AWR-326 Tornado Awareness

Participant Guide
October, 2019
Version 2.0

FEMA

NATIONAL DISASTER PREPAREDNESS TRAINING CENTER

Copyright Information

Tornado Awareness

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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 http://www.firstrespondertraining.gov.

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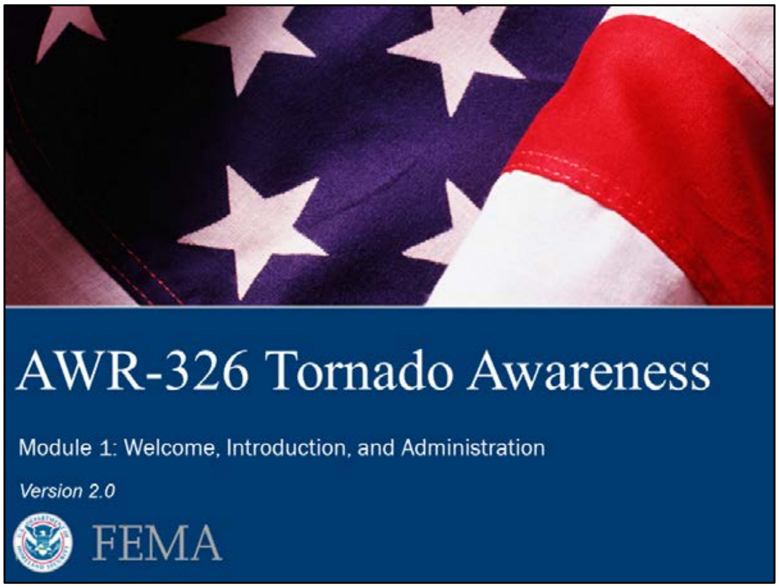
Module 1: Welcome, Introduction and Administration – Administration Page



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.

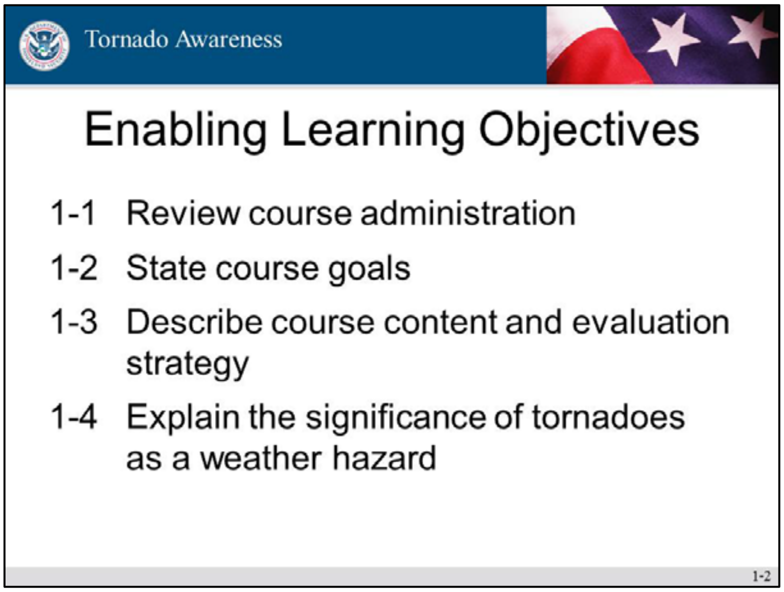
Next, the instructors will:

- 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 https://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

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

Hint: As part of the course preparation, the instructors should conduct research into any historical tornadoes or tornado-related issues in the area where the course is being delivered. This will ensure that participants are actively engaged if and when local issues are raised. A good place to start this research is the local National Weather Service (NWS) website.

Hint: If any participants ask about climate change, the instructors can suggest that climate change is an area of ongoing research. While there is strong evidence that humans are contributing to a changing climate, not much can be concluded about its impacts on tornadoes because of their small scale and isolated nature. The instructors should not make any conclusive statements that climate change is increasing the frequency or severity of tornadoes because that is still largely unknown.

Hint - Special Instructor Requirement: As soon as possible after the course delivery is scheduled, the instructors should:

- Identify the NWS Weather Forecast Office that is responsible for the County Warning Area (CWA) in which the course will be delivered (http://www.weather.gov);
- Inform the office about the course delivery; and
- Invite the office's Meteorologist-in-Charge or Warning Coordination Meteorologist to attend the course.

These actions are intended to ensure open lines of communication between the NDPTC and the NWS. By law, the local NWS office is the official source of weather forecasts and warnings. As such, local emergency managers and first responders must refer to the NWS (not NDPTC or FEMA) for official weather products and alerts. Furthermore, as there may be special tornado-related hazards and policies that are unique to the local area, it is important to have the local NWS representative attend as he/she can contribute to the course discussions.

Likewise, the instructors should not voice any opinions about when and where a severe weather product should be issued. This is particularly important when discussing any ongoing severe weather during the course. Remember, the NWS is the only official entity that can make such decisions.

Hint - Special Instructor Requirement: The instructors who do not have a college degree in meteorology should study the following two books:

- "Severe & Hazardous Weather: An Introduction to High Impact Meteorology" by Rauber, R. M., J. E. Walsh, and D. J. Charlevoix (2008); and
- "Tornado Alley: Monster Storms of the Great Plains" by H.B. Bluestein (2006).

Tornado Awareness

Icon Map

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

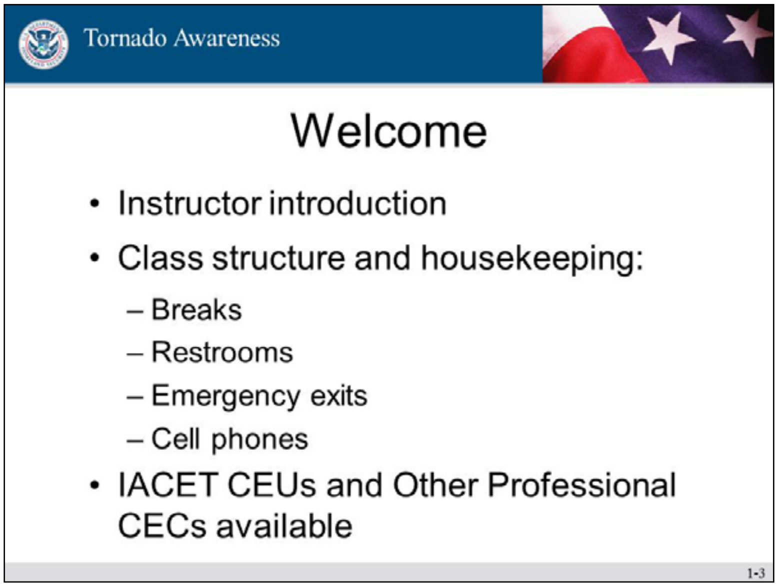
Example: Used when there is a descriptive illustration to show or explain.

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

Hint: Used to cover administrative items or instructional tips that aid in the flow of the instruction.

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

Hint: This section addresses Enabling Learning Objective (ELO) 1-1.

Hint: The lead instructor will:

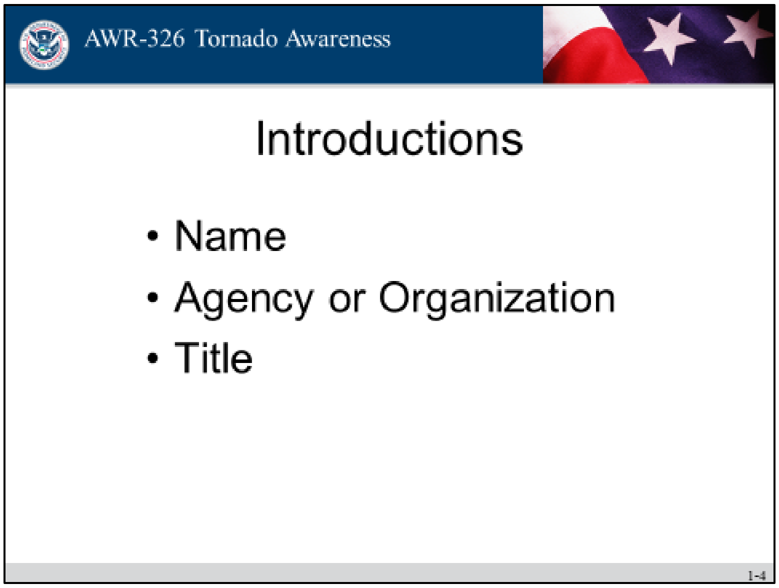
- Begin the class by welcoming participants and introducing the instructional team;
- Review overall course administration (e.g., course structure, instruction duration, breaks, etc.);
- Review classroom protocols (e.g., turn off cellular phones and other electronic devices with alarms, procedures for asking questions, courtesy during discussions, etc.);
- Review available IACET CEUs and other professional CECs that are available for this course; and
- Check with the host Point of Contact (POC) before the course begins to determine if any additional announcements are necessary.

The lead instructor will begin by welcoming participants and introducing the instructional team. The instructor will then review classroom protocols and standard classroom policies, such as breaks, restroom facilities, emergency exits, cell phone and Internet use.

Participant Notes:

Key Point: The National Disaster Preparedness Training Center (NDPTC) mission is as follows: Uniquely positioned geographically and culturally, the 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. It incorporates urban planning and environmental management, emphasizing community preparedness and addressing the needs of vulnerable at-risk populations.

Participant Notes:



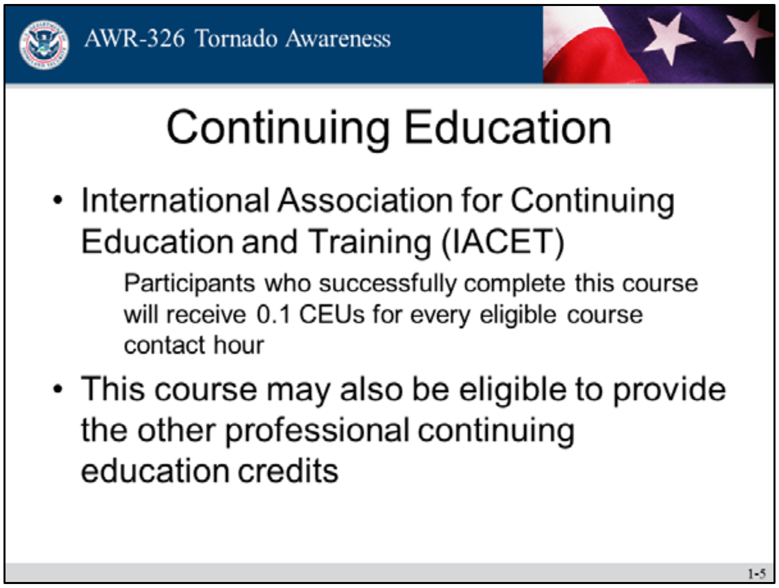
Slide 1-4. Introductions

The instructor will lead a round of participant self-introductions. Participants are asked to provide information designed to help the instructor learn names and understand the participants’ backgrounds and motivations, including:

- Name;
- Agency or Organization;
- Title

Participants are encouraged to take an active role in the class discussions and group activities to demonstrate comprehension. Participant Guides are provided for participants to follow along with the course and to take any notes as needed.

Participant Notes:



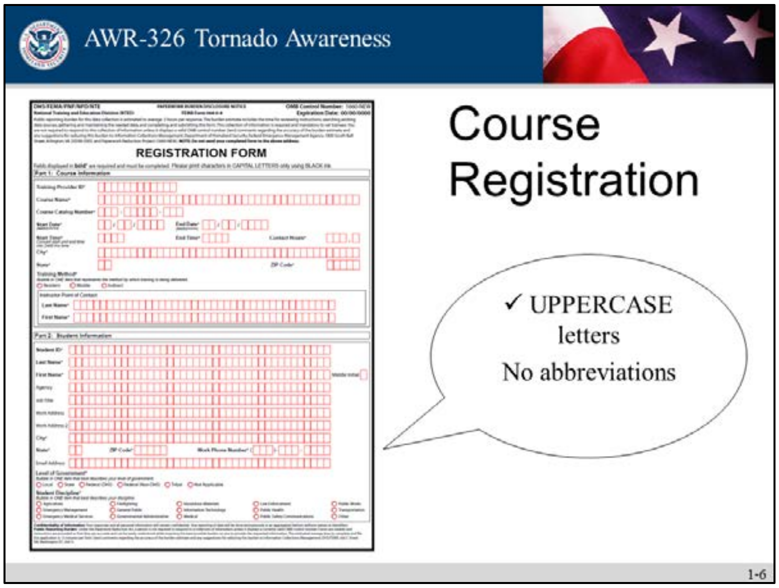
Slide 1-5. Continuing Education

This course may also be eligible to provide the following professional continuing education credits:

1. International Association of Emergency Managers (IAEM) - Training Hours
2. Association of State Floodplain Managers (ASFPM) - Continuing Education Credits (CEC)
3. American Planning Association (APA) - Certification Maintenance (CM)
4. American Institute of Architects (AIA) - Continuing Education System (CES) Learning Units (LU)

Eligibility to receive credits from the designated professional organizations is dependent on the specific membership and/or qualification requirements as enforced by each individual organization. Submission processes enforced by each organization should be followed to successfully receive credits. For more information, visit the NDPTC website or contact NDPTC at 808-725-5220 / ndptc-training@lists. hawaii.edu.

