the mile-wide vortex of the tornado carved a path of destruction through the south side of Joplin. Reports of mass devastation and carnage are beginning to trickle in.

What is the defining characteristic of the radar representation of this supercell thunderstorm? How do you know it's an extremely strong, tornadic storm?

Participant Notes:

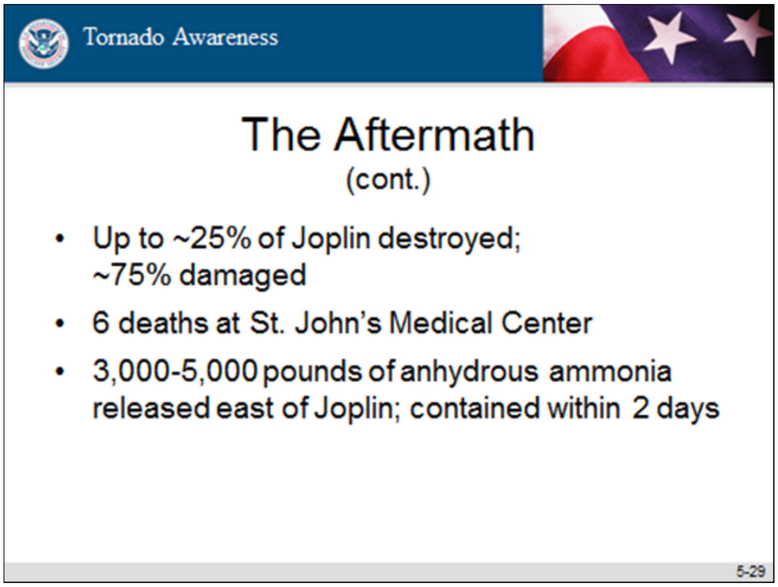


Slide 5-28. The Aftermath

Details regarding the aftermath are listed below:

- 200+ mph winds; ~1 mi wide vortex; ~22 mi track;
- Deadliest tornado since 1953, with 158 fatalities (54% in residences; 14% outdoors/vehicles); and
- ~$2.8 billion in damage (costliest since 1950).

Participant Notes:

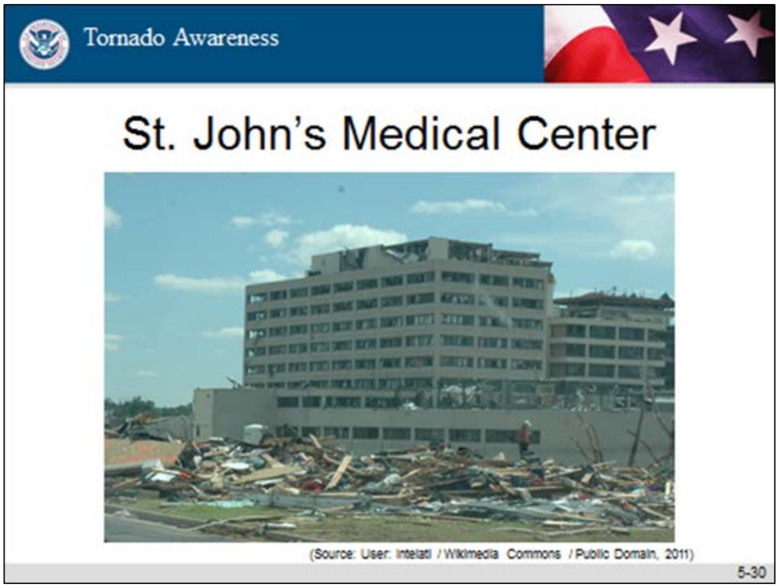


Slide 5-29. The Aftermath (cont.)

Additional details of the aftermath are listed below:

- Up to ~25% of Joplin destroyed and ~75% damaged;
- 6 deaths at St. John's Medical Center; and
- 3,000-5,000 pounds of anhydrous ammonia released east of Joplin, although it was contained within 2 days.

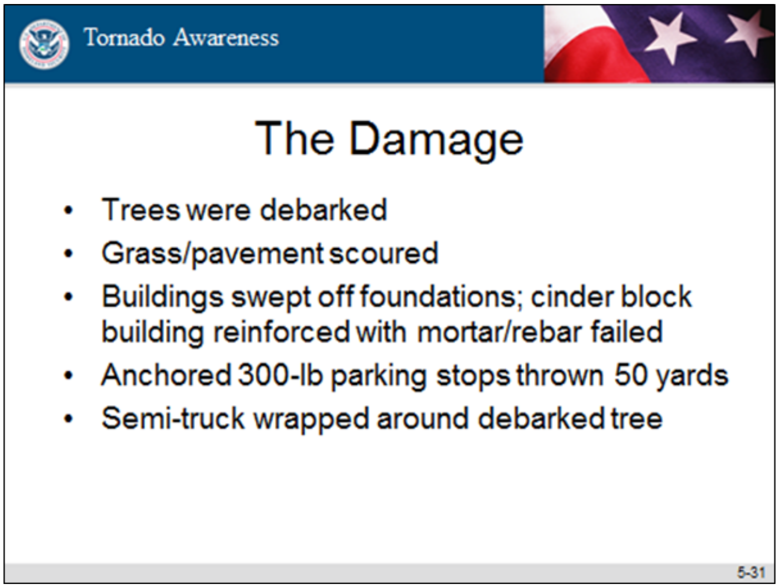
Participant Notes:



Slide 5-30. St. John’s Medical Center

The St. John’s Medical Center was very hard hit, suffering a near direct encounter with the EF-5 tornado. In this photo, debris can be seen in front of the building with windows blown out.

Participant Notes:



Slide 5-31. The Damage

Evidence of damage from the Joplin tornado included the following:

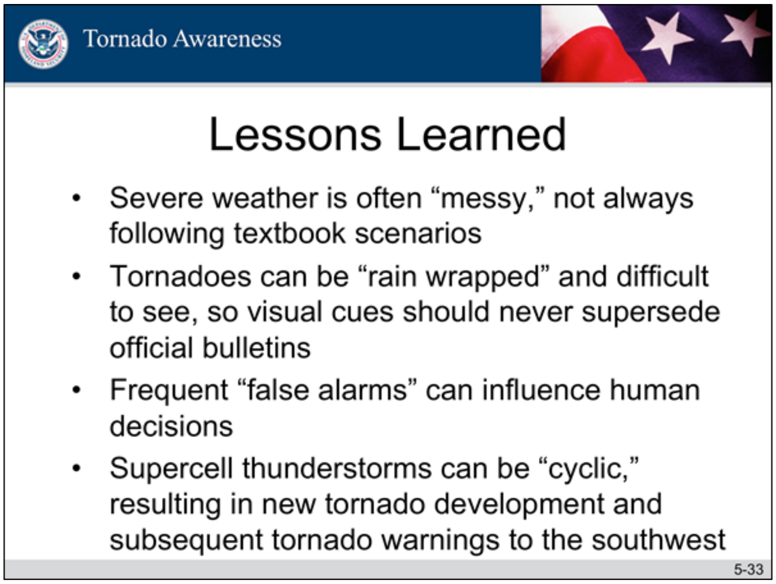
- Trees were debarked;
- Grass/pavement were scoured;
- Buildings were swept off foundations and cinder block building reinforced with mortar/rebar failed;
- Anchored 300-lb parking stops were thrown 50 yards; and
- Semi-truck was wrapped around debarked tree.

Participant Notes:

Slide 5-32. Damage Path

The post-storm damage survey conducted by the National Weather Service showed a large swath of EF-5 damage, with the tornado turning toward the southeast for many miles before dissipating. The tornado exhibited a non-traditional path after passing the Joplin area. This is a good example of why it is good to not make assumption about tornado direction based on previous behavior.

Participant Notes:

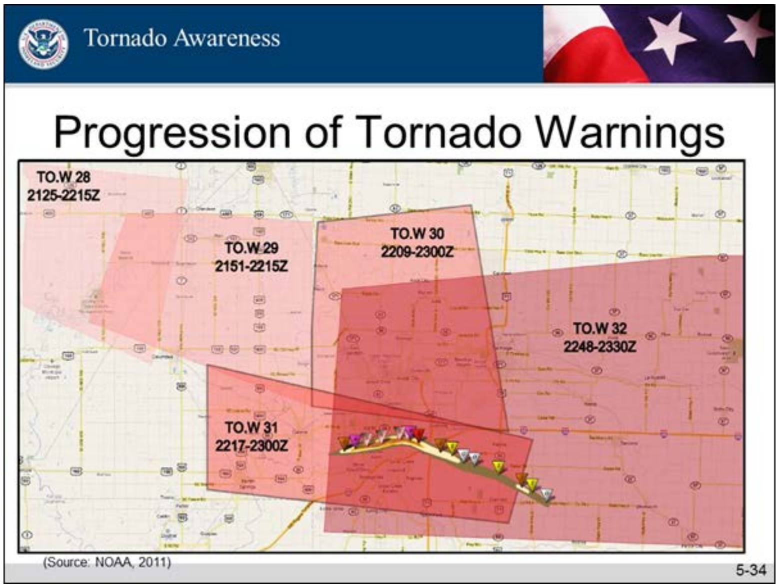


Slide 5-33. Lessons Learned

Some of the lessons learned included the following points:

- Severe weather is often "messy," and does not always follow textbook scenarios.
- Because tornadoes can be "rain wrapped" and difficult to see, visual cues should never supersede official bulletins.
- Frequent "false alarms" can influence human decisions.
- Supercell thunderstorms can be "cyclic," resulting in new tornado development and subsequent tornado warnings.

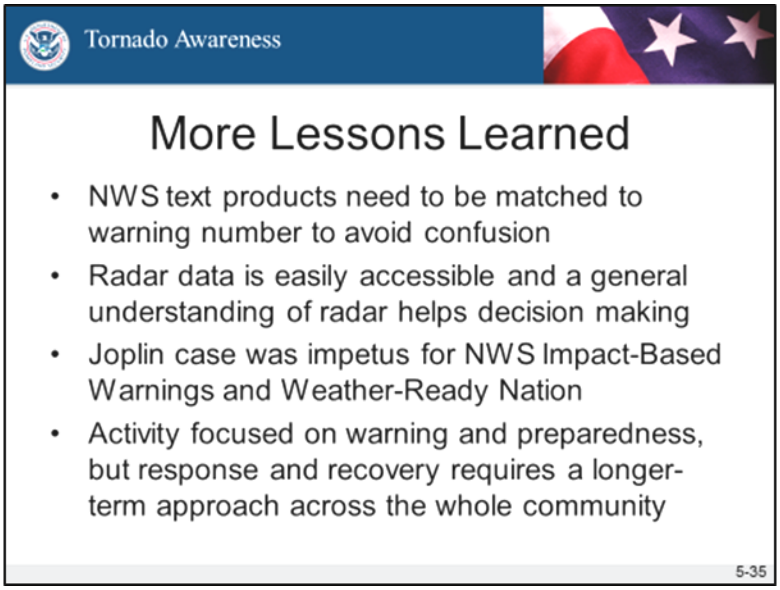
Participant Notes:



Slide 5-34. Progression of Tornado Warnings

A plot of the progression of tornado warnings clearly illustrates how sometimes the most dangerous supercell could develop to the southwest of the original storm. Thus, it is always important to pay attention to the area just outside of a warning polygon and to make sound judgments based on radar interpretation.

Participant Notes:



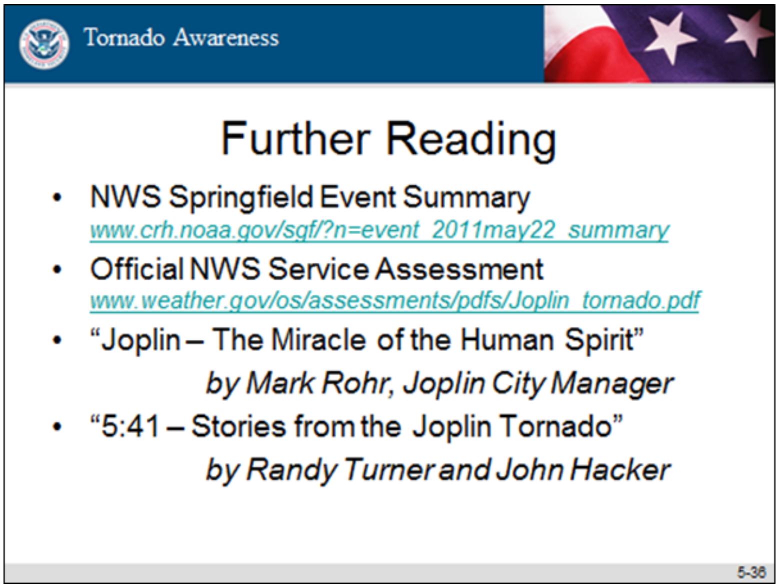
Slide 5-35. More Lessons Learned

Additional lessons from this event are provided below:

- NWS text products should be matched to warning number to avoid confusion.
- Radar data is easily accessible and a general understanding of radar helps decision making.
- The Joplin case was the impetus for NWS Impact-Based Warnings and Weather-Ready Nation.
- While the activity focused on warning and preparedness, response and recovery efforts require a longer-term approach that spans the whole community.

Key Point: This activity was NOT intended to identify problems or to be critical of any element of the operational, preparedness, or response activities of the organizations and individuals involved in the Joplin tornado. Rather, this activity, based on an actual event, was intended to illustrate the potential complexities of a major tornado event. Even though all parties did their jobs to the best of their ability and followed their established plans and preparations, an event such as this can still overwhelm a system and its people who are caught in the path of the storm. Hindsight is always 20/20, particularly in the world of emergency management. What can we do to “close the gaps,” so that we can better mitigate the impacts of a future event that may bring its own unique confluence of conditions and challenges? Are we considering all possibilities?

Participant Notes:

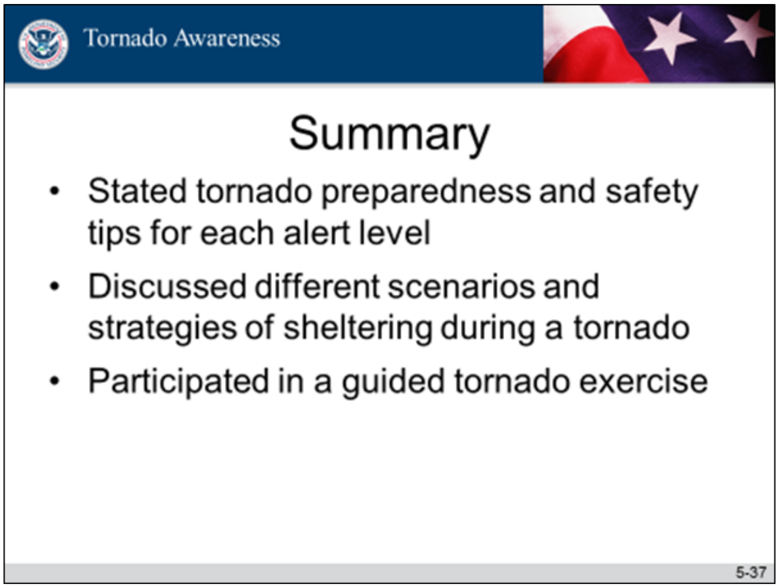


Slide 5-36. Further Reading

One benefit to a guided activity based on an actual event is to utilize it as a springboard for further reading after the course is over, to learn about more details, including the nuances of the case. Participants who are interested in learning more are encouraged to read the following references:

- NWS Springfield Event Summary www.crh.noaa.gov/sgf/?n=event_2011may22_summary;
- Official NWS Service Assessment www.weather.gov/os/assessments/pdfs/Joplin_tornado.pdf;
- "Joplin – The Miracle of the Human Spirit" *by Mark Rohr, Joplin City Manager;* and
- "5:41 – Stories from the Joplin Tornado" *by Randy Turner and John Hacker*.