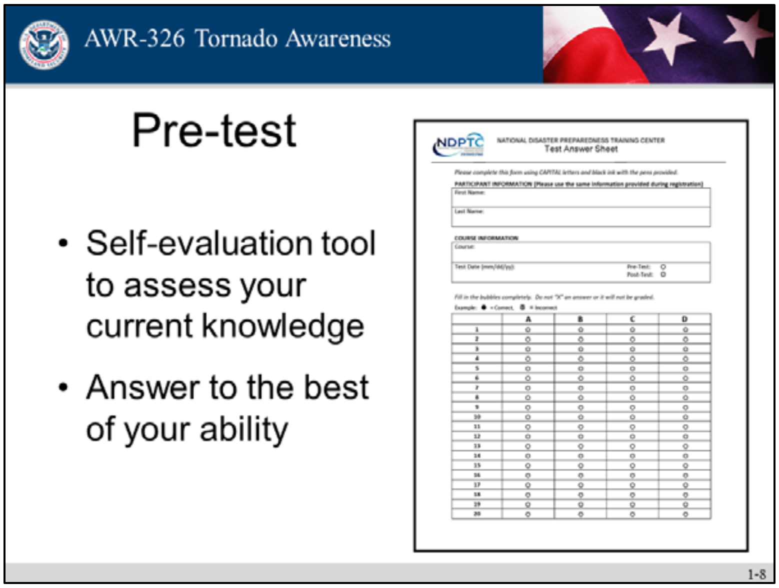
Participant Notes:



Slide 1-6. 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 1-8. Pre-test

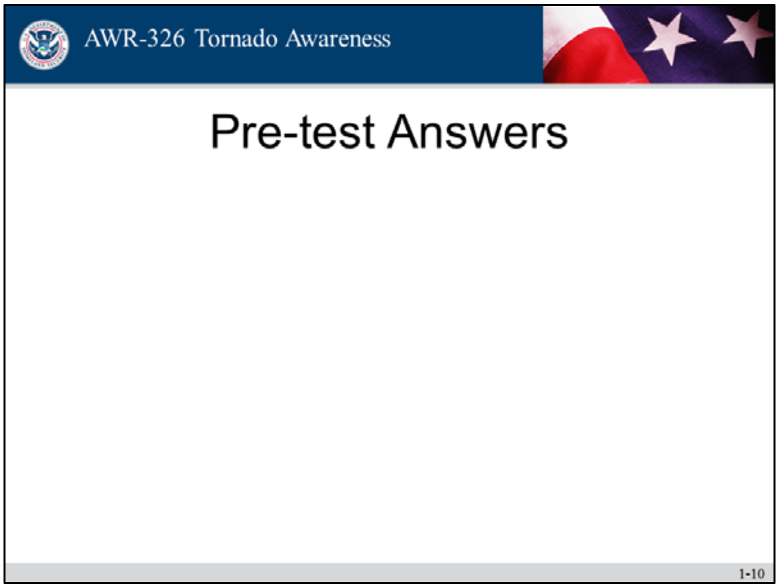
Participants should note the following:

- 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.

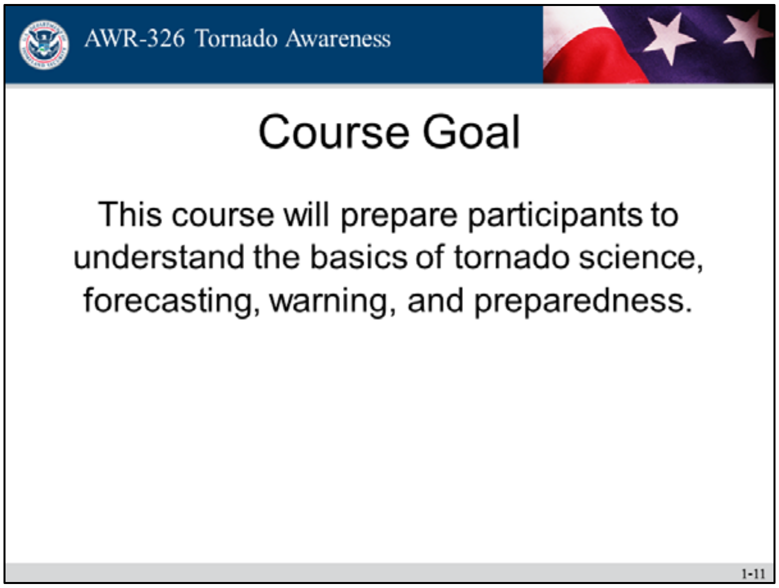
Participant Notes:



Slide 1-10. 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:



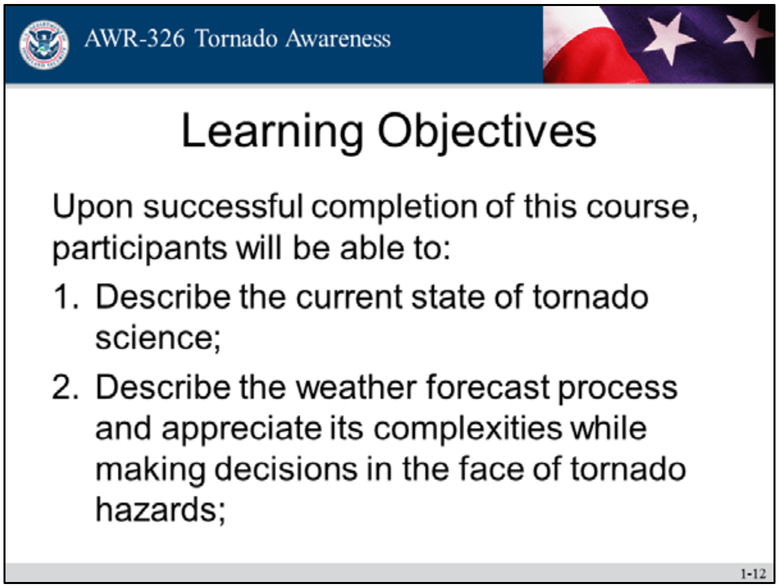
Slide 1-11. Course Goal

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

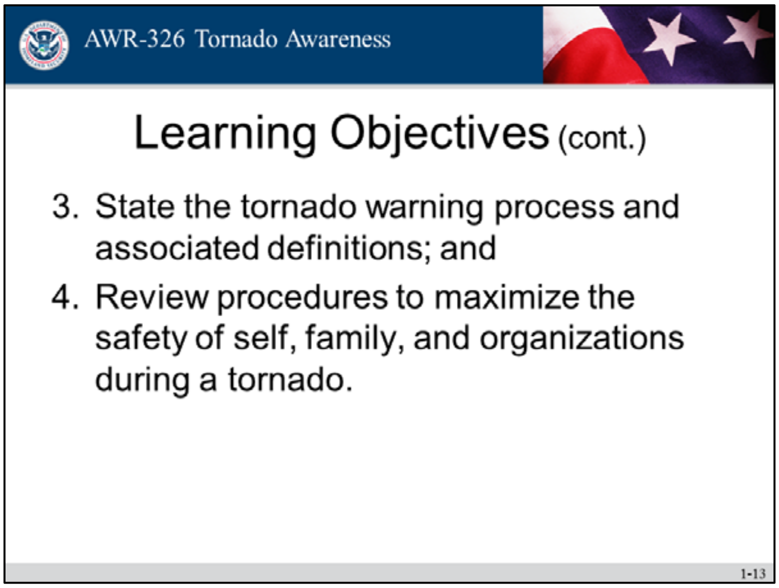
This course does not require any previous subject matter knowledge, so participants should not be concerned about having a background in the topics noted above. All of the knowledge required to answer intra-module and end-of-course assessment questions can be found in the course materials presented in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



Slide 1-12. Learning Objectives



Slide 1-13. Learning Objectives (continued)

Upon successful completion of this course, participants will be able to:

1. describe the current state of tornado science;
2. describe the weather forecast process and appreciate its complexities while making decisions in the face of tornado hazards;
3. state the tornado warning process and associated definitions; and
4. review procedures to maximize the safety of self, family, and organizations during a tornado.

Participant Notes:

Slide 1-14 Alignment with FEMA Strategic Plan 2018-2022

As an instructor, you train participants on the performance measures to meet the Goals and Objectives in FEMA's Strategic Plan. Each NDPTC training course aligns with one or more of the Strategic Goals and Objectives.

During each training, participants should be briefed on the Strategic Goals so they understand the significance of what they are learning in the greater of national preparedness. This involves listing each of the three Strategic Goals and giving a short description of each one. They will also need to understand how their course specifically aligns with individual Objectives within those Goals.

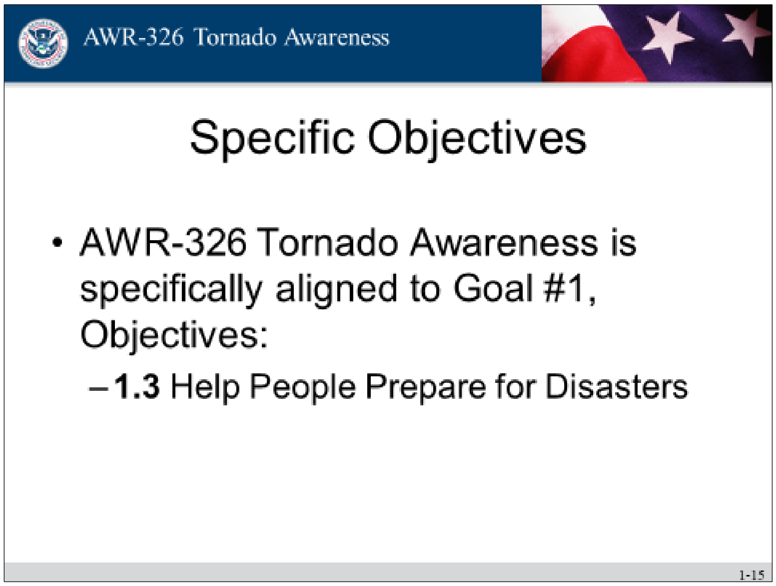
See appendix for more in depth discussion on strategic goals and NDPTC's role.

Talking points: As a Training Partner of FEMA's National Training and Education Division, NDPTC must work to support the achievement of FEMA's Strategic Goals. The way we support these goals is by delivering trainings which align with one or more of the objectives to enhance a performance measure.
The three Strategic Goals are:
1. Build a Culture of Preparedness
Every segment of our society, from individual to government, industry to philanthropy, must be encouraged and empowered with the information it needs to prepare for the inevitable impacts of future disasters.
2. Ready the Nation for Catastrophic Disasters
FEMA will work with its partners across all levels of government to strengthen partnerships and access new sources of scalable capabilities to quickly meet the needs of overwhelming incidents.

Participant Notes:

3. Reduce the Complexity of FEMA
FEMA must continue to be responsible stewards of the resources we are entrusted to administer. We must also do everything that we can to leverage data to drive decision-making, and reduce the administrative and bureaucratic burdens that impede impacted individuals and communities from quickly receiving the assistance they need.

Participant Notes:

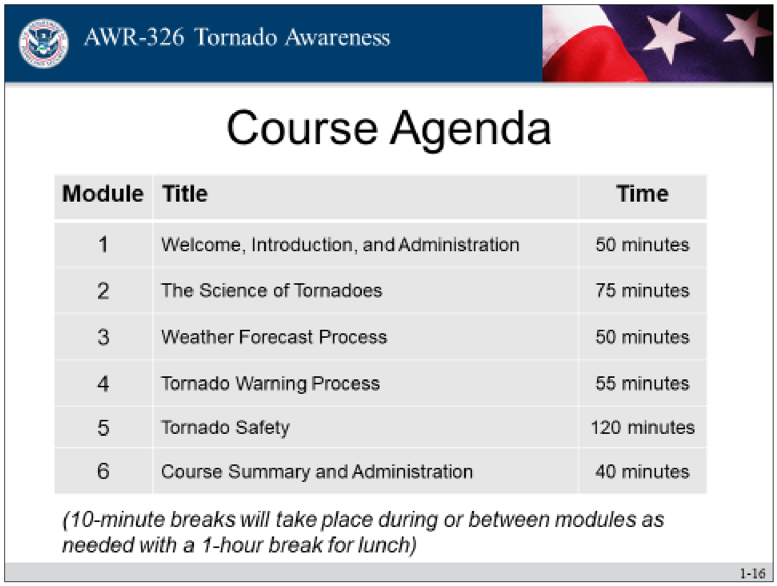


Slide 1-15 Specific Objectives

Additionally, each Goal has Objectives to reach that goal, and our courses are aligned with various Objectives. For this course, the Goals and Objectives we are aligning with today are:

- 1.3 Help people prepare for disasters
    - Increase the percentage of people with savings set aside for an emergency.
    - Deliver training to community-based and non-profit organizations to help them continue service delivery following disasters.
    - Increase the percentage of people who have taken preparedness actions.

Participant Notes:

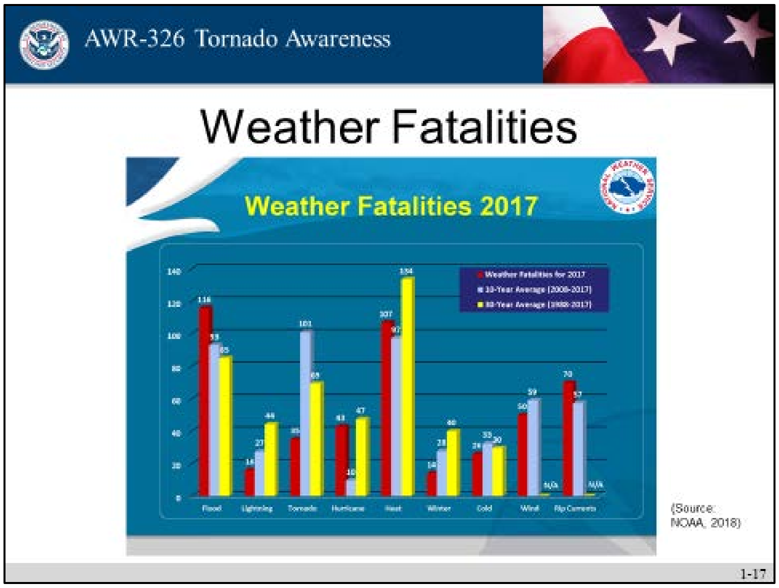


Module	Title	Time
1	Welcome, Introduction, and Administration	50 minutes
2	The Science of Tornadoes	75 minutes
3	Weather Forecast Process	50 minutes
4	Tornado Warning Process	55 minutes
5	Tornado Safety	120 minutes
6	Course Summary and Administration	40 minutes

Slide 1-16. 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:

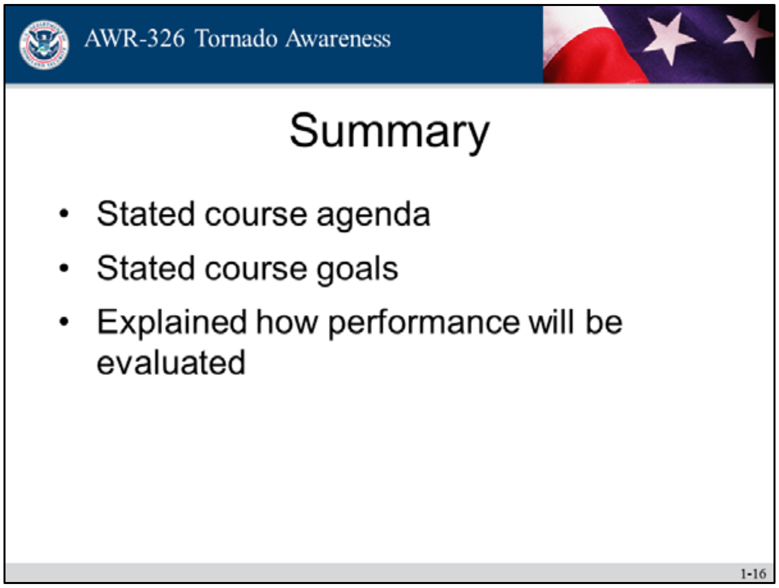


Slide 1-17. Weather Fatalities

The weather events of 2018 were damaging to the United States. According to a review of select statistics (as shown on this slide):

- Preliminary weather fatalities totaled 477.
- In the long-term 30-year average, heat caused the most deaths, followed by flood, and tornadoes.
- In the last 10 years, tornadoes top the list

Participant Notes:



Slide 1-18. 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.

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Tornado Awareness

Module 2: Science of Tornadoes

Version 2.0

FEMA

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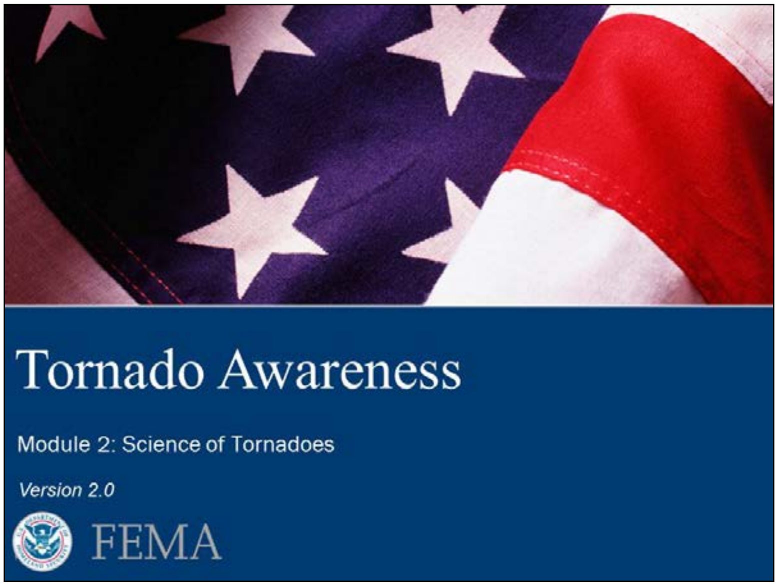
Module 2: Science of Tornadoes – Administration Page



Slide 2-1. Science of Tornadoes

Duration

75 minutes

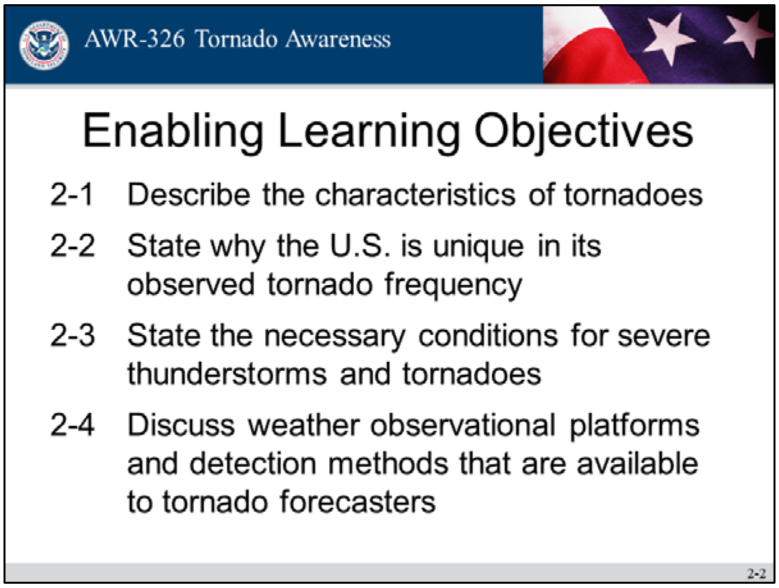
Scope Statement

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 observational platforms and detection methods 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 https://ndptc.hawaii.edu/
    - Participant Handout

Instructor-to-Participant Ratio

2:40

Reference List

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Practical Exercise Statement

Not Applicable

Assessment Strategy

- Instructor observation of participant involvement in classroom discussion
- Instructor-led discussion to gauge participant grasp of the subject matter
- Instructor 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 Point: Used to convey essential learning concepts, discussions and introduction of supplemental material.

Hint: Used to cover administrative items or instructional tips that aid in the flow of the instruction.

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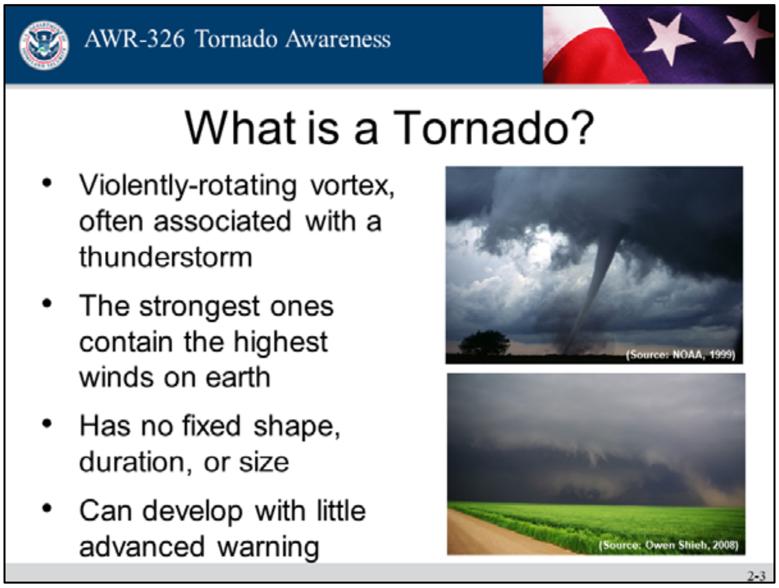

Slide 2-3. What is a Tornado?

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.

Some additional characteristics of tornadoes include:

- Tornadoes typically have winds from 75 to 200 mph – in rare cases 200+ mph
- Tornadoes can occur almost anywhere in the world (they've occurred in every U.S. state)
- Tornadoes generally last a few minutes but can last from seconds to, in some cases, hours, their typical diameter is about 0.4 km but their diameter can range from tens of feet to over a mile
- Typical path length is several km
- Tornadoes typically move NE
- 99% of tornadoes in the Northern Hemisphere rotate counterclockwise

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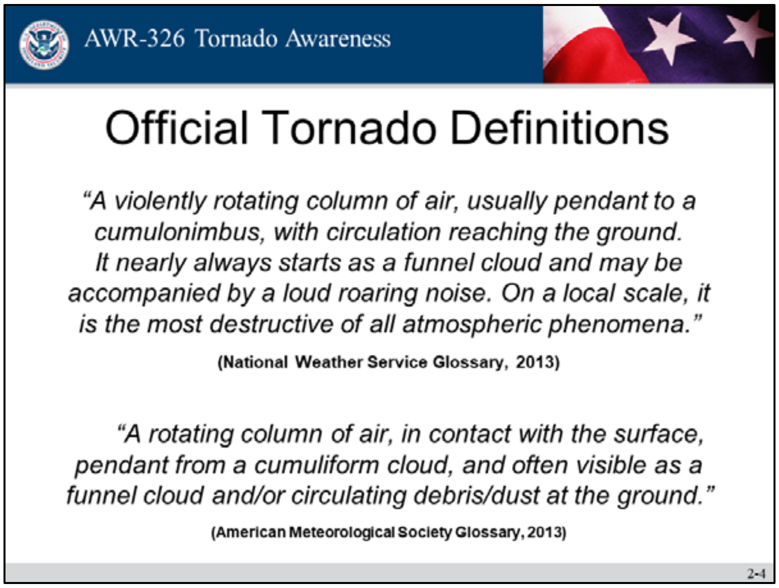

Slide 2-4. Official Tornado Definitions

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)

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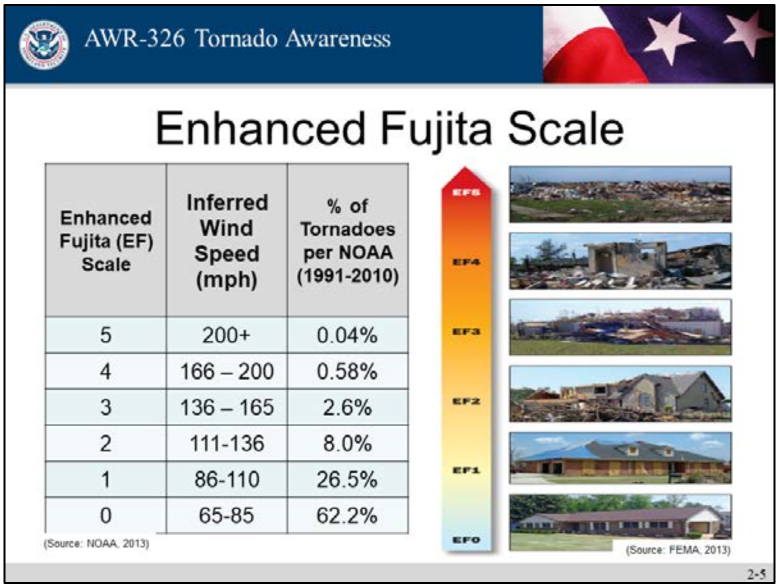

Slide 2-5. Enhanced Fujita Scale

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 scale measures wind speed, not size of tornado. Size of a tornado does not indicate its strength, as some small tornadoes can be very intense and some larger ones can be weak.

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 three-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 one percent 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.

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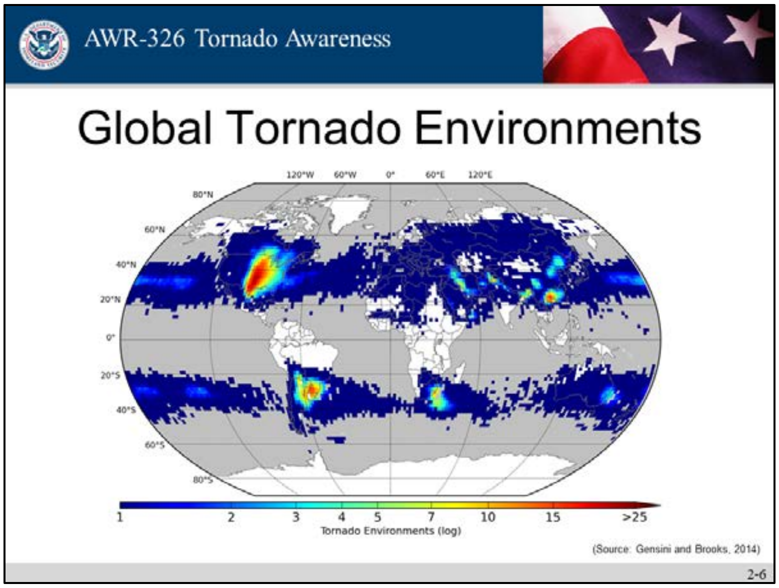

Slide 2-6. Global Tornado Environments

Tornadoes are more commonly found in the mid-latitudes, the belt where the jet stream typically resides year round. It is near the jet stream where the greatest temperature gradients occur, and these temperature gradients help to fuel the mid-latitude cyclones that, in turn, help to trigger tornadoes. 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. Higher density of tornadoes are those in the red and orange areas, where lowest density of tornadoes is in the blue areas. 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. The U.S. is unique in its observed tornado frequency due to the unique convergence of climatological, geographical and topographical factors that result in the high frequency of tornadoes across the center of the U.S., in what has become known as “Tornado Alley”.

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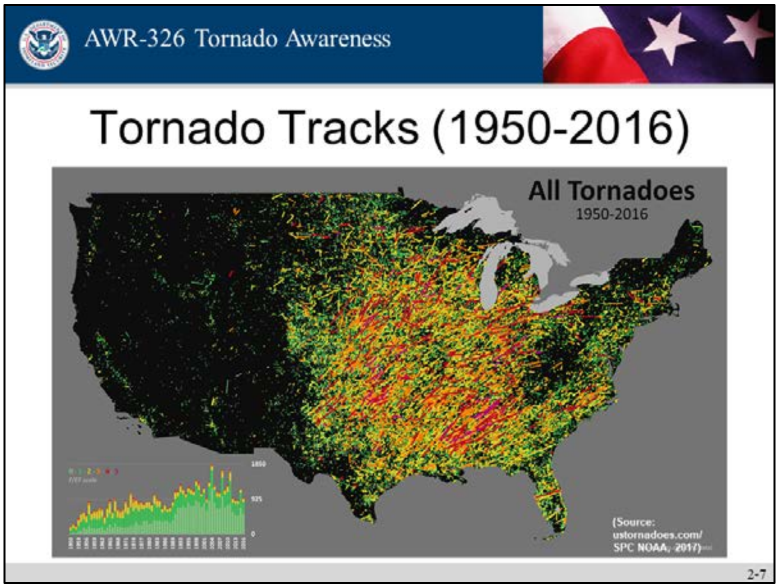

Slide 2-7. Tornado Tracks (1950 – 2016)

The scale to the bottom left shows the number of tornadoes by year from 1950 – 2016, and the color represents EF (from 0-5) scale of the tornadoes. 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. Most tornadoes moves with an eastward component of motion and the predominant motion is NE. 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. Tornadoes can also exhibit erratic motion because of a supercell's interaction with surrounding storms or dynamics within the supercell itself. This could cause a tornado to do strange things like change direction in the middle of its track, backtrack, etc. Supercells are explained in more detail later in this module.

Approximately 1200 tornadoes are either observed or estimated to occur in the U.S. annually, which represents 75% of the global total.