Participant Notes:



Slide 5-37. Summary

This module challenged the participants to think about tornado safety and sheltering within different contexts, culminating in a guided exercise designed to demonstrate the complexities of an actual tornado event as it unfolds.

Tornado Awareness

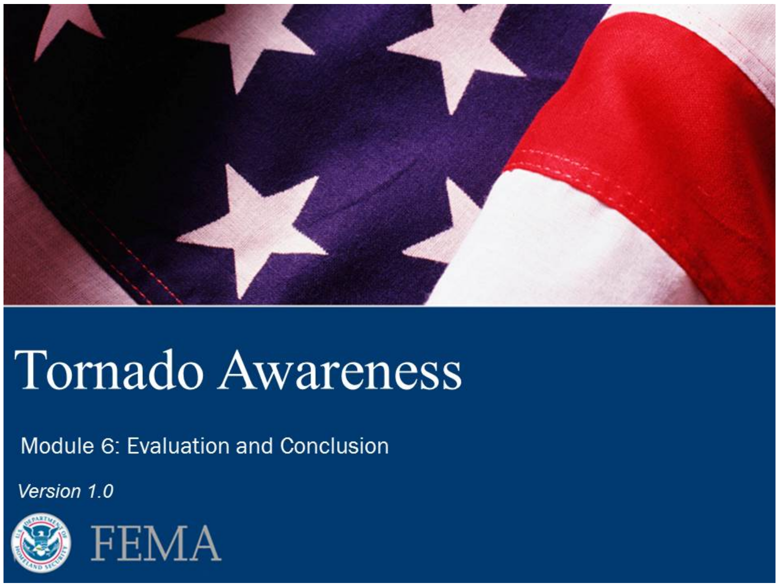
Participant Guide

Module 6: Evaluation and Conclusion

Version 1.0

FEMA

Module 6: Evaluation and Conclusion – Administration Page



Slide 6-1. Evaluation and Conclusion

Duration

45 minutes

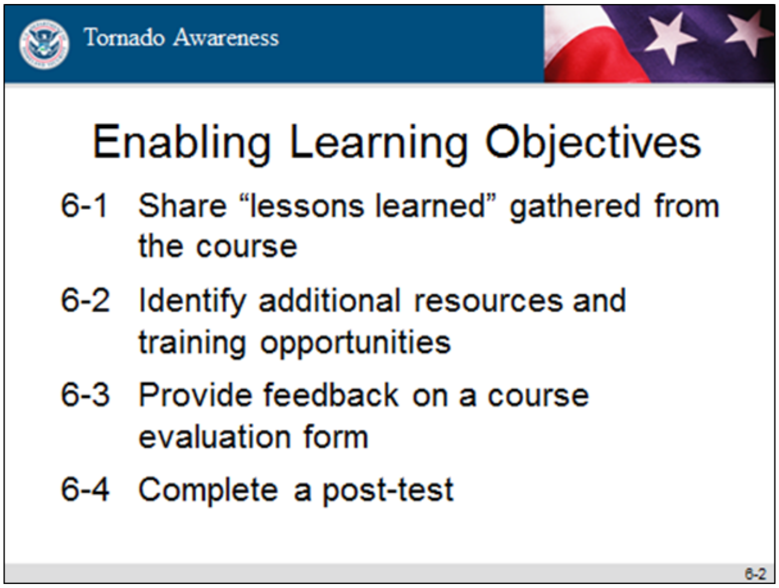
Scope Statement

In this module, participants will review lessons learned from previous modules, be advised of additional resources and training opportunities, complete a post-test and course evaluation form and provide feedback on the course instructions, content and materials.

Terminal Learning Objective (TLO)

Participants will complete a post-test and course evaluation.

Enabling Learning Objectives (ELOs)



Slide 6-2. Enabling Learning Objectives

At the end of this module, participants will be able to:

6-1 Share “lessons learned” gathered from the course.
6-2 Identify additional resources and training opportunities.
6-3 Provide feedback on a course evaluation form.
6-4 Complete a post-test.

Resources

- Instructor Guide (IG)
- Module 6 presentation slides
- Laptop with presentation software installed and CD-ROM capability
- Audio-visual (A/V projection unit)
- Projector screen
- Chalkboard (and chalk), whiteboard (and dry erase markers), or easel and easel paper (and permanent markers)
- One of each of the following items per participant:
  - Participant Guide (PG) available for download from http://ndptc.hawaii.edu/
  - Participant Handout
  - Course Evaluation Forms
  - Post-test answer sheet corresponding to post-test version

Instructor-to-Participant Ratio

2:40

Reference List

Not Applicable

Assessment Strategy

- Instructors observation of participant involvement in classroom discussion
- Instructors administration of objectives-based post-test to assess the knowledge participants have gained in each module

Tornado Awareness

Icon Map

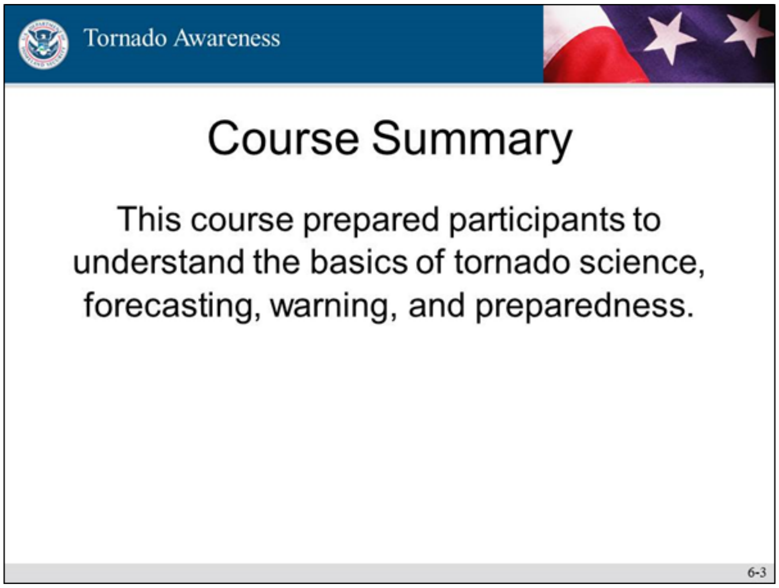
Knowledge Check: Used when it is time to assess participant understanding.

Example: Used when there is a descriptive illustration to show or explain.

Key Points: Used to convey essential learning concepts, discussions and introduction of supplemental material.

Participant Note: Used to indicate text that has been included as additional information for the participant. The text may not be directly addressed in the slide presentation or during class discussion.

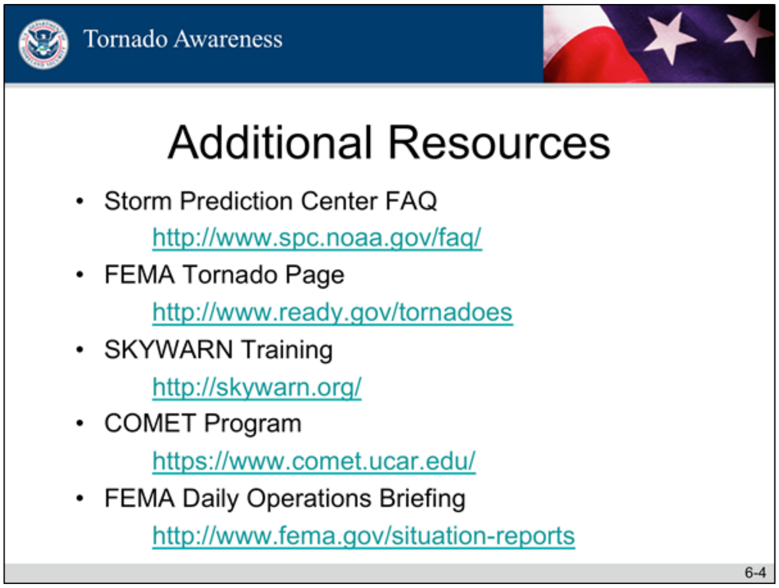
Participant Notes:



Slide 6-3. Course Summary

This course prepared participants to understand the basics of tornado science, forecasting, warning, and preparedness.

Participant Notes:

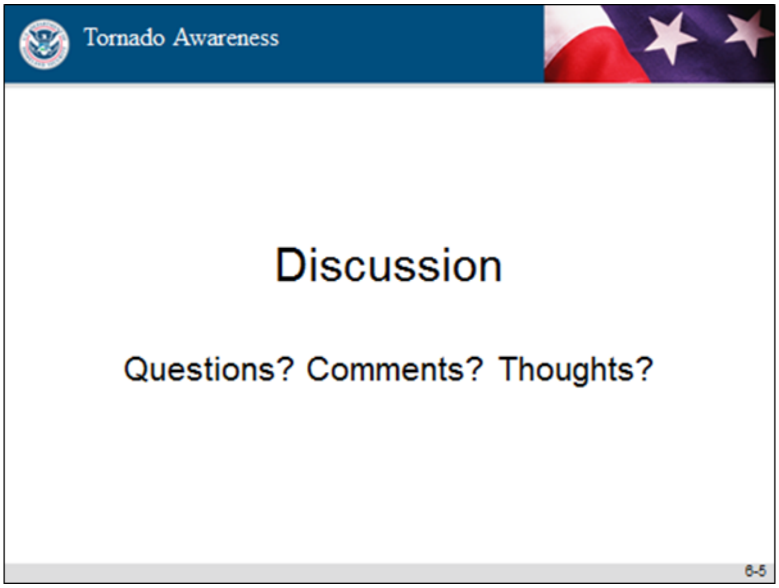


Slide 6-4. Additional Resources

Participants who are interested in learning more may look up the following references:

- Storm Prediction Center FAQ, http://www.spc.noaa.gov/faq/tornado/
- FEMA Tornado Page, http://www.ready.gov/tornadoes
- SKYWARN Training, http://skywarn.org/
- COMET Program, https://www.comet.ucar.edu/
- FEMA Daily Operations Briefing, http://www.fema.gov/situation-reports

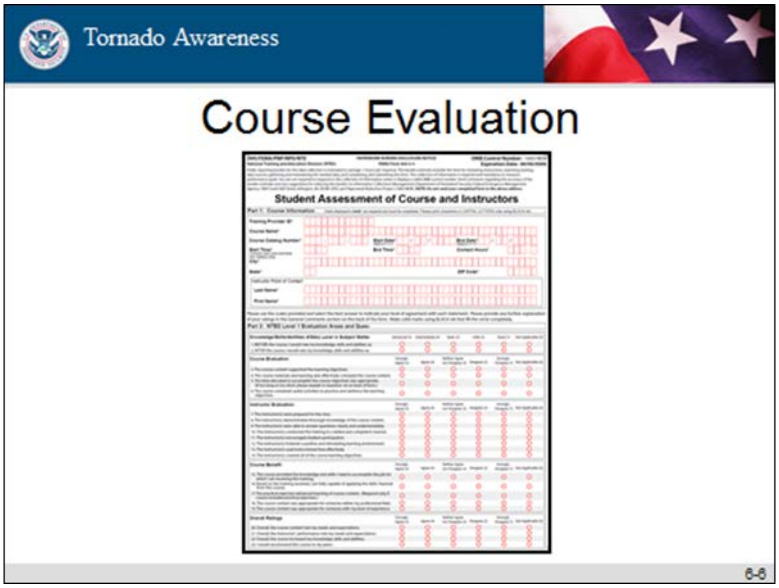
Participant Notes:



Slide 6-5. Discussion

The participants are welcome to ask any questions or share any comments or thoughts about the course.

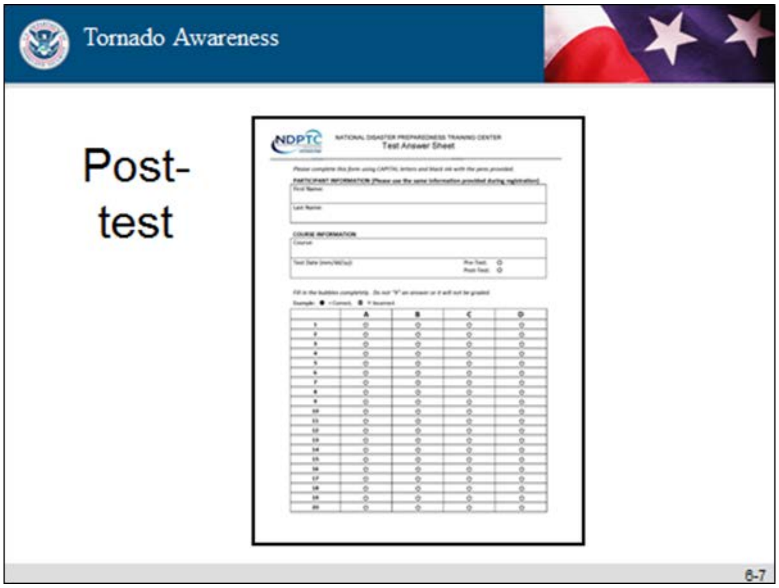
Participant Notes:



Slide 6-6. Course Evaluation

The instructors will distribute a Course Evaluation Form to participants and ask them to provide constructive feedback on the course material and instruction. Participants have 15 minutes to complete the form.

Participant Notes:

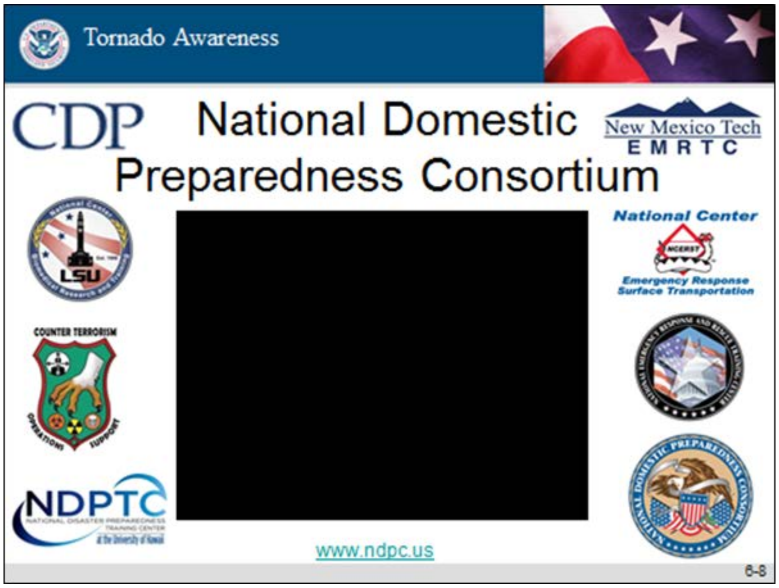


Slide 6-7. Post-test

This course concludes with a post-test, which allows the instructors to evaluate participant knowledge on the topics addressed in the course. The post-test provides participants with an opportunity to demonstrate mastery of the Terminal Learning Objectives, and is similar in design and content to the pre-test that participants completed at the beginning of the course. Participants’ pre-test and post-test scores will be compared to measure the benefit of the course and identify the knowledge and skills participants gained during their attendance.

Unlike the pre-test, every question should be answered. Participants must not leave any answers blank on the answer sheet. Participants will have 20 minutes to complete the post-test, and should work independently to complete the answers.

Participant Notes:



Slide 6-8. National Domestic Preparedness Consortium

The video in this slide is a little over 2.5 minutes in length. This short clip highlights the unique set of assets of each National Domestic Preparedness Consortium (NDPC) member.

The NDPC is a professional alliance sponsored through the Department of Homeland Security/FEMA National Preparedness Directorate.