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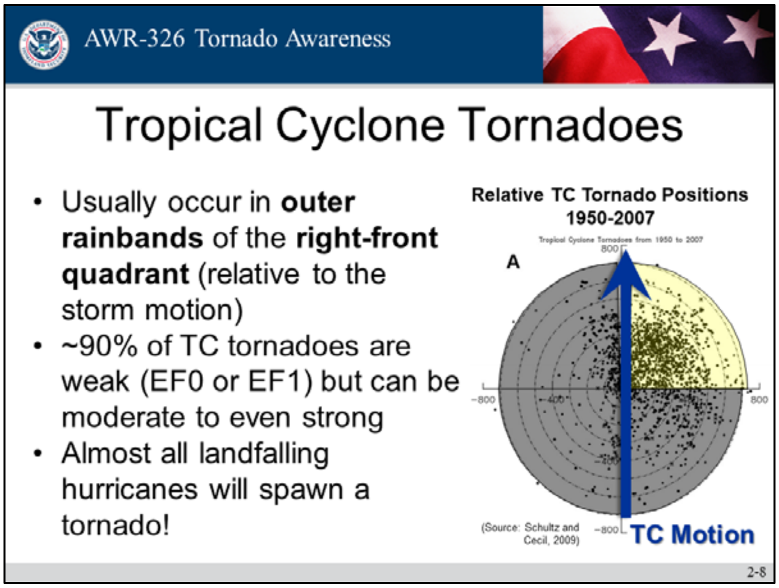

Slide 2-8. Tropical Cyclone Tornadoes

Nearly all tropical cyclones making landfall in the United States spawn at least one tornado. Tropical cyclone-spawned tornadoes most often occur in thunderstorms embedded in rainbands well away from the storm center but they can also occur near the eyewall.

Tornadoes produced by tropical cyclones are usually weak and short-lived, but they still pose a significant threat. Hurricane Ivan in 2004 holds the United States record for the most tornadoes spawned by a tropical cyclone, producing 118 total tornadoes. On average, 14 tornadoes were spawned per United States tropical cyclone landfall between 1990 and 2009.

More information on tropical cyclones and tropical cyclone tornadoes can be found in NDPTC's AWR-343 Hurricane Awareness course.

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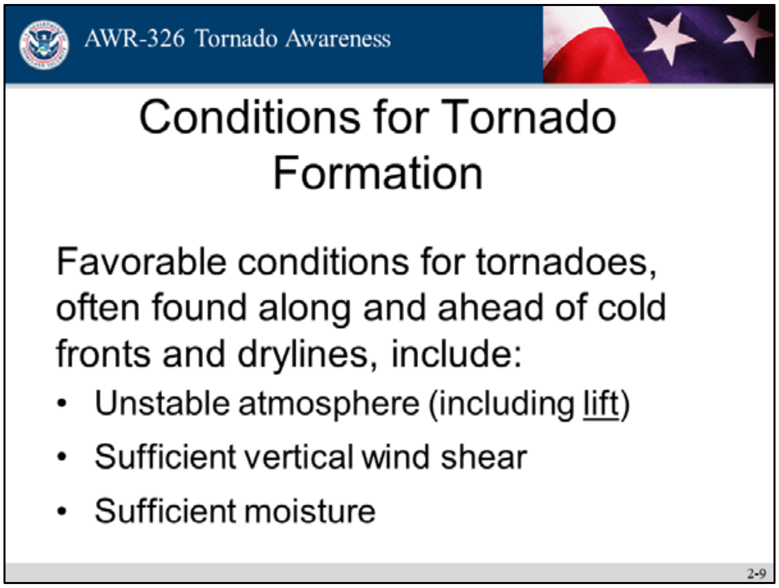

Slide 2-9. Conditions for Tornado Formation

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. The upward moving air in a thunderstorm is known as the updraft, while downward moving air is the downdraft. 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). Although these three conditions are necessary to create severe weather and for tornadic development, by themselves they are not the only conditions necessary.

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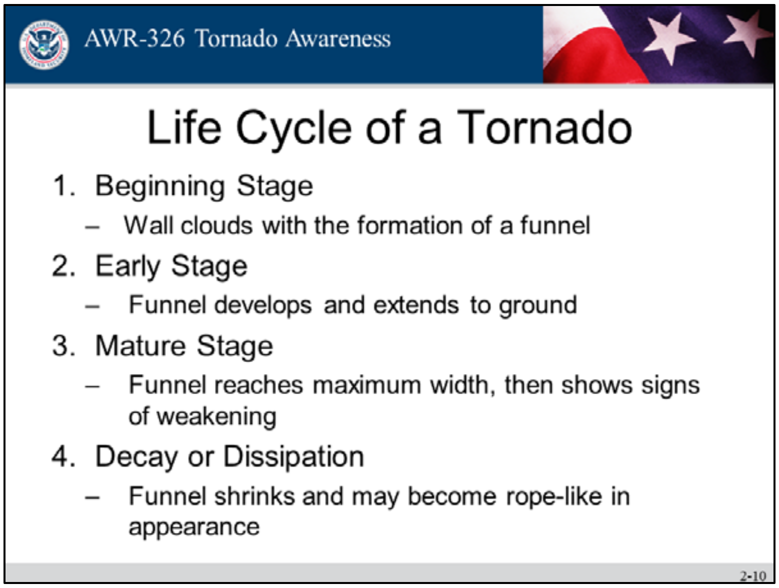

Slide 2-10. Life Cycle of a Tornado

The life cycle of a tornado typically consists of 4 stages:

1. Beginning Stage – During the beginning stage wall clouds form around the mesocyclone. The rear-flank downdraft (explained later) develops and moves towards the ground. A small funnel forms at the bottom of the wall cloud.
2. Early Stage – A funnel cloud continues to develop and follows the rear-flank downdraft to touch the ground. Once the funnel cloud touched the ground, a tornado is formed. Surrounding dirt and other light debris begin to rise up and tornado damage commences.
3. Mature Stage – The tornado reaches its maximum width and then begins to show signs of weakening. This is caused by relative cooling as the storm continues to move. The lack of warmer air begins to weaken the tornado.
4. Decay or Dissipation – The tornado shrinks and may begin to appear rope-like. The warm air has been cut off and the associated mesocyclone will also begin to dissipate. However, there could still be a hazardous weather threat if a new mesocyclone develops in the vicinity of the old one, restarting the life cycle of a tornado.

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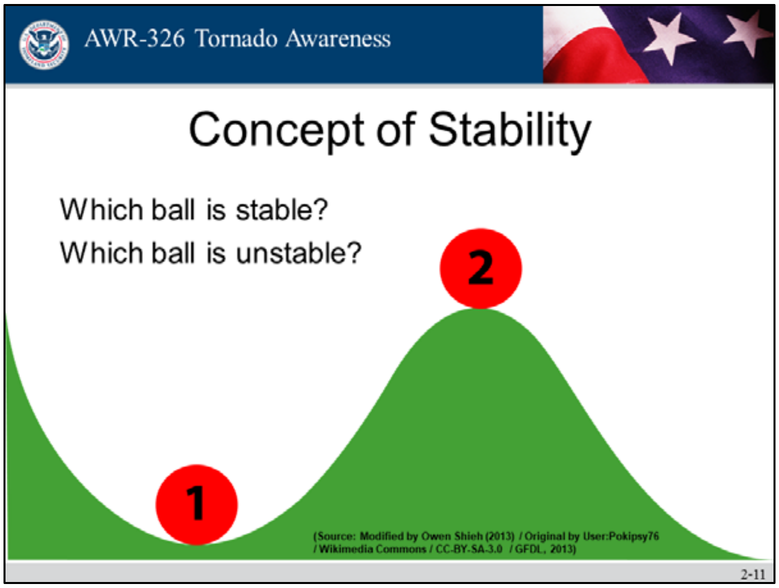

Slide 2-11. Concept of Stability

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.

The graphic on this slide illustrates the concept of stability using 2 balls. If Ball 1 is pushed or displaced, it will easily return to its original state. Therefore, Ball 1 is “stable”. If Ball 2 is pushed or displaced, it will not easily return to its original state. Therefore Ball 2 is “unstable”.

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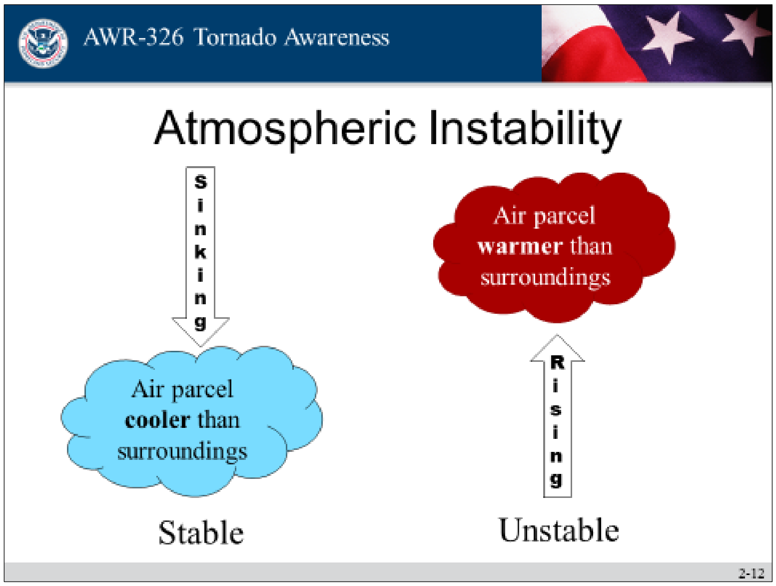

Slide 2-12. Atmospheric Instability

"Atmospheric instability" occurs when parcels of air near the ground warm due to convection and conduction and rise, while cooling.

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. In the column on the right, cooler air is present aloft. This creates a larger temperature difference than the stable column, between the warm air at the surface and cool air aloft. The warm, less dense air parcel rises rapidly in the relatively cooler air column. This rising motion contributes to the instability of the atmosphere.

An additional concept on atmospheric instability is called a "cap". A "cap" is a stable layer in the atmosphere that inhibits upward motion/ascent of air and hence the development of thunderstorms.

The presence of a "cap" does not preclude tornado formation but it could delay thunderstorm and tornado development until very late in the day.

With respect to weather:

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

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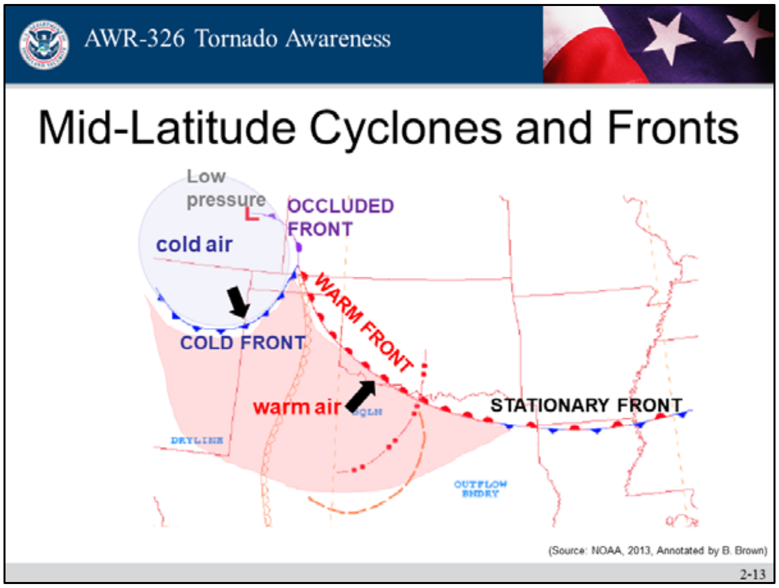

Slide 2-13. Mid-Latitude Cyclones and Fronts

As discussed in a previous slide, a key condition for tornado formation is lift. Lift is 'forced ascent' and occurs along boundaries that separate different air masses or air of different densities. In the case of a cold front, air that is colder and more dense forces warm and moist air to ascend over it, where it condenses to form clouds and precipitation. The 'lift' that occurs along a boundary can be enhanced by an unstable atmosphere. Cold fronts and warm fronts often generate this source of lift. Cold fronts have a greater slope and more associated severe weather than other types of fronts. 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. The "cool sector" of a mid-latitude cyclone is the directly trailing the cold front. The "warm sector" of a mid-latitude cyclone is the area directly trailing the warm front.

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.

Fronts, however, are not the only mechanism to trigger thunderstorms that generate severe weather and tornadoes. Other triggers include: convergence zones, topographic 'lift', surface heating, and boundaries from other thunderstorms (e.g., gust fronts). These triggering mechanisms in an environment of instability and substantial

Participant Notes:

environmental shear can spawn thunderstorms that produce severe weather and deadly tornadoes.

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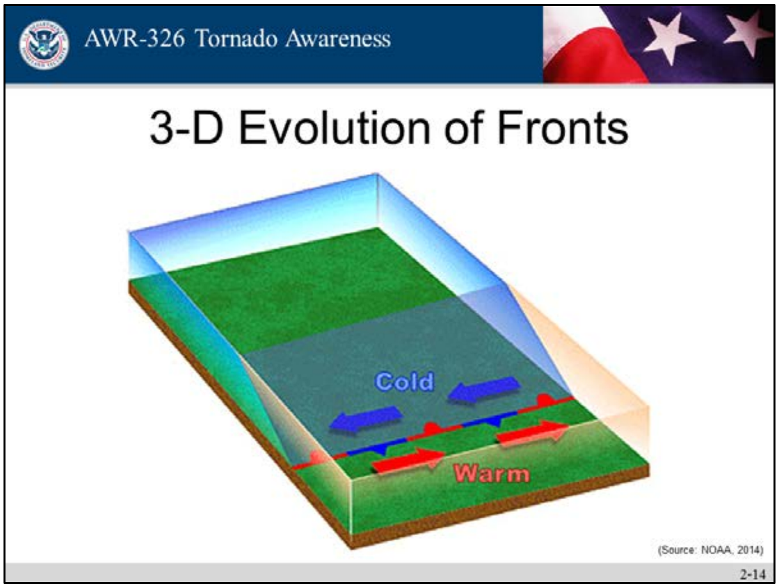

Slide 2-14. 3-D Evolution of Fronts

This image shows a three-dimensional perspective of the life cycle of a mid-latitude cyclone. As described in the previous slide, cold air to the north and warm air to the south collide along a frontal boundary. The front slopes back with height because warm air that is dense overrides the colder and denser 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.

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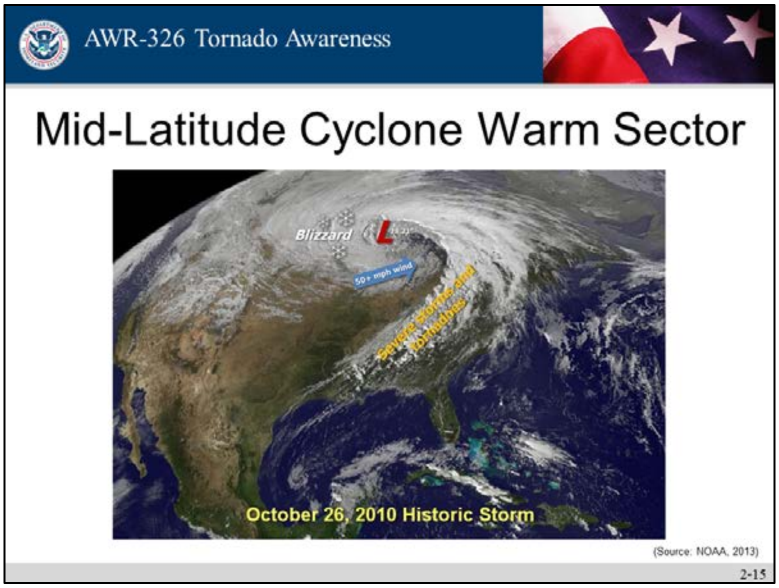

Slide 2-15. Mid-Latitude Cyclone Warm Sector

On October 26, 2010, an intense mid-latitude cyclone impacted the central United States. As stated previously, the “cool sector” of a mid-latitude cyclone is the directly trailing the cold front. The “warm sector” of a mid-latitude cyclone is the area directly trailing the warm front.

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.

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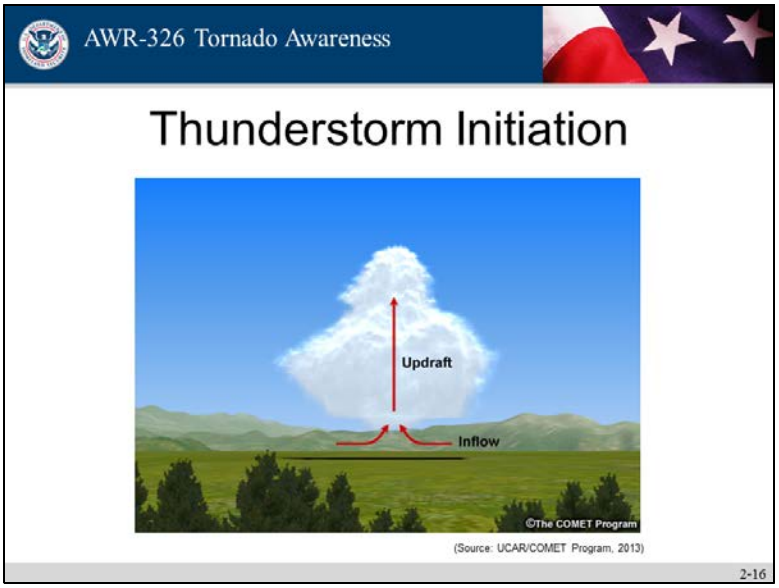

Slide 2-16. Thunderstorm Initiation

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.

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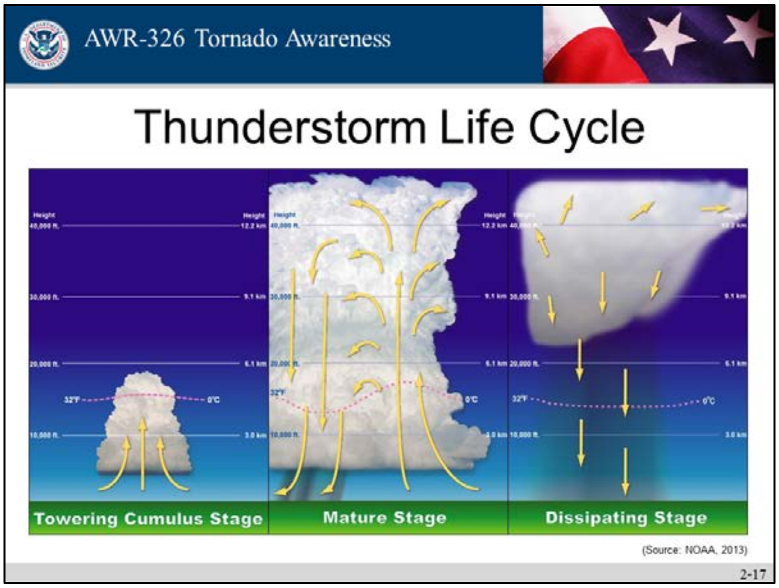

Slide 2-17. Thunderstorm Life Cycle

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 air mass thunderstorm typically goes through this cycle in 20- 30 minutes. However, sometimes the downdraft rushing out of a thunderstorm can act as a mini-cold front, producing extra ‘lift’ of warm, moist area, which in turn initiates new storms.

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.

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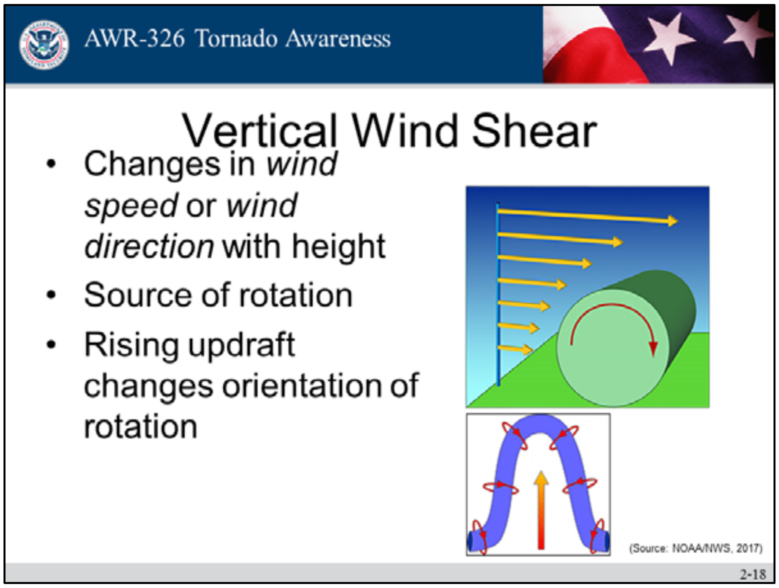

Slide 2-18. Vertical Wind Shear

A key element of supercell thunderstorm and tornado development is a rotating updraft. One way that a column of air can develop into a rotating updraft is through wind shear. This image 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.

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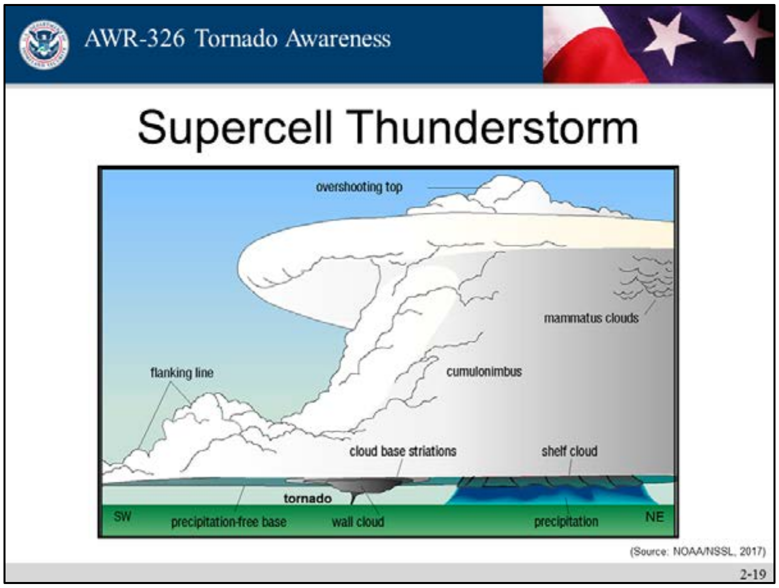

Slide 2-19. Supercell Thunderstorm

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. But it is important to note that the formation of a supercell does not ensure that a tornado would follow. According to NSSL (National Sever Storms Library of NOAA) only 20% of supercell storms 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.

Supercells are the most uncommon type of thunderstorm but are the most dangerous, they tend to produce all instances of very large hail and EF4-5 tornadoes, can last 1-4 hours due to environmental shear and dynamical processes in a storm, contains a sustained rotating updraft. It is estimated that 20% of all supercells produce tornadoes (NSSL).

The following list includes some, but not all tornado indicators or signs that a tornado may be approaching:

- A greenish-colored sky (possibly associated with the scattering of light by graupel or hail)
- Large hail of ¾" in diameter and in the absence of rain

Participant Notes:

- Mammatus clouds in conjunction with a sudden drop in barometric pressure, a rotating wall cloud or a low-hanging cloud in the sky perhaps even with a cloud of debris, increasing winds and a loud rumbling noise.

Participant Notes:

Slide 2-20. Supercell Thunderstorm Timelapse

This video is a timelapse 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.

Unofficial Video Transcript:

Supercell Thunderstorm Timelapse

Mike Oblinski Photography

June 3rd, 2013

A beautiful, rotating supercell near Booker, TX

(song 'impact lento' by Kevin Macleod)

Thank you for watching

Follow along with me during the summer monsoon in Arizona:

www.mikeolbinski.com

twitter.com/mikeolbinski

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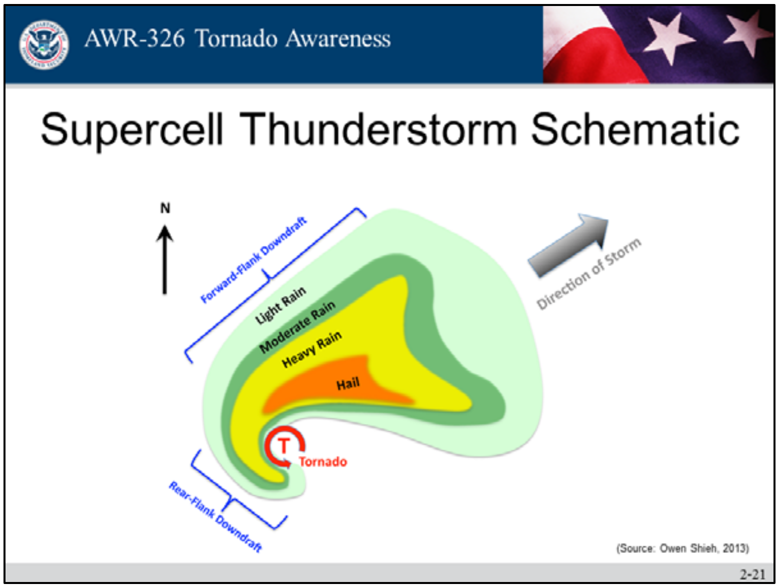

Slide 2-21. Supercell Thunderstorm Schematic

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.) A ‘wall cloud’, which is a low-hanging cloud base behind the rain shaft, often exhibits strong rotation that normally would be a precursor to a tornado. 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, dangerous tornadoes can also occur in storms that do not exhibit this structure. Furthermore, radar images can be lagged in time by several minutes, so it is best not to make assumptions about the behavior of a particular storm when a Tornado Warning is issued for your location. Remember to always listen to recommended actions from officials.

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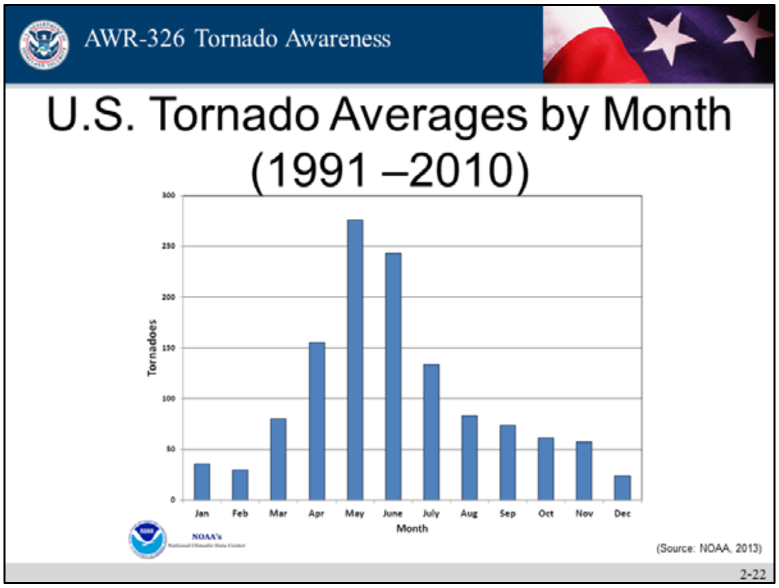


Slide 2-22. U.S. Tornado Averages by Month (1991 – 2010)

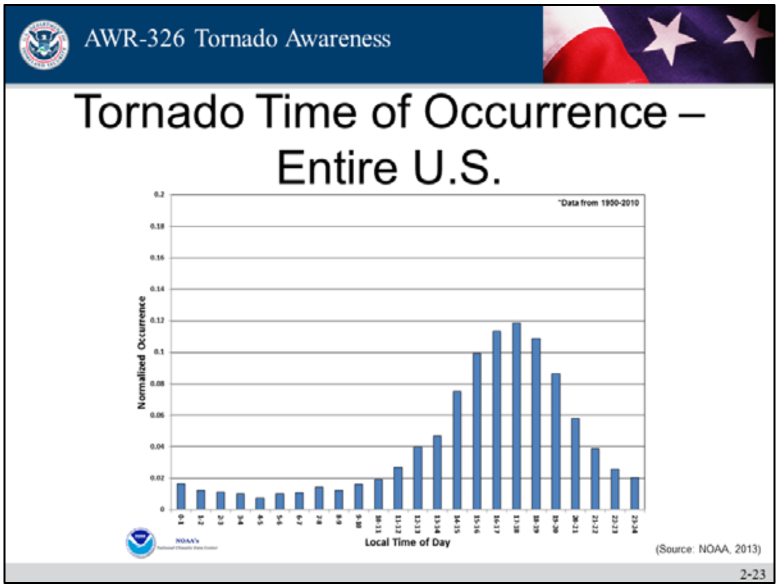
On average, the height of tornado occurrence in the country is in the spring season. However, there is no official "tornado season" because tornadoes can occur year-round with an annual peak frequency falling on different months depending on its geographic location:

- 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.
- Approximately 1200 tornadoes are either observed or estimated to occur in the U.S. annually, which represents 75% of the global total.
- In the South and the Southeast of the US, peak season for severe weather and tornados is February – March.