The NDPC membership includes:

- University of Hawai'i: National Disaster Preparedness Training Center (NDPTC);
- Louisiana State University's Academy of Counter-Terrorist Education: National Center for Biomedical Research and Training;
- Texas A&M: National Emergency Response and Rescue Center;
- The New Mexico Institute of Mining and Technology: Energetic Materials Research and Testing Center;
- Center for Domestic Preparedness (CDP);
- US Department of Energy Nevada Test Site: Counter-Terrorism Operations Support; and
- Transportation Technology Center, Inc./National Center for Emergency Response in Surface Transportation.

Unofficial Video Transcript

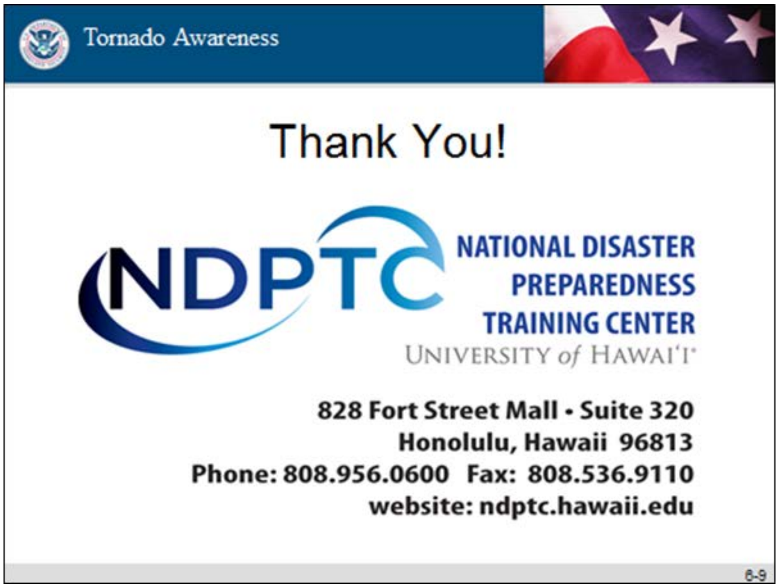
The National Domestic Preparedness Consortium or NDPC is a national homeland security resource and DHS/FEMA training partner that has supported the preparedness needs of the country since 1998. It is a partnership of several nationally recognized public universities, and

Participant Notes:

private and government organizations. The NDPC's mission is to develop and deliver advanced all-hazards training to prepare the nation. The seven NDPC members and their core competencies are: CDP – DHS/FEMA's Center for Domestic preparedness in Anniston, AL with core competencies in chemical, biological and nuclear attacks involving HazMat; NCBRT – LSU's National Center for Biomedical Research and Training in Baton Rouge, LA whose core competencies are law enforcement and biological and agricultural terrorism; EMRTC – New Mexico Tech's Energetic Materials Research and Testing Center in Socorro, NM with core competencies in explosive and incendiary attacks; NCERST – The Transportation Technology Center's National Center for Emergency Response in Surface Transportation in Pueblo, CO whose core competencies are surface transportation security and specialized highway and rail emergency response; NNSA/NSO/CTOS – The National Nuclear Security Administration's Nevada Site Office Center for Radiological/Nuclear training at the Nevada National Security site in Las Vegas, NV whose core competencies include radiological and nuclear WMD attacks, prevention, and response training; NDPTC – University of Hawai'i's National Disaster Preparedness Training Center in Honolulu, HI whose core competencies are natural hazards, risks to urban populations, and planning for urban areas following a disaster; and NERRTC – TEEX's Nation Emergency Response and Rescue Training Center at Texas A&M University in College Station, TX with core competencies in incident management, health and medical services, critical infrastructure protection, disaster preparedness and response, executive leadership and management, and cyber security. For more information on the NDPC, contact us at www.ndpc.us.

Additional training opportunities can be found on FEMA's National Training and Education Division (NTED) website at www.firstrespondertraining.gov.

Participant Notes:



Slide 6-9. Thank You!

The instructors may close the course with a summary of NDPTC and upcoming courses.

Key Point: The NDPTC is a member of the National Domestic Preparedness Consortium (NDPC).

NDPTC works collaboratively to develop and deliver training and education in the areas of disaster preparedness, response, and recovery to governmental, private, tribal, and non-profit entities, and under-represented/under-served communities.

Tornado Awareness

Participant Guide

Appendices

Version 1.0

FEMA

This page is intentionally left blank.

Tornado Awareness

Participant Guide

Appendix A: Acronyms and Abbreviations

Version 1.0

FEMA

This page is intentionally left blank.

Appendix A: Acronyms and Abbreviations

ASOS: Automated Surface Observing System

CDP: Center for Domestic Preparedness

CWA: County Warning Area

DOD: Department of Defense

EF: Enhanced Fujita

ELO: Enabling Learning Objective

EMRTC: New Mexico Tech's Energetic Materials Research and Testing Center

FAA: Federal Aviation Administration

FEMA: Federal Emergency Management Agency

FFD: Forward-Flank Downdraft

GFS: Global Forecasting System

NCBRT: National Center for Biomedical Research and Training

NCERST: The Transportation Technology Center's National Center for Emergency Response in Surface Transportation

NERRTC: National Emergency Response and Rescue Training Center

NDPC: National Domestic Preparedness Consortium

NDPTC: National Disaster Preparedness Training Center

NOAA: National Oceanic and Atmospheric Administration

NTS-CTOS: Nevada Test Site/Counter-Terrorism Operations Support

NWFO: National Weather Forecasting Office

NWS: National Weather Service

PDS: Particularly Dangerous Situation

POES: Polar-Orbiting Satellites

QLCS: Quasi-Linear Convective System

RFD: Rear-Flank Downdraft

SAME: Specific Area Messaging Encoding

SPC: Storm Prediction Center

TLO: Terminal Learning Objective

WEA: Wireless Emergency Alerts

WFO: Weather Forecasting Office

Tornado Awareness

Participant Guide

Appendix B: Activity Worksheets

Version 1.0

FEMA

This page is intentionally left blank.

Appendix B: Activity Worksheets

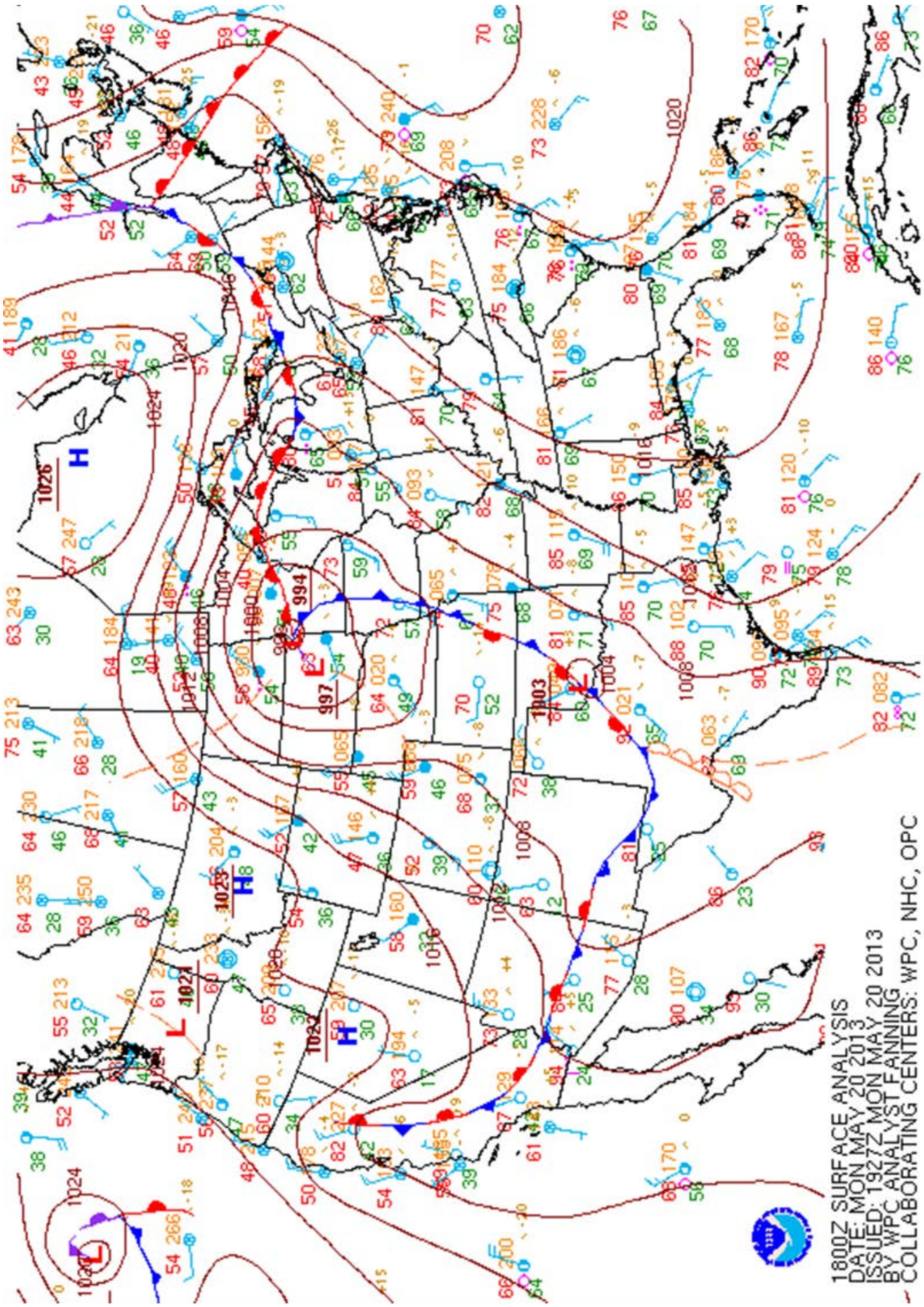
List of Handouts:

This appendix includes the following handouts:

- Module 3: Handout #1
- Module 5: Handout #1
- Module 5: Handout #2
- Module 5: Handout #3
- Module 5: Handout #4
- Module 5: Handout #5
- Module 5: Handout #6

This page is intentionally left blank.

Module 3: Handout #1
Surface Analysis Map
(page 1 of 10)

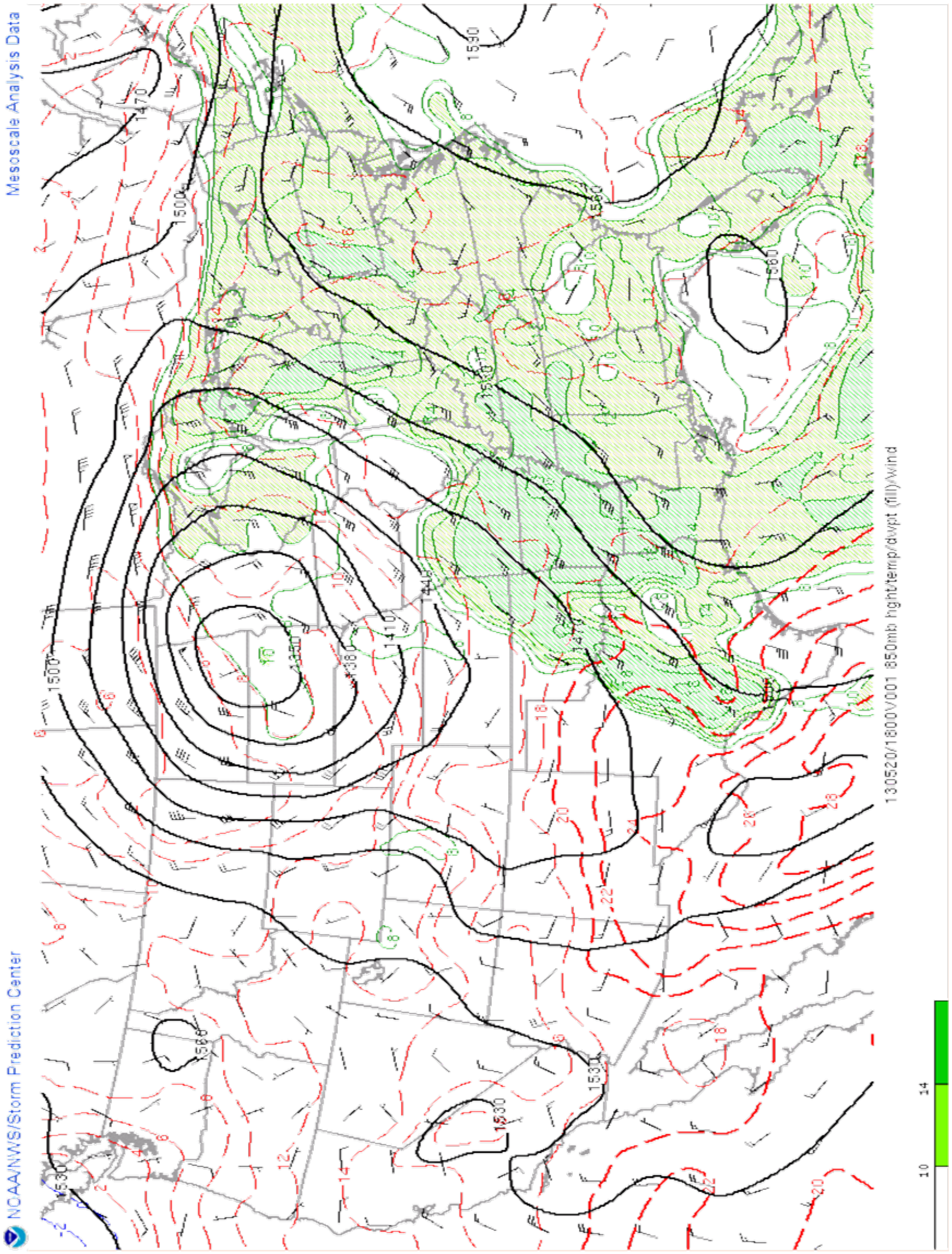


(Source: NOAA, 2013)

Module 3: Handout #1
Surface Analysis Map
(page 2 of 10)

This surface analysis map depicts the weather systems that were in place across the continental United States at 18Z on May 20, 2013. Note the mid-latitude cyclone over the northern Plains, with a frontal boundary draped through Iowa, Kansas, Oklahoma, and Texas. Another low-pressure system is located over southwest Oklahoma. Think about where severe weather is most likely in relation to these weather features.