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: https://www.spc.noaa.gov/

Participant Notes:



Slide 2-23. 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.

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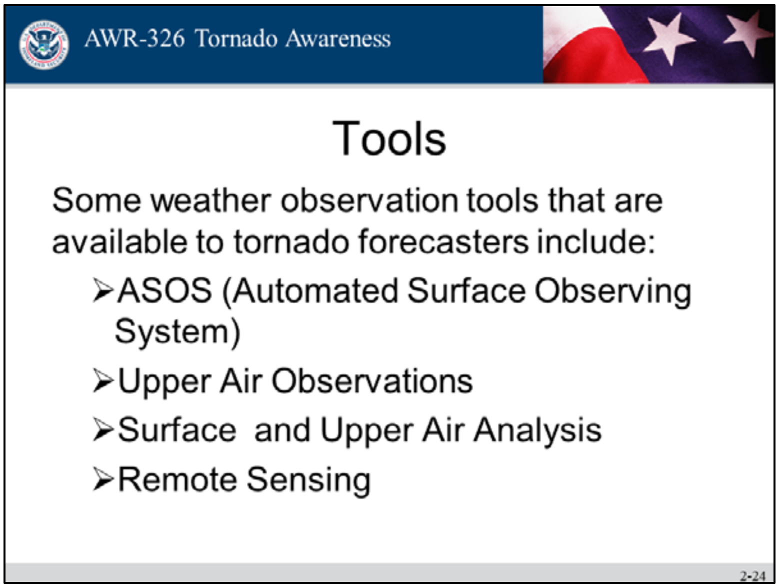

Slide 2-24. Tools

The following are some tools that meteorologists can use to evaluate and forecast tornados. We will go over each of these in detail on the following slides.

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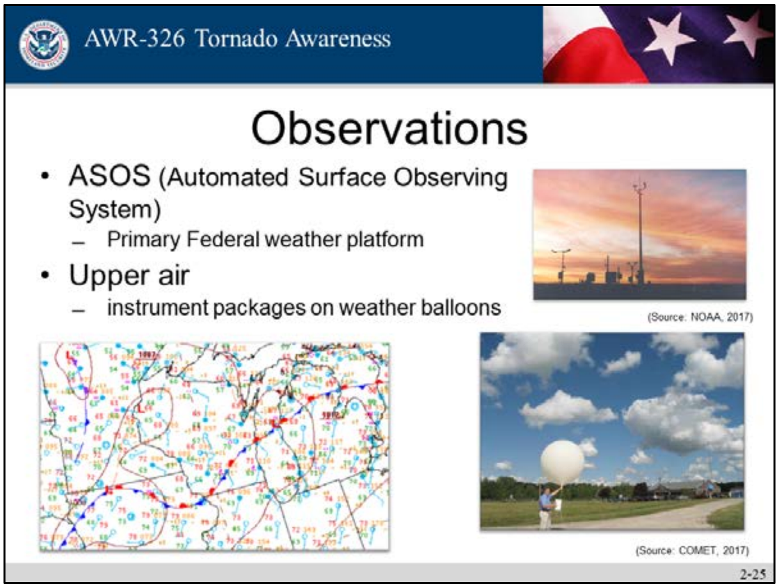

Slide 2-25. Automated Surface Observing System

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, intensity, and/or accumulated precipitation;
- Sea-level pressure;
- Temperature and dewpoint temperature;
- Wind direction and speed, including gusts; and
- Significant weather changes.

However ASOS stations collect data for the fixed point in which they are located. 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 (www.ndbc.noaa.gov)

also maintains a network of sea-based weather sensors (buoys), which collect crucial weather and ocean data along the United States coastlines including the Great Lakes.

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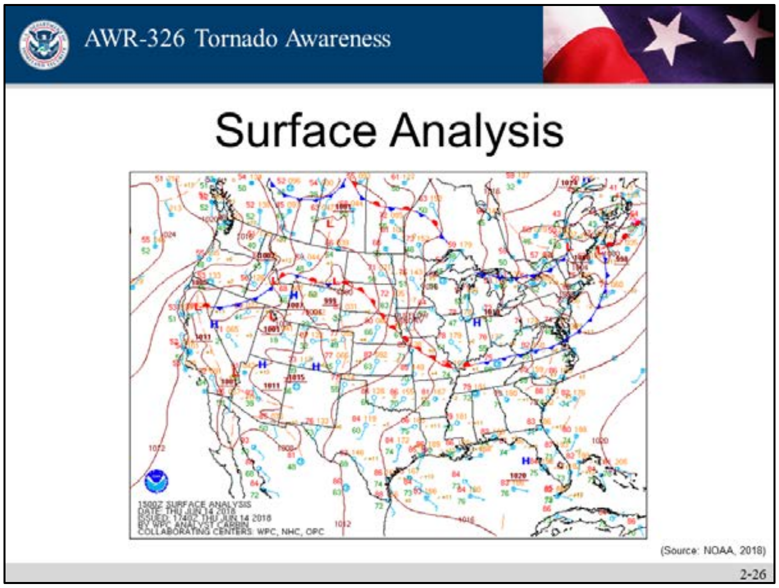

Slide 2-26. Surface Analysis

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.

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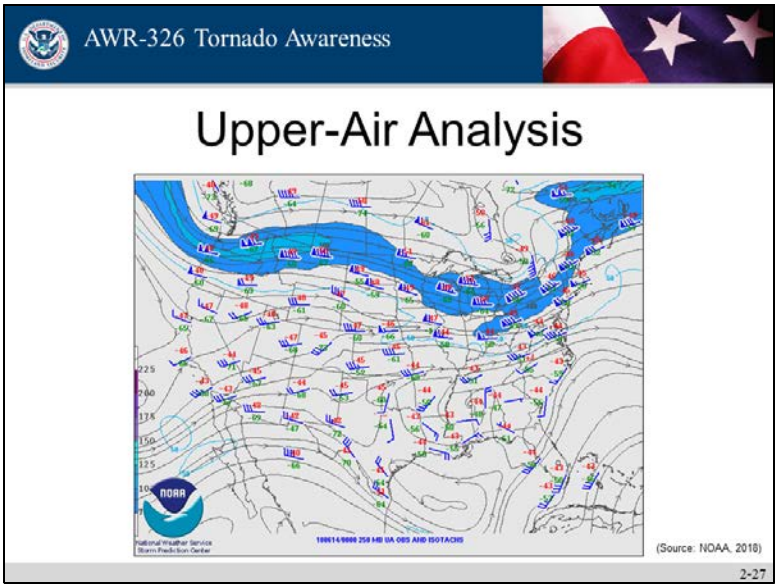

Slide 2-27. Upper-Air Analysis

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.

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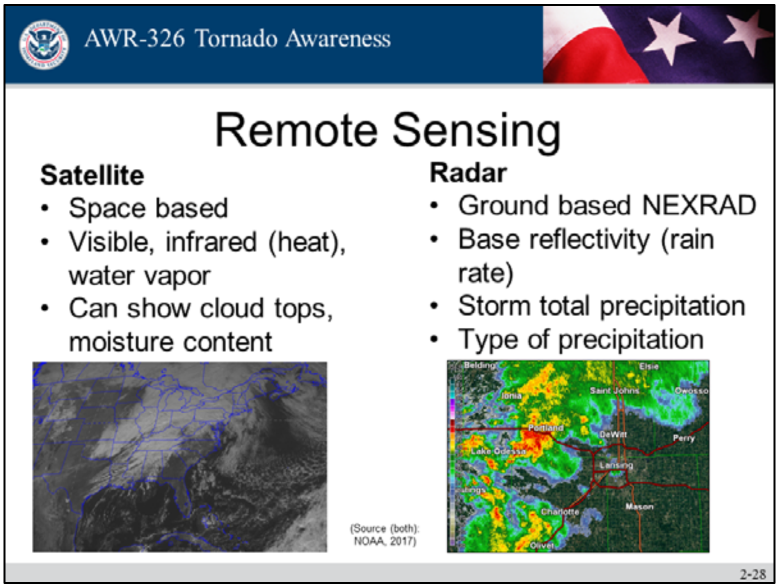

Slide 2-28. Remote Sensing

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." Orbiting 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 United States operates several Geostationary Operational Environmental Satellites (GOES).

"Polar-Orbiting Satellite" is the second type of satellites. These satellites orbit the earth at much lower altitude and typically travel on longitudinal paths from pole-to-pole. The data that they collect serve as input in the NWP models that likely enhance the quality of the forecasts. There are many more of these satellites nowadays, and the large increase in satellite data has led to the boom in NWP that we've seen over the last couple of decades. 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.

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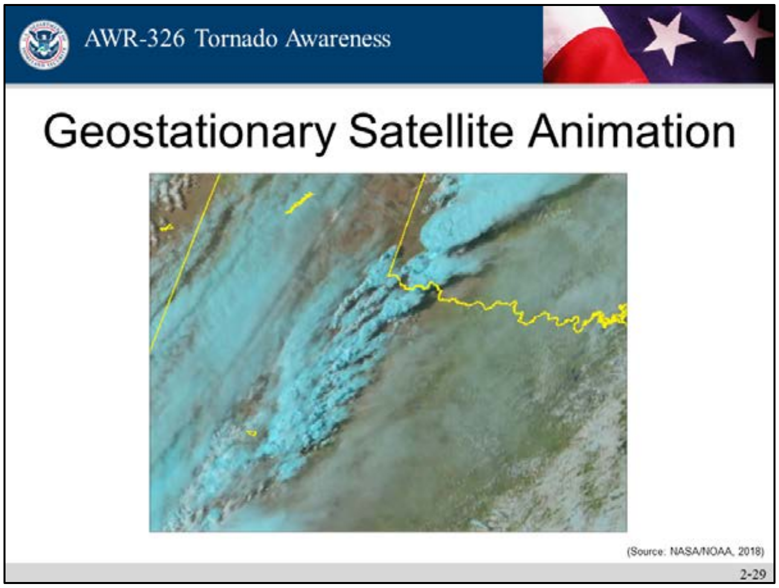

Slide 2-29. Geostationary Satellite Animation

This animation shows the severe thunderstorms developing over the Great Plains. Note the explosive development of thunderstorms.

> **Example:** This particular geostationary satellite animation shows severe thunderstorms in Texas and Oklahoma on May 3, 2018. While tornadoes are too small to see via satellite, the parent storm systems (mid-latitude cyclones) can be clearly tracked by satellite.

Rapid-scan, very high resolution satellite imagery from the GOES satellites are used by forecasters to monitor the evolution of storms that spawn tornadoes in real time. The hope is that the increasingly greater spatial and temporal detail in these images will give forecasters additional tools to increase lead times for tornado warnings in the future.

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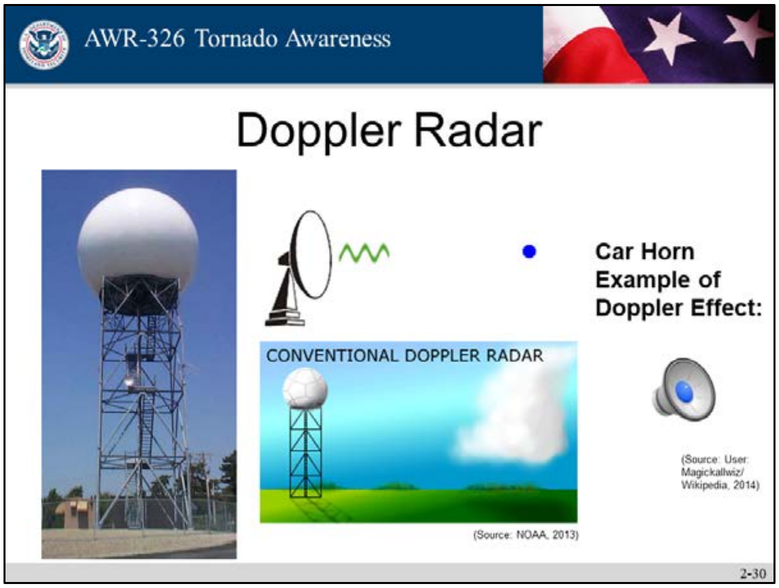

Slide 2-30. Doppler Radar

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. The backscattered energy from electromagnetic pulses of radiation from the radar site can be used to infer the intensity of precipitation, precipitation type, and the 3-D motion of air within and around a storm. 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. The radar pulse/beam sent from the radar hits various targets along its path and the strength, frequency and phase/shift of the return signal to the radar is analyzed to estimate its motion. 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 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

Participant Notes:

rain/snow/sleet/hail and subsequent hazards. Some research radars such as the KOUN radar in Oklahoma can emit simultaneous vertical and horizontal pulses.

With the advent of dual polarized Doppler Radar, the forecaster can now detect the presence of random shaped and sized targets like leaves, insulation or other debris. This would give the forecaster increased confidence that a tornado is or is not on the ground using this new type of technology.

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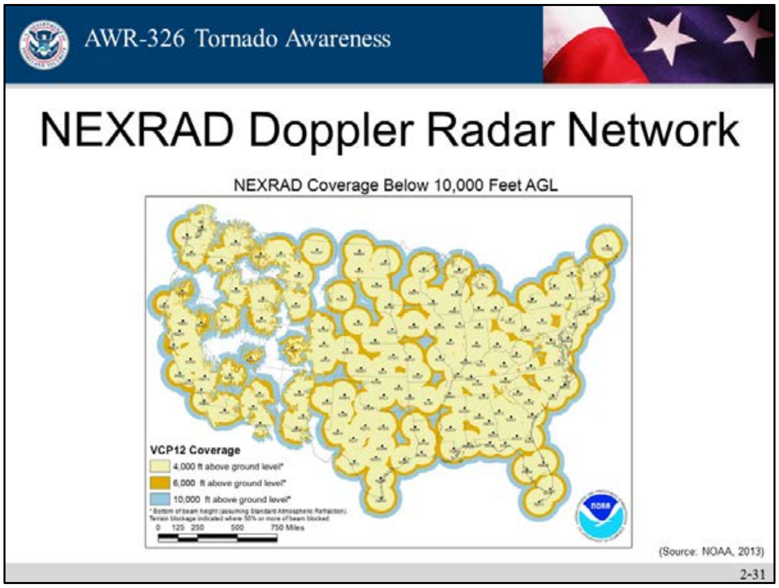

Slide 2-31. NEXRAD Doppler Radar Network

The National Weather Service currently operates a series of 159 WSR-88D Doppler Radar systems around the country. These systems provide non-stop surveillance of the skies, and 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 United States. Furthermore, given that radar beams are angled slightly above the horizon and the earth curves away from the radar site, the beam can overshoot a storm cell, making it difficult to detect the precipitation and air motions occurring at the base of thunderstorms where tornadoes affect people. Finally, radar ranges do not extend far beyond the United States coastline, so storm systems such as tropical cyclones and hurricanes, are not detectable by radar until just before or near landfall.