Module 3: Handout #1
Low-Level Moisture (green contours)
(page 3 of 10)

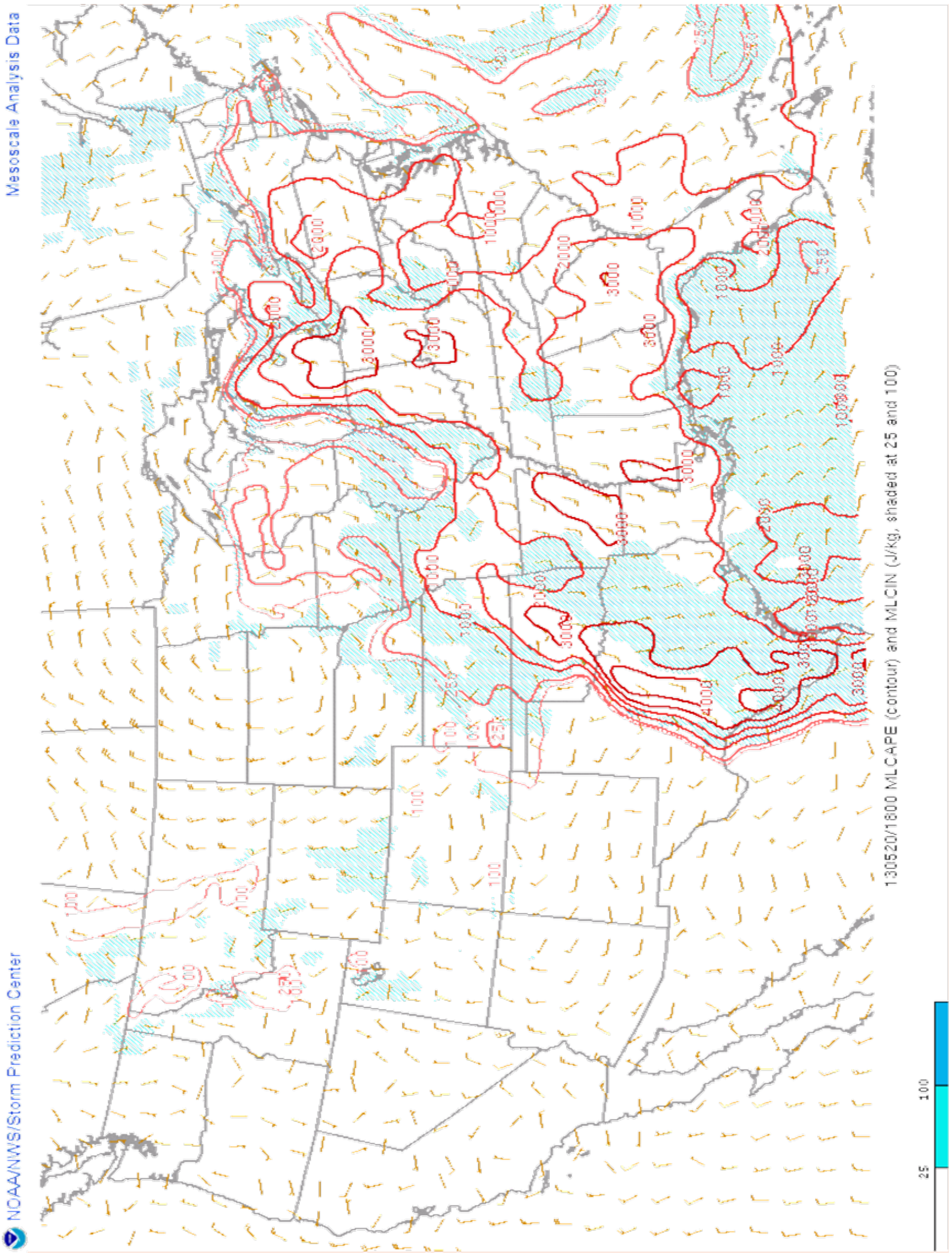


(Source: NOAA, 2013)

Module 3: Handout #1
Low-Level Moisture (green contours)
(page 4 of 10)

This is a map of low-level moisture, expressed as dewpoint temperature, valid at the same time as the surface map. For the purposes of this simplified exercise, the numerical values are not as important as the relative magnitude of the moisture: the darker the shade of green, the higher the moisture content of the air. Pay attention to areas of enhanced low-level moisture when considering severe weather risk.

Module 3: Handout #1
Atmospheric Instability (red contours)
(page 5 of 10)

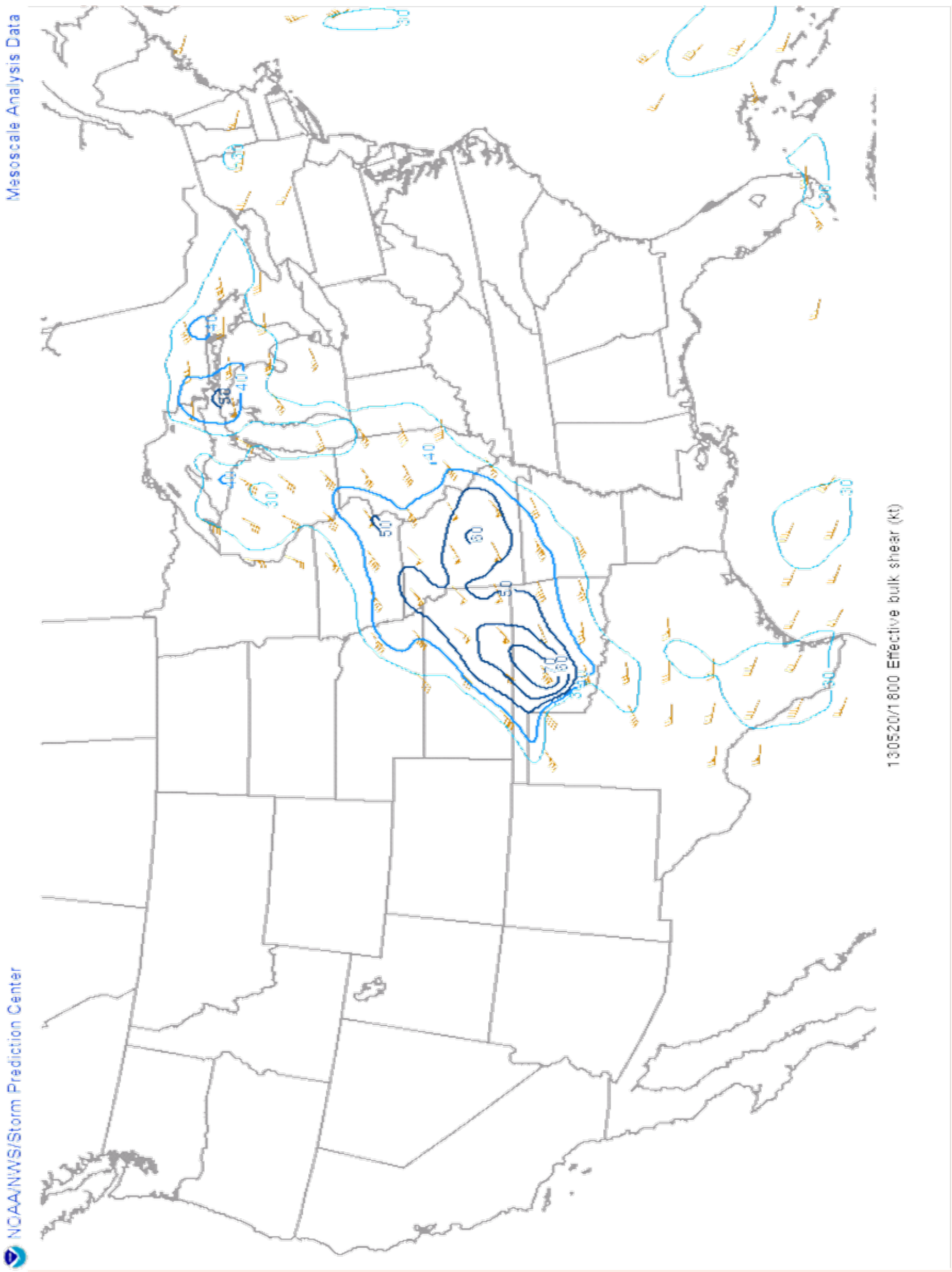


(Source: NOAA, 2013)

Module 3: Handout #1
Atmospheric Instability (red contours)
(page 6 of 10)

This is a map of instability, valid at the same time as the surface map, depicted by the red contours. For the purposes of this simplified exercise, the numerical values are not as important as the relative magnitude of the instability: the greater the contour value, the greater the instability. Pay attention to areas of enhanced instability when considering severe weather risk.

Module 3: Handout #1
Vertical Wind Shear (blue contours)
(page 7 of 10)



(Source: NOAA, 2013)

Module 3: Handout #1
Vertical Wind Shear (blue contours)
(page 8 of 10)

This is a map of effective bulk shear, which is an expression of wind shear, depicted by blue contours and valid at the same time as the surface map. For the purposes of this simplified exercise, the numerical values are not as important as the relative magnitude of the shear: the greater the contour value, the greater the shear. Pay attention to areas of enhanced shear when considering severe weather risk.

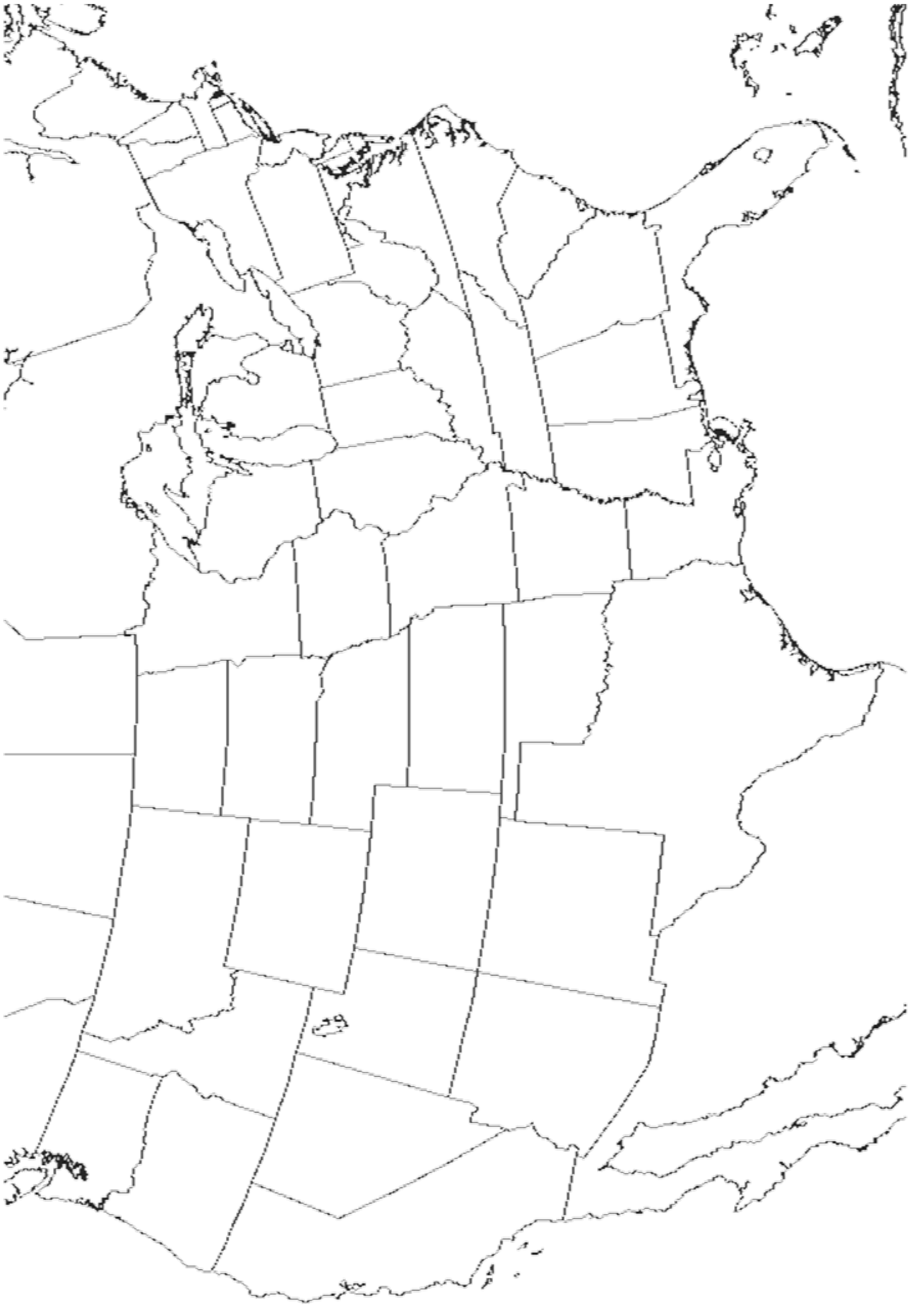
Module 3: Handout #1
Questions
(page 9 of 10)

1. As discussed in Module 2, what are the conditions that can lead to tornado formation?

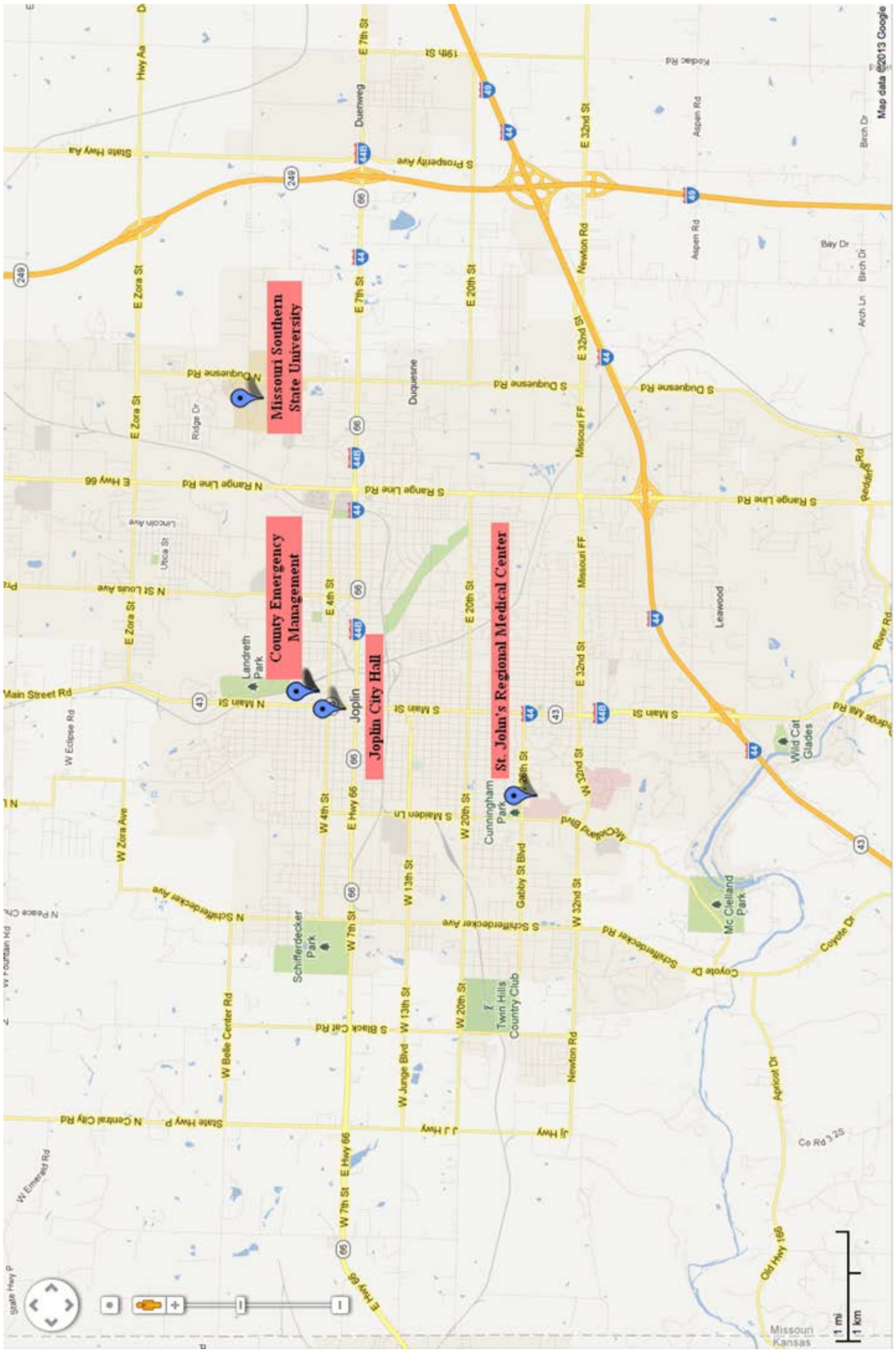
2. From your basic understanding of the science of tornadoes, assume you are a tornado forecaster. What parts of the country would you advise people to be prepared for tornadoes later in the day? Shade in the area of concern on the map on the next page.