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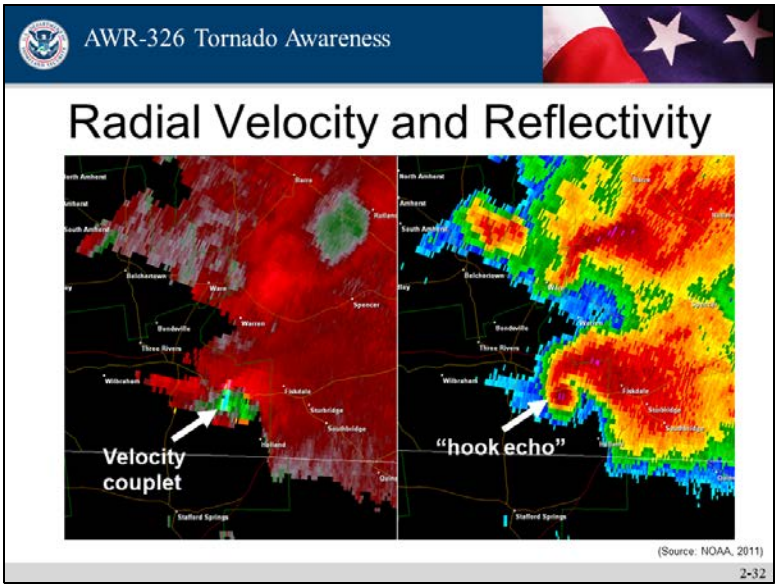

Slide 2-32. Radial Velocity and Reflectivity

The above slide illustrates the type of valuable information that can be derived from Doppler radars. Doppler radars detect the motion of the wind. This motion is not the direction of the wind, but the portion of the wind's motion that is moving either directly toward or away from the radar. On the right is a radar reflectivity image showing the "hook" shaped pattern of heavy rain and hail.

A tornado forecaster can use Doppler Radar data to detect a mesocyclone, but the presence of a mesocyclone (even one well defined) does not necessarily mean that a tornado is on the ground. This is where trained spotters come in handy.

In this slide, the following should be noted:

- The storm-relative velocity figure is on the left. 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, known as 'velocity couplet' suggest the presence of strong rotation.
- One of the important parameters measured by weather radar systems is the reflectivity of the precipitation targets in the volume of atmosphere being observed.
- Reflectivity is defined as simply "a measure of the of the fraction of radiation reflected by a given surface; expressed as a ratio of the

Participant Notes:

radiant energy reflected to the total amount of energy incident upon that surface" (weather.gov)

Meteorologists use these Doppler radar displays to issue tornado warnings.

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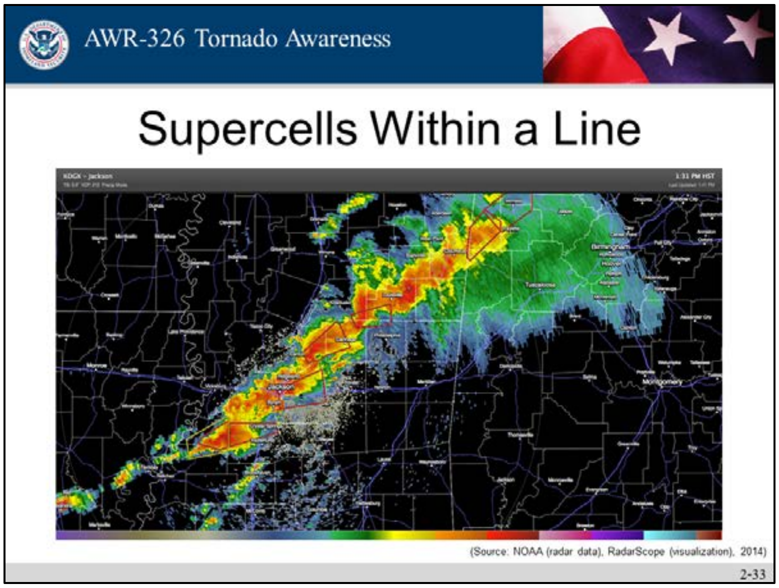

Slide 2-33. Supercells Within a Line

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 United States. 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.

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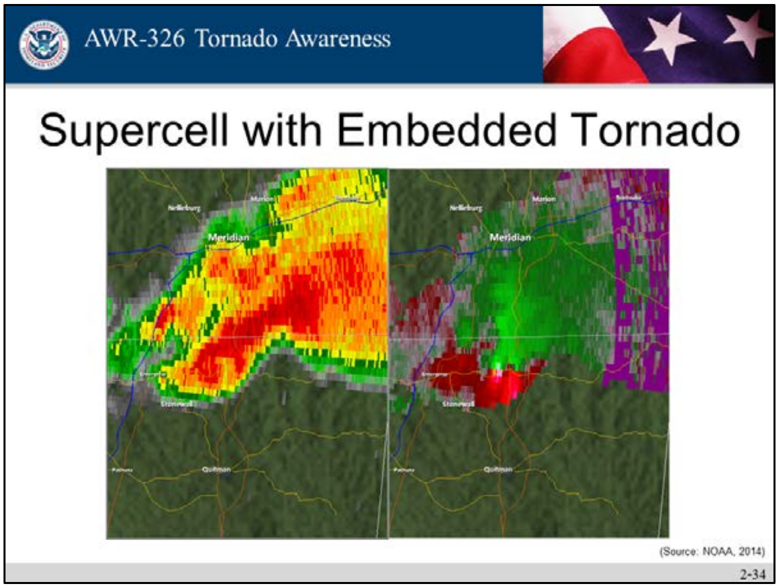

Slide 2-34. Supercell with Embedded Tornado

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.

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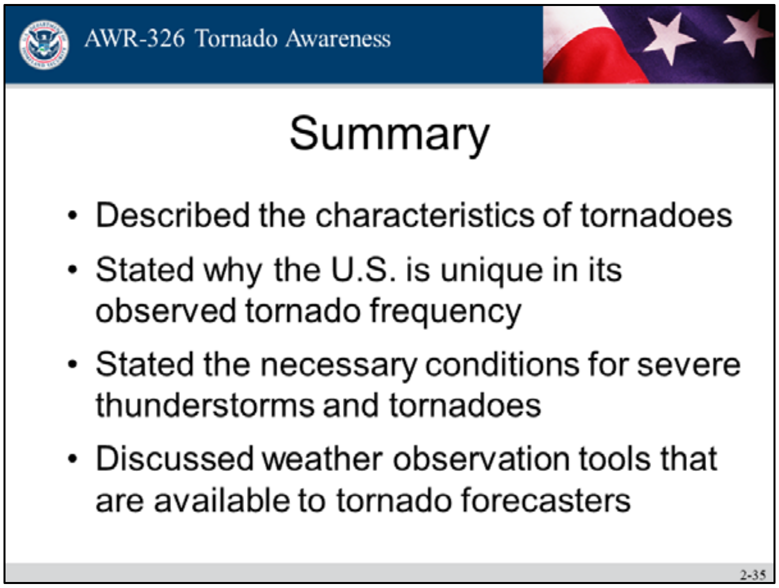

Slide 2-35. Summary

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

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AWR-326 Tornado Awareness

Module 3: Weather Forecast Process

Version 2.0

FEMA

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Module 3: Weather Forecast Process – Administration Page

Slide 3-1. Weather Forecast Process

Duration

50 minutes

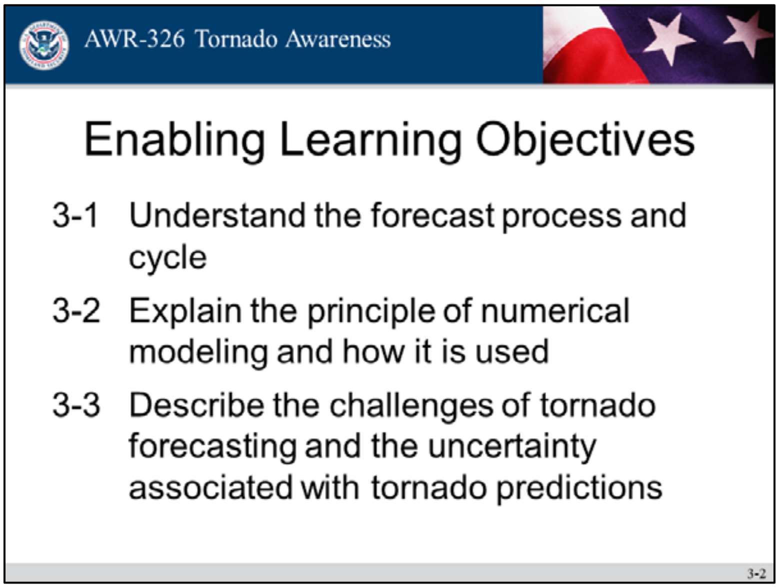
Scope Statement

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; and
- 3-3 Describe the challenges of tornado forecasting and the uncertainty associated with tornado predictions.

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

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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

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

Tornado Awareness

Icon Map

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

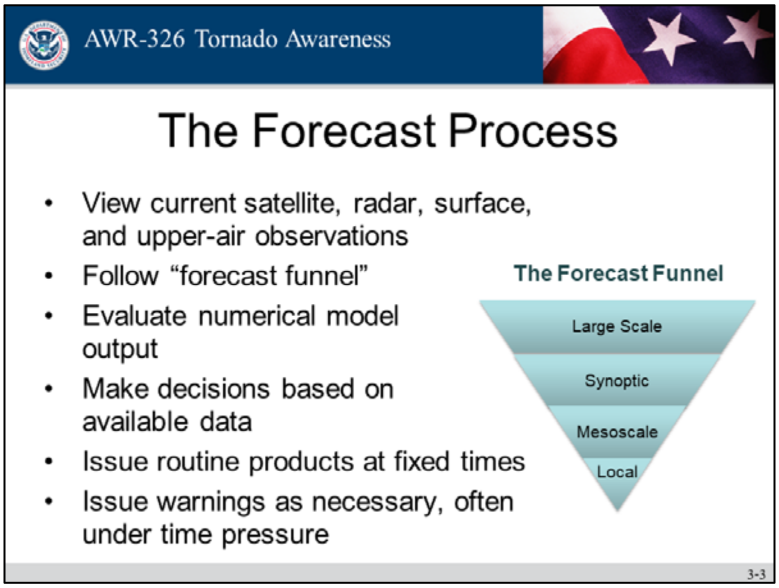
Example: Used when there is a descriptive illustration to show or explain.

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

Hint: Used to cover administrative items or instructional tips that aid in the flow of the instruction.

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.

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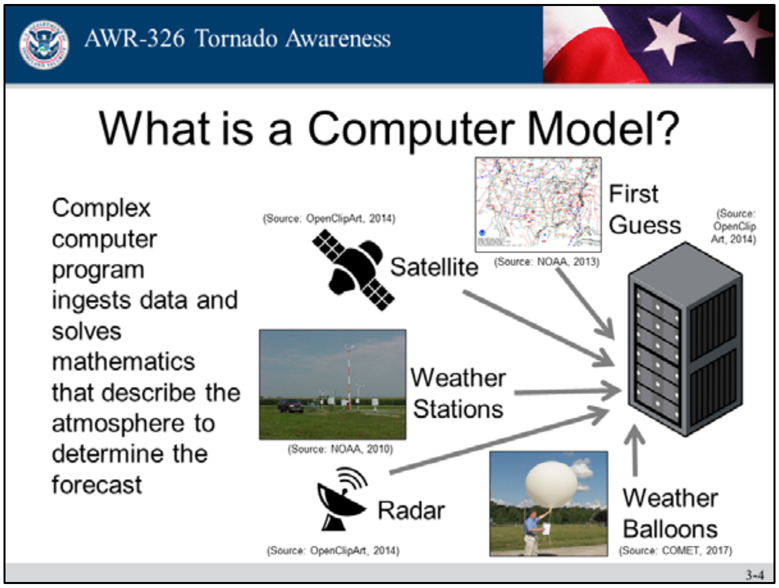

Slide 3-4. What is a Computer Model?

Supercomputers like NOAA's regularly run complex weather forecast models. These models ingest data from a wide variety of sources (surface observations from many sources, radiosondes, fixed and drifting buoys, ship observations, aircraft observations, satellite soundings, cloud and water vapor track winds, satellite- and radar-derived data) and solve mathematical expressions or equations based on physics that characterize how the air moves and heat/moisture are exchanged in the atmosphere to model the earth's atmosphere. Ninety-nine percent of the data used in NWP coming from satellites.

Computer models are the primary modern tool meteorologists use to make forecasts, predicting the evolution of weather patterns several days in advance.

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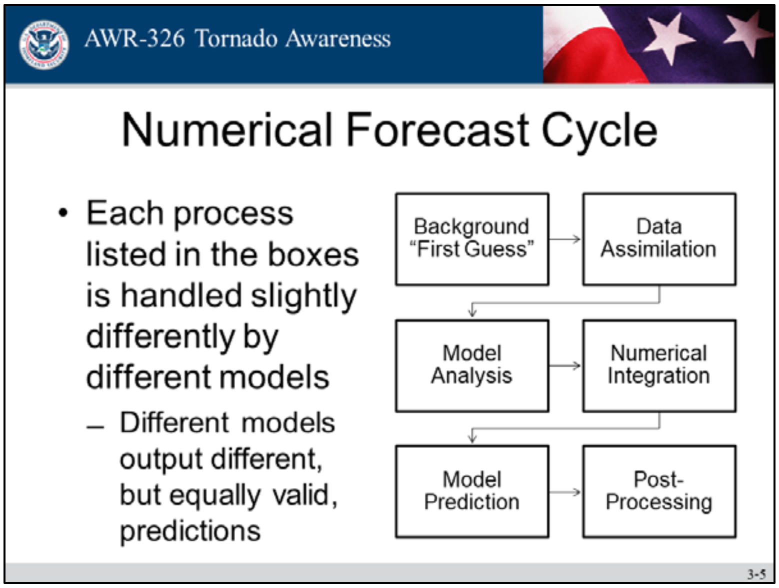

Slide 3-5. Numerical Forecast Cycle

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.
- The model utilizes real-time data to modify the background field of temperature, pressure, moisture, and other variables from the previous model cycle. The modified parameters represent the initial conditions for the next model run.
- 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.