3. From this simplified example, why do you think tornado forecasting is so challenging?

Module 3: Handout #1
Map of the Continental United States
(page 10 of 10)



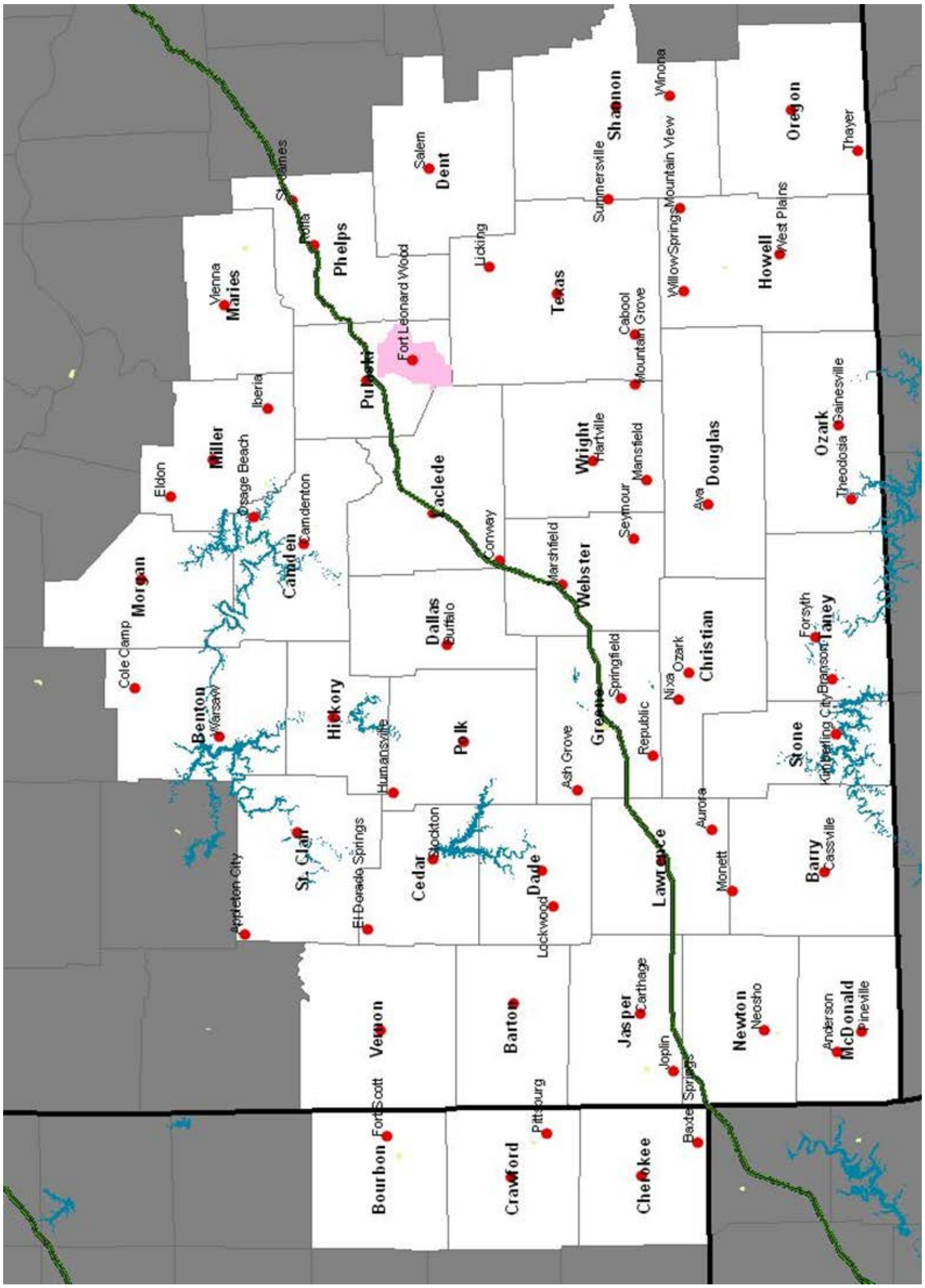
Module 5: Handout #1
Map of Joplin, MO
(page 1 of 5)



Module 5: Handout #1
Map of Joplin, MO
(page 2 of 5)

Map of Joplin, MO and areas surrounding the city. The locations of certain landmarks are highlighted: Joplin City Hall and County Emergency Management are located near the center of town, St. John's Regional Medical Center is located to the southwest, and Missouri Southern State University is located to the northeast.

Module 5: Handout #1
County Warning Area of Springfield, MO
(page 3 of 5)



(Source: NOAA, 2013)

Module 5: Handout #1
County Warning Area of Springfield, MO
(page 4 of 5)

Map of NWS WFO Springfield, MO, county warning area (CWA), showing Joplin, MO (Jasper County), located toward the western periphery of the CWA.

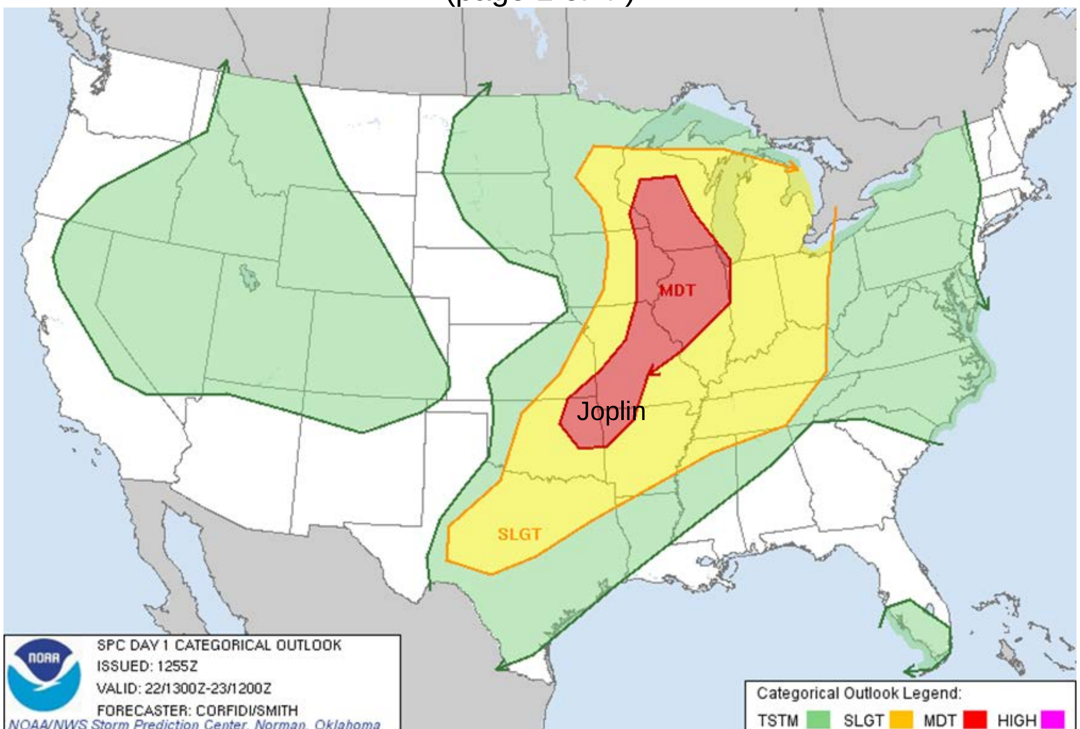
Module 5: Handout #1
Discussion Questions
(page 5 of 5)

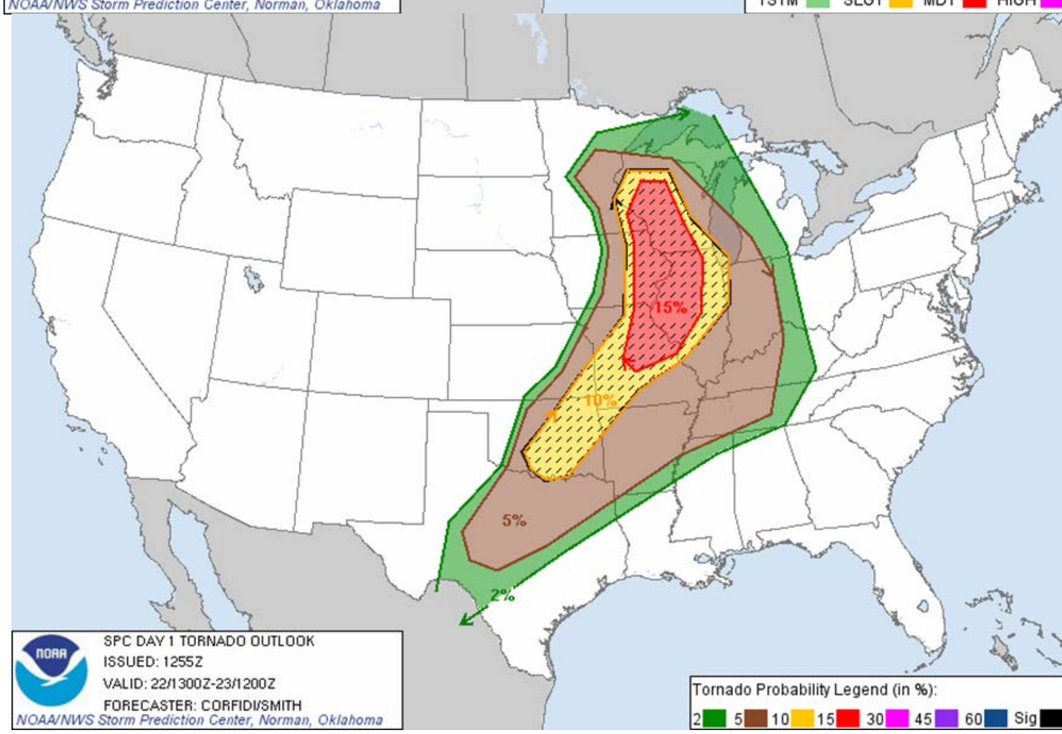
1. Given your geographic location, what type of weather hazards can threaten your city? What season is the greatest risk?

2. Think about the professional role that you represent. What are your primary concerns if this type of weather threatens your area of responsibility?

This page is intentionally left blank.

Module 5: Handout #2
SPC Convective Outlook (1300Z / 8:00 am CDT)
(page 1 of 4)





(Source: NOAA, 2013)

Module 5: Handout #2
SPC Convective Outlook (1300Z / 8:00 am CDT)
(page 2 of 4)

Convective outlook maps issued by the SPC, showing a slight risk of severe weather extending from central Texas northeastward to Minnesota, Michigan, and Kentucky. A moderate risk of severe weather extends from northeastern Oklahoma toward Illinois and Wisconsin. A graded risk of tornadoes increases from the outer periphery of the risk areas toward the upper Mississippi Valley, where the greatest risk of a tornado occurring within 25 miles of a point is estimated to be near 15%.

Module 5: Handout #2

(page 3 of 4)

```
DAY 1 CONVECTIVE OUTLOOK
NWS STORM PREDICTION CENTER NORMAN OK
0755 AM CDT SUN MAY 22 2011

VALID 221300Z - 231200Z

...SYNOPSIS...
SD CLOSED LOW EXPECTED TO TRACK ENE TO SRN MN THIS EVE AND EVOLVE
INTO AN OPEN WAVE OVER WI EARLY MON AS BROAD...NEGATIVE TILT
UPSTREAM TROUGH AMPLIFIES SE ACROSS THE WRN U.S.  BETWEEN THESE TWO
FEATURES...A WEAK SHORTWAVE RIDGE WILL SHIFT E FROM THE CNTRL/SRN
RCKYS TO THE CNTRL/SRN PLNS.  AT THE SFC...A COLD/OCCLUDED FRONT
WILL MOVE E ACROSS THE MID/UPR MS VLY AND ACROSS ERN KS/MO LATER
TODAY/TONIGHT...WHILE FARTHER S...DRYLINE WILL PERSIST FROM SE KS TO
THE TX BIG BEND.  THE DRYLINE WILL INTERSECT THE COLD FRONT IN KS
AND WILL RETREAT NW ACROSS THE SRN PLNS LATER IN THE PERIOD.

BOTH THE COLD FRONT AND THE DRYLINE WILL SERVE TO FOCUS INTENSE TSTM
DEVELOPMENT LATER TODAY INTO TONIGHT.  GIVEN THE DEGREE OF BOTH
INSTABILITY AND SHEAR PRESENT NEAR THE BOUNDARIES...SOME OF THE
STORMS LIKELY WILL YIELD VERY LARGE HAIL...TORNADOES...AND DMGG
WIND.

...SRN PLNS...
VERY RICH GULF MOISTURE...WITH LOW 70S F SFC DEWPOINTS AND PW AROUND
1.75 INCHES...WILL PERSIST/SPREAD NWD ACROSS THE SRN HALF OF THE
PLNS TODAY BENEATH BROAD STEEP MID LVL LAPSE RATE PLUME ASSOCIATED
WITH SRN STREAM WSWLY FLOW/EML.  COUPLED WITH STRONG SFC
HEATING...SETUP LIKELY WILL YIELD A CORRIDOR OF VERY STRONG
INSTABILITY /SBCAPE UP TO 6000 J PER KG/ ALONG AND AHEAD OF DRY
LINE/COLD FRONT FROM S CNTRL TX NEWD INTO SE KS...SW MO...AND NW AR
BY LATE TODAY.

LARGE SCALE FORCING FOR ASCENT WILL BE WEAK THROUGH THE
PERIOD...WITH SLIGHT HEIGHT RISES POSSIBLE AS LOW AMPLITUDE RIDGE
APPROACHES REGION.  IN ADDITION...APPRECIABLE CINH WILL BE PRESENT
DUE TO EML.  BUT COMBINATION OF STRONG INSTABILITY WITH SLIGHTLY
CONFLUENT LOW LVL SSWLY FLOW SHOULD SUPPORT AT LEAST WDLY SCTD
INTENSE STORMS FROM ERN OK INTO SW MO/NW AR BY LATE IN THE DAY.
MORE ISOLD INTENSE ACTIVITY ALSO MAY OCCUR FROM CNTRL OK SWD INTO S
CNTRL TX.

GIVEN DEGREE OF INSTABILITY AND AMPLE DEEP SHEAR FOR
SUPERCELLS...POTENTIAL WILL BE VERY HIGH FOR AT LEAST A FEW
INSTANCES OF EXTREMELY LARGE HAIL...IN ADDITION TO TORNADOES/LOCALLY
DMGG WIND.  STRENGTHENING LLJ AFTER NIGHTFALL AND CONTINUING
PRESENCE OF VERY RICH MOISTURE SUGGEST THAT THE TORNADO THREAT COULD
CONTINUE WELL INTO THE EVENING.

ADDITIONAL STORMS MAY FORM OVER PARTS OF CNTRL AND NW TX AND
CNTRL/WRN OK LATE TONIGHT AND EARLY MONDAY AS LLJ CONTINUES TO
STRENGTHEN AND SLIGHTLY BACKS AHEAD OF AMPLIFYING SRN STREAM
TROUGH...ENHANCING WAA/MOISTURE FLUX INVOF RETREATING DRY LINE.
```

Module 5: Handout #2
Discussion Questions
(page 4 of 4)

1. Evaluate the severe weather threat. Based on the latest SPC Convective Outlook, what is the risk of tornadoes for your area?

2. What type of preparations should be made this morning for your profession?

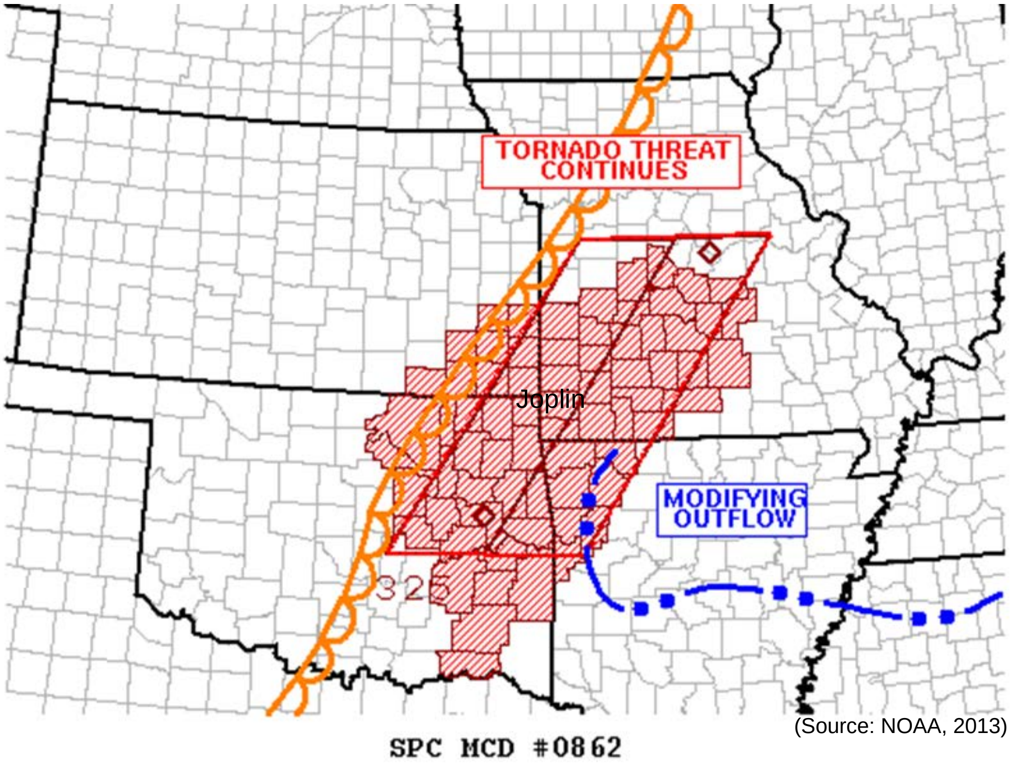
3. Based on what you have learned about official NWS severe weather products, what is the next type of alet that you should expect if the risk for tornadoes escalates?

Module 5: Handout #3
SPC Tornado Watch (1830Z / 1:30 pm CDT)
(page 1 of 3)

Map showing a tornado watch extending from eastern Oklahoma through southwest Missouri, including southeast Kansas and northwest Arkansas.

```
URGENT - IMMEDIATE BROADCAST REQUESTED
TORNADO WATCH NUMBER 325
NWS STORM PREDICTION CENTER NORMAN OK
130 PM CDT SUN MAY 22 2011

EFFECTIVE THIS SUNDAY AFTERNOON AND EVENING FROM 130 PM UNTIL 900 PM CDT.

   TORNADOES...HAIL TO 4 INCHES IN DIAMETER...THUNDERSTORM WIND
   GUSTS TO 70 MPH...AND DANGEROUS LIGHTNING ARE POSSIBLE IN THESE
   AREAS.

   REMEMBER...A TORNADO WATCH MEANS CONDITIONS ARE FAVORABLE FOR
   TORNADOES AND SEVERE THUNDERSTORMS IN AND CLOSE TO THE WATCH
   AREA. PERSONS IN THESE AREAS SHOULD BE ON THE LOOKOUT FOR
   THREATENING WEATHER CONDITIONS AND LISTEN FOR LATER STATEMENTS
   AND POSSIBLE WARNINGS.

   DISCUSSION...EXPLOSIVE TSTM DEVELOPMENT IS EXPECTED WITHIN THE NEXT
   ONE TO TWO HOURS ALONG COLD FRONT MOVING THROUGH SERN KS AND NERN
   OK.  WARM SECTOR AIR MASS IS QUITE MOIST WITH DEWPOINTS IN THE LOWER
   70S.  WHEN COUPLED WITH STEEP MIDLEVEL LAPSE RATES...ENVIRONMENT HAS
   BECOME STRONGLY TO EXTREMELY UNSTABLE WITH MLCAPE OF 3000-5000 J/KG.
   THE PRESENCE OF 35-40 KT WLY DEEP-LAYER SHEAR WILL BE SUPPORTIVE OF
   SUPERCELLS CAPABLE OF DESTRUCTIVE HAIL.  MOREOVER...SWRN EXTENSION
   OF A 30-35 KT SWLY LLJ WILL BE MAINTAINED ACROSS THE
   REGION...RESULTING IN EFFECTIVE SRH VALUES OF 150-250 M2/S2 AND AN
   ASSOCIATED TORNADO THREAT.  A STRONG TORNADO OR TWO IS POSSIBLE.
```

Module 5: Handout #3
SPC Mesoscale Discussion (2048Z / 3:48 pm CDT) – UPDATE
(page 2 of 3)



(Source: NOAA, 2013)

Graphical update to the tornado watch showing a continuing threat in the area as the dryline pushes eastward through the region.

```
MESOSCALE DISCUSSION 0862
NWS STORM PREDICTION CENTER NORMAN OK
0348 PM CDT SUN MAY 22 2011

AREAS AFFECTED...ERN OK...SERN KS...SWRN MO

CONCERNING...TORNADO WATCH 325...

VALID 222048Z - 222245Z

THE SEVERE WEATHER THREAT FOR TORNADO WATCH 325 CONTINUES.

VIGOROUS CONVECTION CONTINUE TO INTENSIFY ALONG THE DRYLINE FROM WRN
MO INTO SERN KS. A MODIFIED 19Z SGF SOUNDING USING OBSERVED SURFACE
OBSERVATIONS ALONG THE DRYLINE YIELDS OVER 5000 J/KG MUCAPE WITH A
300 MB LI OF -19C. ALSO DEPICTED IN THIS SOUNDING...AND ON NDS AND
CNW PROFILERS...IS 40-50 KT MID LEVEL FLOW ATOP VEERING LOW LEVEL
FLOW...MORE THAN SUFFICIENT FOR SUPERCELLS. EXISTING STORMS WILL
PERSIST WITH AN EXTREME HAIL THREAT AS WELL AS THE POSSIBILITY OF
CYCLIC TORNADOES.
ATTN...WFO...LSX...LZK...SGF...EAX...TSA...ICT...OUN...
```

Module 5: Handout #3
Discussion Questions
(page 3 of 3)

1. Where is Joplin, MO in relation to this Tornado Watch?

2. Based on knowledge of weather radar obtained during this course, can you tell whether thunderstorms have formed within the watch area when this bulletin was issued? Are storms already widespread or are skies still sunny within the tornado watch area?

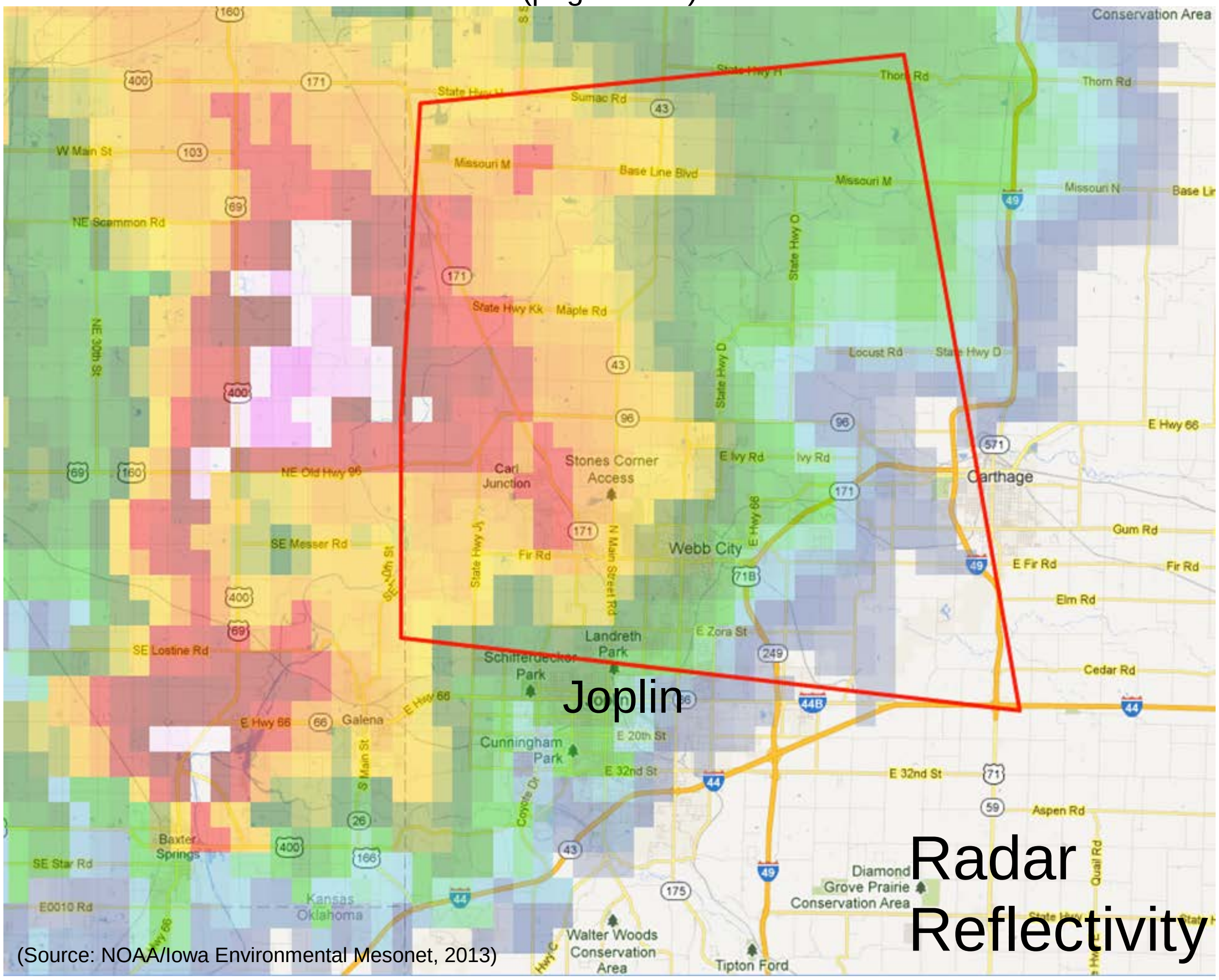
3. Now that a Tornado Watch has been issued, what preparations does your profession need to make?

4. Some of your constituents approach you and question your decisions, because it is warm and sunny in Joplin as far as the eyes can see. How do you respond?

5. What is the next type of NWS alert that you should expect if the tornado risk becomes imminent?

This page is intentionally left blank.

Module 5: Handout #4
NWS SGF Tornado Warning #30
(2209-2300Z / 5:09-6:00 pm CDT)
(page 1 of 3)



Radar and warning data from NOAA/NWS. Figure generated using the VTEC Product Browser developed by the Iowa Environmental Mesonet / Iowa State University Department of Agronomy. For more information, please refer to: *http://mesonet.agron.iastate.edu/current/severe.phtml*

Map showing radar reflectivity of first supercell thunderstorm with a hook echo and accompanying tornado warning that threatens the area just north of Joplin. Storm motion is toward the east.

Module 5: Handout #4
NWS SGF Tornado Warning #30
(2209-2300Z / 5:09-6:00 pm CDT)
(page 2 of 3)

```
BULLETIN - EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE SPRINGFIELD MO
509 PM CDT SUN MAY 22 2011

THE NATIONAL WEATHER SERVICE IN SPRINGFIELD HAS ISSUED A

* TORNADO WARNING FOR...
  WESTERN JASPER COUNTY IN SOUTHWEST MISSOURI...

* UNTIL 600 PM CDT.

* AT 505 PM CDT...NATIONAL WEATHER SERVICE DOPPLER RADAR INDICATED A
  TORNADO 10 MILES WEST OF CARL JUNCTION...OR 6 MILES EAST OF
COLUMBUS...MOVING EAST AT 30 MPH. THIS STORM HAS A HISTORY OF
PRODUCING FUNNEL CLOUDS AND TENNIS BALL SIZE HAIL.

* LOCATIONS IMPACTED INCLUDE AIRPORT DRIVE...ALBA...ASBURY...ATLAS...
  BROOKLYN HEIGHTS...CARL JUNCTION...CARTERVILLE...LAKESIDE...NECK
  CITY...NORTHEASTERN JOPLIN...OAKLAND PARK...ORONOGO...PURCELL...
  WACO AND WEBB CITY.

INTERSTATE 44 BETWEEN MILE MARKERS 13 AND 18 WILL ALSO BE IMPACTED BY
THIS TORNADO.

IN ADDITION TO A TORNADO...THIS STORM IS CAPABLE OF PRODUCING LARGE
DAMAGING HAIL UP TO TENNIS BALL SIZE.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

THE SAFEST PLACE TO BE DURING A TORNADO IS IN A BASEMENT. GET UNDER A
WORKBENCH OR OTHER PIECE OF STURDY FURNITURE. IF NO BASEMENT IS
AVAILABLE...SEEK SHELTER ON THE LOWEST FLOOR OF THE BUILDING IN AN
INTERIOR HALLWAY OR ROOM SUCH AS A CLOSET. USE BLANKETS OR PILLOWS TO
COVER YOUR BODY AND ALWAYS STAY AWAY FROM WINDOWS.

IF IN MOBILE HOMES OR VEHICLES...EVACUATE THEM AND GET INSIDE A
SUBSTANTIAL SHELTER. IF NO SHELTER IS AVAILABLE...LIE FLAT IN THE
NEAREST DITCH OR OTHER LOW SPOT AND COVER YOUR HEAD WITH YOUR HANDS.
```

Module 5: Handout #4
Discussion Questions
(page 3 of 3)

1. Now that a tornado warning is issued, it's critical to identify threats to your specific location. Where are you in relation to the tornado warning polygon?

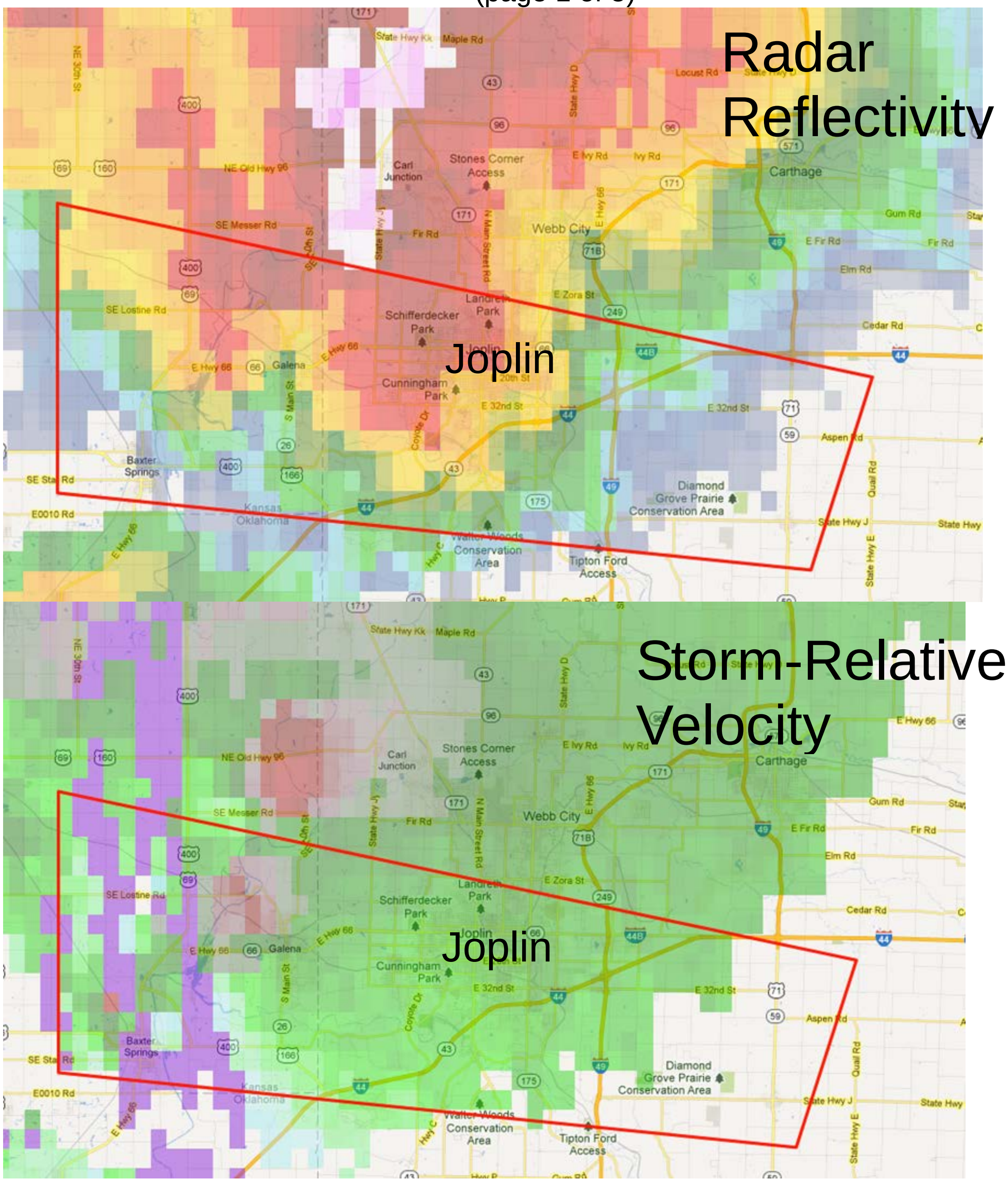
2. What's the tell-tale sign in this radar reflectivity pattern that indicates the potential for a tornadic supercell thunderstorm?

3. Based on this tornado warning, where do you expect the tornado to move? Will you be affected in your part of Joplin, MO?

4. Based on all available data, alerts, and reports, what decisions will you make for your profession?

This page is intentionally left blank.

Module 5: Handout #5
NWS SGF Tornado Warning #31
(2217-2300Z / 5:17-6:00 pm CDT)
(page 1 of 5)



(Source: NOAA/Iowa Environmental Mesonet, 2013)

Radar and warning data from NOAA/NWS. Figure generated using the VTEC Product Browser developed by the Iowa Environmental Mesonet / Iowa State University Department of Agronomy. For more information, please refer to: [*http://mesonet.agron.iastate.edu/current/severe.phtml*](http://mesonet.agron.iastate.edu/current/severe.phtml)

Module 5: Handout #5
NWS SGF Tornado Warning #31
(2217-2300Z / 5:17-6:00 pm CDT)
(page 2 of 5)

Maps of radar reflectivity and storm-relative velocity showing a new supercell with a developing hook echo to the southwest of the original threat with a new tornado warning that includes all of Joplin.

Module 5: Handout #5
NWS SGF Tornado Warning #31
(2217-2300Z / 5:17-6:00 pm CDT)
(page 3 of 5)

```
BULLETIN - EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE SPRINGFIELD MO
517 PM CDT SUN MAY 22 2011

THE NATIONAL WEATHER SERVICE IN SPRINGFIELD HAS ISSUED A

* TORNADO WARNING FOR...
  NORTHWESTERN NEWTON COUNTY IN SOUTHWEST MISSOURI...
  SOUTHEASTERN CHEROKEE COUNTY IN SOUTHEAST KANSAS...
  SOUTHWESTERN JASPER COUNTY IN SOUTHWEST MISSOURI...

* UNTIL 600 PM CDT.

* AT 514 PM CDT...NATIONAL WEATHER SERVICE DOPPLER RADAR INDICATED A
  TORNADO NEAR RIVERTON...OR 4 MILES NORTH OF BAXTER SPRINGS...MOVING
  NORTHEAST AT 40 MPH.

* LOCATIONS IMPACTED INCLUDE BAXTER SPRINGS...CLIFF VILLAGE...DENNIS
  ACRES...DIAMOND...DUENWEG...DUQUESNE...FIDELITY...GALENA...IRON
  GATES...JOPLIN...LEAWOOD...LOWELL...REDINGS MILL...RIVERTON...
  SAGINAW...SHOAL CREEK DRIVE...SHOAL CREEK ESTATES...SHOAL CREEK
  ESTATE AND SILVER CREEK.

INTERSTATE 44 BETWEEN MILE MARKERS 0 AND 13 WILL ALSO BE IMPACTED BY
THIS TORNADO.

IN ADDITION TO A TORNADO...THIS STORM IS CAPABLE OF PRODUCING LARGE
DAMAGING HAIL UP TO GOLF BALL SIZE.

THERE IS ADDITIONAL TORNADO WARNING FOR A SEPARATE STORM ACROSS
CENTRAL AND NORTHERN JASPER COUNTY.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

THE SAFEST PLACE TO BE DURING A TORNADO IS IN A BASEMENT. GET UNDER A
WORKBENCH OR OTHER PIECE OF STURDY FURNITURE. IF NO BASEMENT IS
AVAILABLE...SEEK SHELTER ON THE LOWEST FLOOR OF THE BUILDING IN AN
INTERIOR HALLWAY OR ROOM SUCH AS A CLOSET. USE BLANKETS OR PILLOWS TO
COVER YOUR BODY AND ALWAYS STAY AWAY FROM WINDOWS.

IF IN MOBILE HOMES OR VEHICLES...EVACUATE THEM AND GET INSIDE A
SUBSTANTIAL SHELTER. IF NO SHELTER IS AVAILABLE...LIE FLAT IN THE
NEAREST DITCH OR OTHER LOW SPOT AND COVER YOUR HEAD WITH YOUR HANDS.
```

Module 5: Handout #5
NWS SGF Tornado Warning #31 -- UPDATES
(page 4 of 5)

Severe Weather Statement
(2230-2300Z / 5:30-6:00 pm CDT)

```
SEVERE WEATHER STATEMENT
NATIONAL WEATHER SERVICE SPRINGFIELD MO
530 PM CDT SUN MAY 22 2011

...A TORNADO WARNING REMAINS IN EFFECT UNTIL 600 PM CDT FOR
NORTHWESTERN NEWTON...SOUTHWESTERN JASPER AND SOUTHEASTERN CHEROKEE
COUNTIES...

AT 524 PM CDT...NATIONAL WEATHER SERVICE DOPPLER RADAR CONTINUED TO
INDICATE A TORNADO NEAR RIVERTON...OR NEAR GALENA...MOVING EAST AT 20
MPH. THIS STORM HAS A HISTORY OF PRODUCING A FUNNEL CLOUD IN
RIVERTON KANSAS.

LOCATIONS IMPACTED INCLUDE CLIFF VILLAGE...DENNIS ACRES...DIAMOND...
DUENWEG...DUQUESNE...FIDELITY...GALENA...IRON GATES...JOPLIN...
LEAWOOD...LOWELL...REDINGS MILL...RIVERTON...SAGINAW...SHOAL CREEK
DRIVE...SHOAL CREEK ESTATES...SHOAL CREEK ESTATE AND SILVER CREEK.

INTERSTATE 44 BETWEEN MILE MARKERS 0 AND 13 WILL ALSO BE IMPACTED BY
THIS TORNADO.

IN ADDITION TO A TORNADO...THIS STORM IS CAPABLE OF PRODUCING LARGE
DAMAGING HAIL UP TO BASEBALL SIZE.
```

Severe Weather Statement
(2239-2300Z / 5:39-6:00 pm CDT)

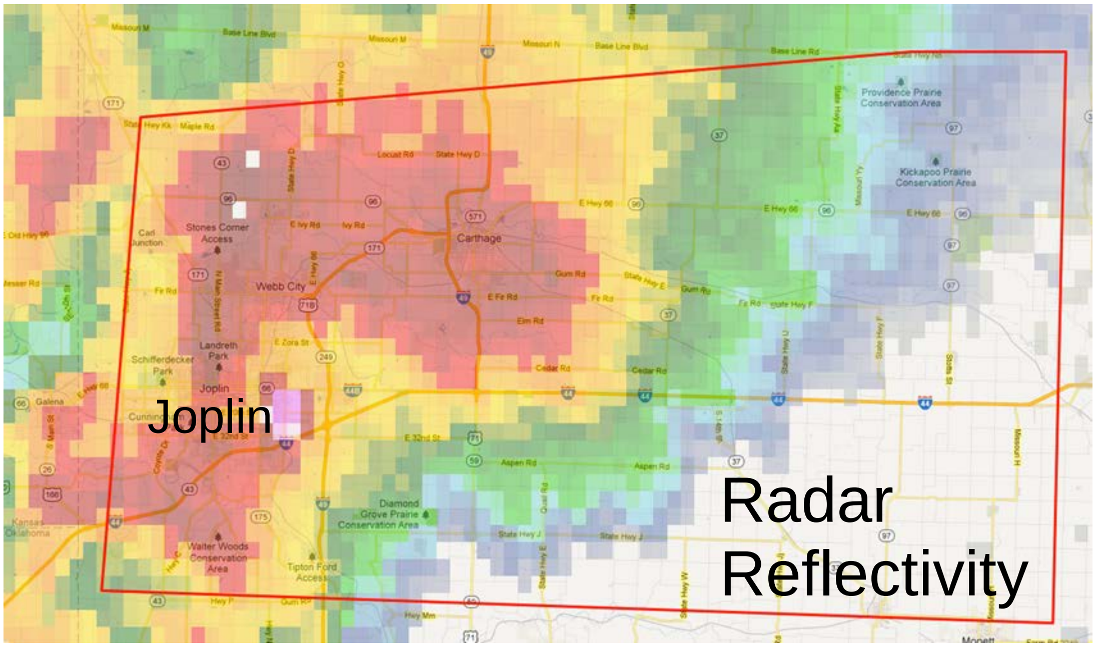
```
SEVERE WEATHER STATEMENT
NATIONAL WEATHER SERVICE SPRINGFIELD MO
539 PM CDT SUN MAY 22 2011

...A TORNADO WARNING REMAINS IN EFFECT UNTIL 600 PM CDT FOR
NORTHWESTERN NEWTON...SOUTHWESTERN JASPER AND SOUTHEASTERN CHEROKEE
COUNTIES...

AT 534 PM CDT...TRAINED WEATHER SPOTTERS REPORTED A TORNADO NEAR
GALENA...MOVING EAST AT 25 MPH. THIS STORM IS MOVING INTO THE CITY
OF JOPLIN.

LOCATIONS IMPACTED INCLUDE CLIFF VILLAGE...DENNIS ACRES...DIAMOND...
DUENWEG...DUQUESNE...FIDELITY...GALENA...IRON GATES...JOPLIN...
LEAWOOD...LOWELL...REDINGS MILL...RIVERTON...SAGINAW...SHOAL CREEK
DRIVE...SHOAL CREEK ESTATES...SHOAL CREEK ESTATE AND SILVER CREEK.

INTERSTATE 44 BETWEEN MILE MARKERS 0 AND 13 WILL ALSO BE IMPACTED BY
THIS TORNADO.

IN ADDITION TO A TORNADO...THIS STORM IS CAPABLE OF PRODUCING LARGE
DAMAGING HAIL UP TO BASEBALL SIZE.
```

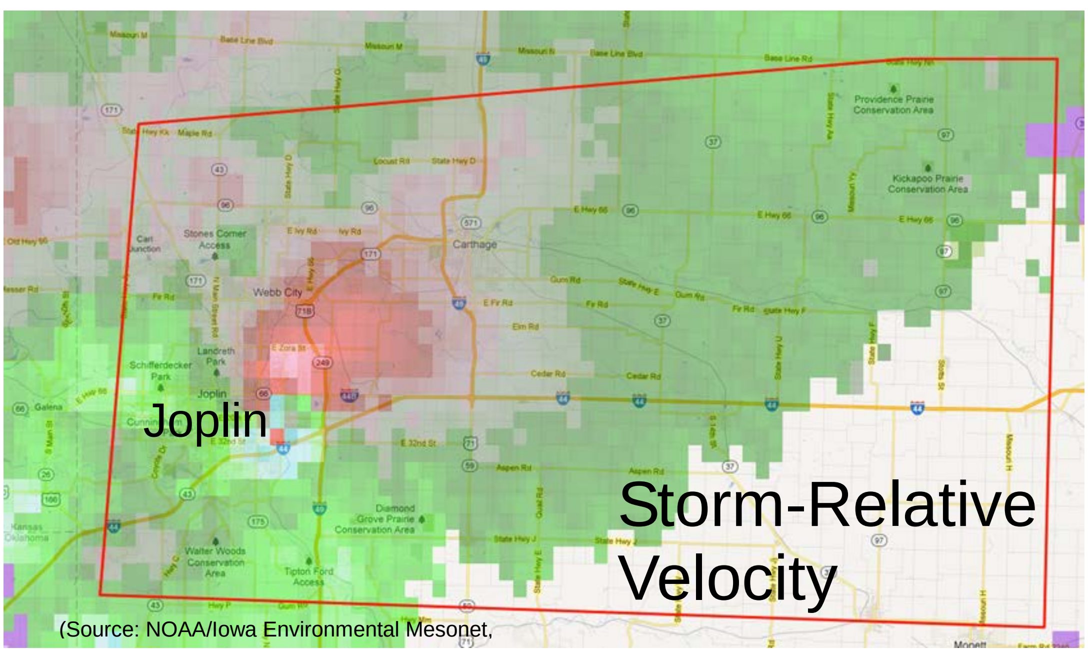
Module 5: Handout #5
Discussion Questions
(page 5 of 5)

1. What points of confusion do you anticipate among your constituents and the general public in Joplin, given how this situation is evolving?

This page is intentionally left blank.

Module 5: Handout #6
NWS SGF Tornado Warning #32
(2248-2330Z / 5:48-6:30 pm CDT)
(page 1 of 4)





(Source: NOAA/Iowa Environmental Mesonet, *Radar and warning data from NOAA/NWS. Figure generated using the VTEC Product Browser developed by the Iowa Environmental Mesonet / Iowa State University Department of Agronomy. For more information, please refer to: http://mesonet.agron.iastate.edu/current/severe.phtml*

Module 5: Handout #6
NWS SGF Tornado Warning #32
(2248-2330Z / 5:48-6:30 pm CDT)
(page 2 of 4)

Map showing new larger tornado warning that encompasses all of Joplin and areas to the east. Both the radar reflectivity and storm-relative velocity maps indicate a large supercell with intense rotation just east of downtown Joplin.

Module 5: Handout #6
Discussion Questions
(page 3 of 4)

1. What is the defining characteristic of the radar representation of this supercell thunderstorm?

2. How do you know it’s an extremely strong, tornadic storm?

Module 5: Handout #6
NWS SGF Tornado Warning #32
(2248-2330Z / 5:48-6:30 pm CDT)
(page 4 of 4)

BULLETIN - EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE SPRINGFIELD MO
548 PM CDT SUN MAY 22 2011

THE NATIONAL WEATHER SERVICE IN SPRINGFIELD HAS ISSUED A

* TORNADO WARNING FOR...
  NORTHERN NEWTON COUNTY IN SOUTHWEST MISSOURI...
  SOUTHERN JASPER COUNTY IN SOUTHWEST MISSOURI...
  WESTERN LAWRENCE COUNTY IN SOUTHWEST MISSOURI...

* UNTIL 630 PM CDT.

* AT 543 PM CDT...**TRAINED WEATHER SPOTTERS REPORTED A TORNADO NEAR EASTERN JOPLIN**...OR 9 MILES EAST OF GALENA...**MOVING EAST AT 45 MPH**. **DAMAGING AND MULTIPLE VORTEX TORNADO WAS REPORTED WITH THIS STORM.**

* LOCATIONS IMPACTED INCLUDE AIRPORT DRIVE...ALBA...ATLAS...AVILLA... BROOKLYN HEIGHTS...CARL JUNCTION...CARTERVILLE...CARTHAGE... CARYTOWN...CLIFF VILLAGE...DENNIS ACRES...DIAMOND...DUENWEG... DUQUESNE...FIDELITY...FREISTATT...IRON GATES...JOPLIN...LA RUSSELL...LAKESIDE...LEAWOOD...MAPLE GROVE...NECK CITY...OAKLAND PARK...ORONOGO...PIERCE CITY...PURCELL...RED OAK...REDINGS MILL... REEDS...SAGINAW...SARCOXIE...SHOAL CREEK DRIVE...SHOAL CREEK ESTATES...SHOAL CREEK ESTATE...SILVER CREEK...STOTTS CITY...WEBB CITY AND WENTWORTH.

INTERSTATE 44 BETWEEN MILE MARKERS 4 AND 42 WILL ALSO BE IMPACTED BY THIS TORNADO.

IN ADDITION TO A TORNADO...THIS STORM IS CAPABLE OF PRODUCING LARGE **DAMAGING HAIL UP TO BASEBALL SIZE**.

THIS TORNADO WARNING REPLACES THE TORNADO WARNINGS PREVIOUS OUT FOR THESE LOCATIONS.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

THE SAFEST PLACE TO BE DURING A TORNADO IS IN A BASEMENT. GET UNDER A WORKBENCH OR OTHER PIECE OF STURDY FURNITURE. IF NO BASEMENT IS AVAILABLE...SEEK SHELTER ON THE LOWEST FLOOR OF THE BUILDING IN AN INTERIOR HALLWAY OR ROOM SUCH AS A CLOSET. USE BLANKETS OR PILLOWS TO COVER YOUR BODY AND ALWAYS STAY AWAY FROM WINDOWS.

IF IN MOBILE HOMES OR VEHICLES...EVACUATE THEM AND GET INSIDE A SUBSTANTIAL SHELTER. IF NO SHELTER IS AVAILABLE...LIE FLAT IN THE NEAREST DITCH OR OTHER LOW SPOT AND COVER YOUR HEAD WITH YOUR HANDS.

Tornado Awareness

Participant Guide

Appendix C: Best Practices for Outdoor Warning Sirens

Version 1.0

FEMA

This page is intentionally left blank.

Appendix C: Best Practices for Outdoor Warning Sirens

Version 1.0 09/12/2011

Best Practices for Outdoor Warning Sirens

Developed by the Workgroup for Warning Systems
Chair – Rob Dale rdale@skywatch.org

Purpose

The purpose of this document is to establish common guidelines for activation of outdoor warning sirens throughout the United States. The intent of this best practices list is to enhance decision making by citizens when outdoor warning sirens are activated. It is NOT intended to remove a jurisdiction's obligation or responsibility to alert or warn its community if a situation falls outside of the parameters of this policy.

Outdoor warning sirens represent only one part of a broader public emergency notification system. Other components include: NOAA All-Hazards Weather Radio, law enforcement, emergency management, text notification networks, private sector meteorologists and the media. Sirens are used to alert citizens of an imminent hazard, and prompt them to find shelter and seek further information.

Background

Research shows that confusion hinders public response during emergencies. Using common guidelines for outdoor warning sirens throughout the various jurisdictions of the United States will minimize confusion in emergency situations. Establishing a standard will also enable communities to partner in an area-wide public education campaign regarding sirens and the overall public emergency notification system.

These guidelines are based on communication technology and systems available in the United States, and also on the current science of severe weather warnings.

Best Practices

Siren Testing

- Warning Siren testing shall be done on a regular schedule (at least monthly) using the standard "ALERT" sound.
    - Some states legally mandate the testing day.
- Testing of Sirens should *not* be done if thunderstorms are in the area and should *not* be rescheduled.

1 | Page

Source: "Best Practices for Outdoor Warning Sirens." *Developed by the Workgroup for Warning Systems*, skywatch.org, n.d. Web.12 Sep. 2011< http://skywatch.org/ows.pdf>.

Siren Alerting

- ONLY the "ALERT" (steady) Sound is to be used, lasting for at least 3 minutes.
  - If sirens have more than one tone, local officials should pre-determine the tone that is most discernible and use that tone for all alerts.
- Only sirens in the path of the storm (within the National Weather Service warning polygon) should be activated, if the siren system is capable.
- An "all clear" tone WILL NOT be used.

Siren Activation

- When the National Weather Service issues or re-issues a Tornado Warning.
  - Do NOT sound for a warning in a neighboring county.

    If a tornado is confirmed in the area, continue to sound the sirens at regular intervals. Use local guidance and siren manufacturer's suggestions to avoid damaging the equipment, with the goal of sounding as much as possible while the tornado is still on the ground in the area.

  ...or...

- Without a warning, when reliable reports from TRAINED weather spotters indicate a tornado is occurring or imminent in the area.
  - Immediately notify the National Weather Service and local media!
  - Preferably use NWSChat to let all know why sirens were activated.

  ...or...

- During a Severe Thunderstorm Warning ONLY IF:
  - Destructive winds of 75mph or greater have been <u>confirmed</u>.

    Do NOT sound just because a Severe Thunderstorm Warning has been issued while a Tornado Watch is in progress.

Addendum

This project began as concerns over siren usage mounted in the meteorological community at large, due to extremely varying policies from county to county or even city to city. A call was made to the Weather & Society * Integrated Studies (WAS*IS) discussion list for volunteers to form a best practices committee, and it moved forward over the summer of 2011 with representatives from emergency management, the National Weather Service, and private sector / broadcast meteorologists. A draft policy was disseminated through wider channels for review, and input was received from various professions from all across the country. Review comments were taken into consideration as the final version was developed. Some areas that were removed or we felt needed clarification are included below.

One of the primary goals is to get communities to use the "polygon" outline in the warning as the determination for which sirens to sound and which can remain silent. We understand that not all locations have that ability, but some do and simply don't utilize that feature because "it's the way we've always done it." With the number of warnings being issued on a steady rise the past decade, reducing the coverage of siren alerts to areas truly threatened by the storm is crucial.

Other Siren Uses

We realize that some communities have other uses for siren systems. This document was not intended to deal with those situations, such as alerts around nuclear plants, dam break flood sirens, and the like. Those are best handled locally, where the emergency manager can educate the community regarding these alternate uses.

Some communities use a different type of tone (usually an alternating high / low combination) for flash flood warnings in their area. Since that threat is not a widespread national issue, we did not want to try to incorporate it into these best practices. Do not let the absence here interfere with your alerting and educating regarding floods.

We originally considered using very large hail (2" or more) as a trigger point, but again that is very location specific. In many parts of the country, those hail sizes are quite isolated so by the time the report comes in and the decision is made to activate the siren, the threat has passed. In areas where hail swaths are more common, keeping that criteria may be of use.

Bad Practices

By and large most communities have fairly similar criteria for utilizing the siren system. However many "bad practices" exist, and the intent of this document was just as much geared towards removing those as it was towards adding anything new.

An "all-clear" tone does nothing but add confusion to the public. Outdoor warning sirens are simply notification to citizens that something hazardous could be approaching, so they need to go to a place of safety and find out more information. Using the sirens to signify that there is no threat diminishes the value of the siren system. There are many other methods for the public to find out that the threat has passed, so there is no reason for sounding an all-clear.

Some communities sound their sirens for warnings in neighboring counties just as an added level of protection. However that adds no value and only causes confusion when people tune in for more information and find they are not really under any weather warning. Other jurisdictions alert for any severe thunderstorm warning issued during a tornado watch, because “xx years ago a tornado touched down with no warning.” While that may be true, a very large majority of severe thunderstorm warnings do not contain tornadoes, and lowering the criteria means the sirens are sounded much more often than needed which desensitizes people to the siren tone. Many post-event surveys of the public conclude that they feel the sirens are used too frequently in those cases.

We understand that these are “your” sirens and you can activate them at any time you deem there is a threat to the public. However when activation is done outside of a NWS warning, and the reason for the alert is not communicated to the public, different messages will be delivered. A local spotter may see a funnel cloud approaching town, but if it’s not evident on radar and there is no warning, it is likely that the television stations will simply tell viewers that they don’t know why the sirens are sounding. It’s a true statement unless they are informed otherwise, and it leads to the public not responding. Using NWSChat lets you to notify the NWS, media outlets and neighboring jurisdictions immediately, which allows one unified message to be disseminated and provides the confirmation that the public needs to hear in order to respond.

Best Practices

In the NWS Service Assessment of the 2011 Joplin, Missouri tornado, many people commented that the first siren activation did not prompt them to shelter, but the second alert caught their attention and made them more likely to react. We suggest that if a tornado is actively causing damage in the community or approaching based on spotter reports, then the sirens be activated as often as possible until the threat passes. Older mechanical sirens have limitations that newer digital systems do not, so use the manufacturer’s recommendations regarding the amount of time your system is activated, with the goal being simply as much as possible during an active threat.

A low end tornado can only have winds of 50-60mph causing minor damage with minimal life threat. We felt that it didn’t make sense to sound a siren for that event, yet not for extremely damaging straightline winds. Therefore we deemed receiving reports of confirmed 75mph winds and/or extreme damage from downburst winds as activation criteria. We understand that spotter estimated winds are usually notably higher than actual wind speeds, so the concentration should be more on the damage reported versus actual wind speed numbers.

Feel free to contact us for any additional clarifications, or with suggestions for future revisions.

Tornado Awareness

Participant Guide

Appendix D: Changes to Storm Prediction Center (SPC) for Convective Outlooks

Version 1.0

FEMA

This page is intentionally left blank.

Appendix D: Changes to Storm Prediction Center (SPC) Convective Outlooks

Changes to Storm Prediction Center (SPC) Convective Outlooks

Background

The Storm Prediction Center (SPC) issues regional forecasts for thunderstorms and their expected severity. These forecasts are maintained and updated several times each day with projections as far as eight days in the future. Called "convective outlooks," these forecasts are commonly used for mid to long-term severe thunderstorm hazards planning.

Prior to October 22, 2014, the SPC utilized a risk mapping system that relied upon **four severe weather risk categories**:

0. General Thunderstorms (TSTM)
1. See Text
2. Slight (SLGT)
3. Moderate (MDT)
4. High (HIGH)

Current System

In October 2014, the SPC implemented a new system with **five severe weather risk categories**:

0. General Thunderstorms (TSTM)
1. Marginal (MRGL)
2. Slight (SLGT)
3. Enhanced Slight (ENH)
4. Moderate (MDT)
5. High (HIGH).

Improvements

The current convective outlook system improves upon the previous format in several ways, including the following:

1. Severe weather threat can now be visualized **in greater detail** with **risk more easily conveyed** in categories.

2. Geographic Information Systems (GIS) were not previously able to integrate the "See Text" category as it did not have any spatial characteristics. **"See Text" regions have been replaced with the "Marginal" area.**

3. The **five-tiered category system and number scale for severe weather risk** is now similar in appearance to other numbered hazardous weather scales (e.g., Saffir-Simpson Hurricane Wind Scale).

Additional Information and Resources

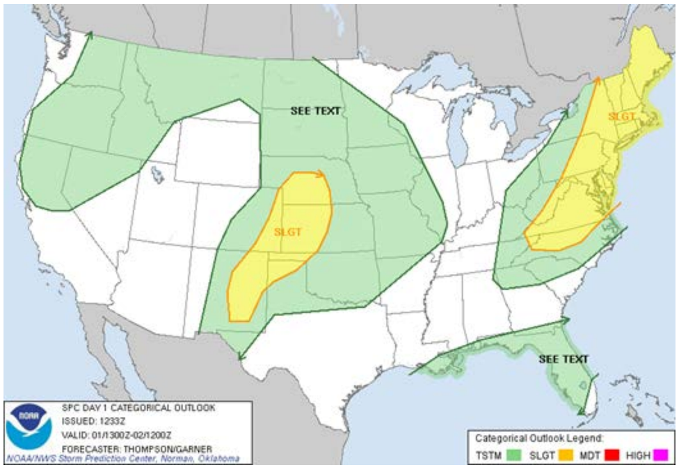
On the back of this page, you will find a more detailed comparison between the previous and current convective outlook system alongside a description of the criteria for forecasted threat categories.

For the current convective outlook, please visit the SPC website: http://www.spc.noaa.gov/

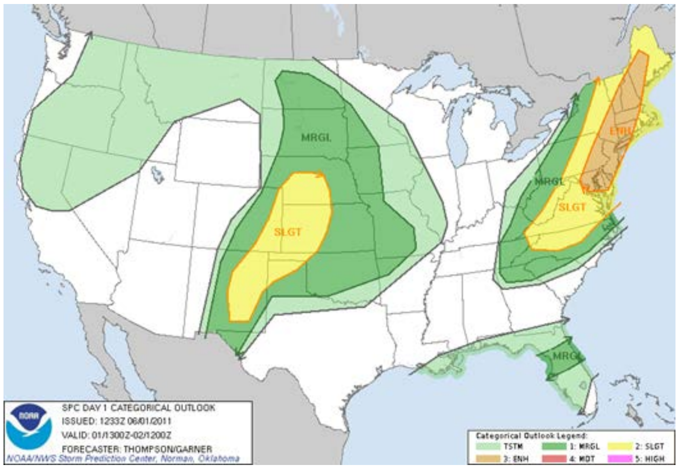
For more detailed information regarding the SPC's new Convective Outlook system, please refer to these websites: http://www.spc.noaa.gov/exper/dy1-3example/ and http://www.spc.noaa.gov/faq

For a video overview of this product, please download the video file here:
http://www.spc.noaa.gov/misc/2014OutlookChanges.mp4

Visual Comparison to Prior System



(Source: SPC, 2014)



(Source: SPC, 2014)

Note the changes between the prior convective outlook system (left) and the current system (right). The most notable difference between the two systems is the added spatial detail. This detail is intended to allow users to better understand the level of severe thunderstorm risk in their region. The SPC's new system will also allow for the current system to be better integrated into GIS as the "See Text" regions have now been replaced with "Marginal" regions with spatial attributes. The probability maps (not shown) continue to accompany these maps and are available from the SPC website.

Visually Understanding the Threat Category

Day 1 Outlook Probability	TORN	WIND	HAIL
2%	MRGL	Not Used	Not Used
5%	SLGT	MRGL	MRGL
10%	ENH	Not Used	Not Used
10% with Significant Severe	ENH	Not Used	Not Used
15%	ENH	SLGT	SLGT
15% with Significant Severe	MDT	SLGT	SLGT
30%	MDT	ENH	ENH
30% with Significant Severe	HIGH	ENH	ENH
45%	HIGH	ENH	ENH
45% with Significant Severe	HIGH	MDT	MDT
60%	HIGH	MDT	MDT
60% with Significant Severe	HIGH	HIGH	MDT

The table on the left shows the probabilities assigned to each risk category for the Day 1 Convective Outlook. Similar tables for Day 2 and 3 (not shown) are available from the SPC website.

Each probability on the graph represents "the probability of one or more events occurring within 25 miles of any point during the outlook period" (Source: SPC, 2014).

The "significant severe" parameter is assigned to a tornado, damaging wind, or hail event if the phenomena reaches or exceeds a certain threshold.

-A significant severe tornado is rated at EF-2 or stronger.

-A significant severe damaging wind is at least 74 mph.

-A significant severe hailstone is at least 2" in diameter.

Severe Weather Threat Categories:
0 – General Non-Severe Thunderstorms (TSTM)
1 – Marginal (MRGL)
2 – Slight (SLG)
3 – Enhanced (ENH)
4 – Moderate (MDT)
5 – High (HIGH)

(Source: SPC, 2014)