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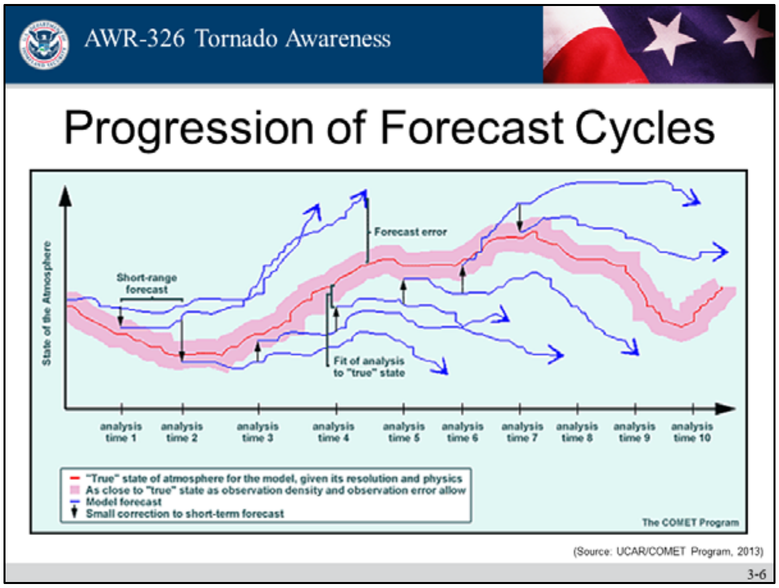

Slide 3-6. Progression of Forecast Cycles

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.

Key Point: Weather models are used to forecast day-to-day changes in the weather and can be used predict specifics about the weather at a particular location and time. Climate models can't provide output to forecast the weather at a particular location/time. Rather they're used to predict how average conditions are likely to change over a longer time interval (averaging period).

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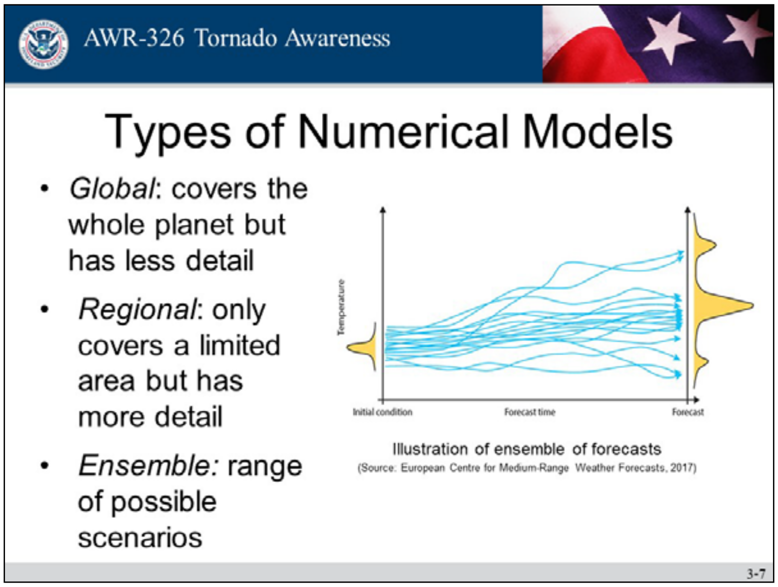

Slide 3-7. Types of Numerical Models

There are many types of numerical weather prediction models and a comprehensive discussion of each would be well beyond the scope of this course. We will only discuss two types of models:

- Global vs. Regional;

Definitions of each type are provided below:

- “Global 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.
- These are run four times per day (every six hours).
- Produce a forecast for the entire world.
- “Regional models” are typically initiated based on boundary conditions supplied by global models with an inner “nested” domain that is at a higher resolution.

Ensemble forecasts produce a range of possible scenarios using slightly different initial conditions for each variation. This allows forecasters to account for slight imperfections in the current analysis and produces the most likely scenario. This also helps quantify the uncertainty in each model outcome for the forecasters.

NOAA’s National Centers for Environmental Information runs the Global Ensemble Forecast System that is made up of 21 separate forecasts.

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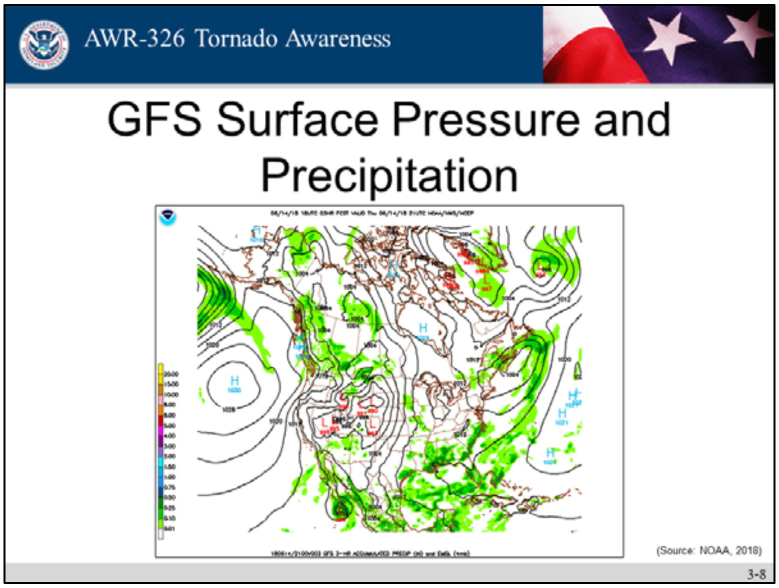

Slide 3-8. GFS Surface Pressure and Precipitation

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 18 UTC on June 14, 2018. 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).

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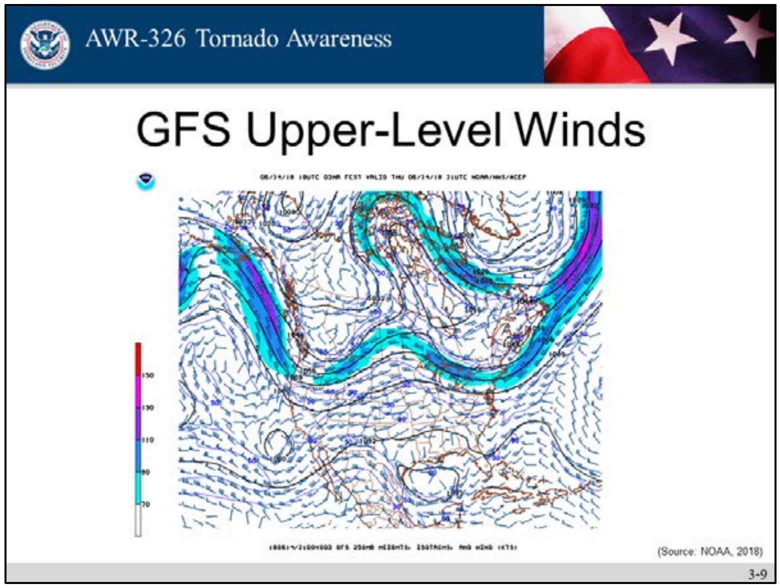
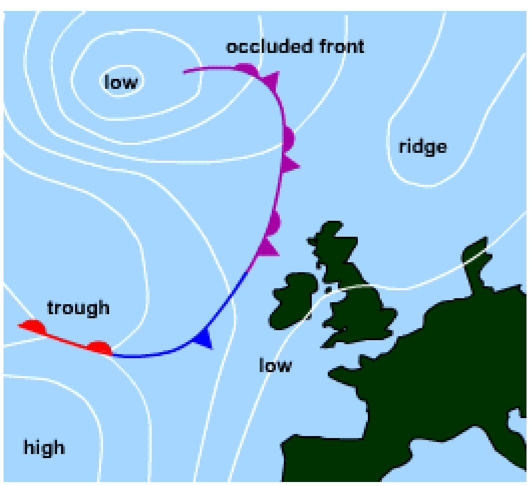


Slide 3-9. GFS Upper-Level Winds

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.

A ridge is an elongated area of relatively high pressure extending from the center of a high-pressure region. A trough is an elongated area of relatively low pressure extending from the center of a region of low pressure.

Example:



(www.pbs.org/weta/roughscience, 2019)

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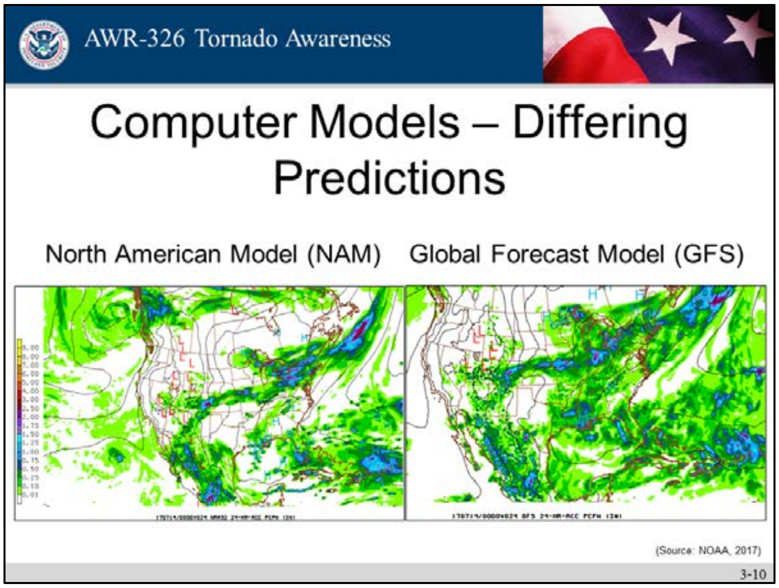

Slide 3-10. Computer Models – Differing Predictions

This slide illustrates the difference between different computer weather models. The image on the left shows the North American Model and the image on the right shows the Global Forecast Systems model. There is an apparent difference in the amount of predicted precipitation for the same time period between the the two models.

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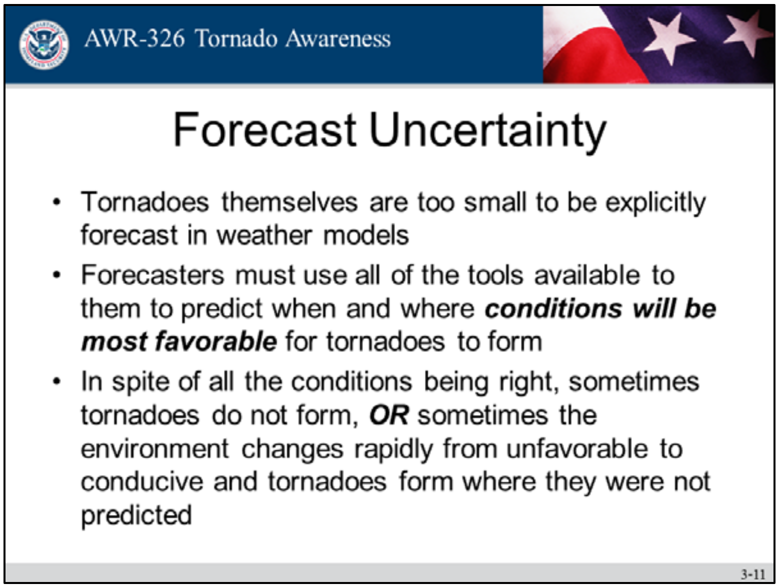

Slide 3-11. Forecast Uncertainty

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.

Forecasters not only interpret model guidance but they use their own knowledge and experience to arrive at the best possible forecast. This becomes considerably important since model solutions can show considerable disagreement and/or vary wildly from one model cycle to another.

Tornado prediction presents numerous challenges to forecasters. Forecasters rely on NWP models several days in advance to look for large-scale weather patterns of moisture, lift, instability, and shear that are conducive for tornado generation. It usually takes the right combination of the four factors to realize severe weather and tornadoes, but how much is enough of each factor is sometimes uncertain. And there is no single pattern that produces tornadoes, although there are some patterns that are more ideal than others. Once a potential event is closer in time, the forecaster tends to rely more on real-time weather data/observations, and less so on forecast models, to refine the forecast and to be more precise about where and when tornadoes are expected to occur. Although the uncertainty associated with any forecast decreases as an event approaches in time, there is always an inherent level of uncertainty in predicting an atmospheric phenomenon that exists on small spatial and temporal scales and which is beyond the capability of the most sophisticated NWP models and observational platforms to resolve.

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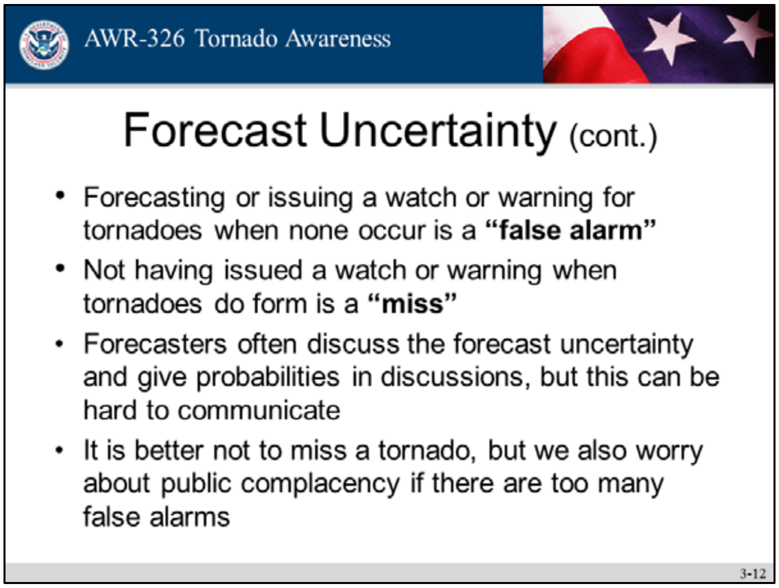

Slide 3-12. Forecast Uncertainty (continued)

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. Both emergency managers and the whole community must also consider the level of acceptable risk when receiving severe weather forecasts, warnings, watches, and advisories.

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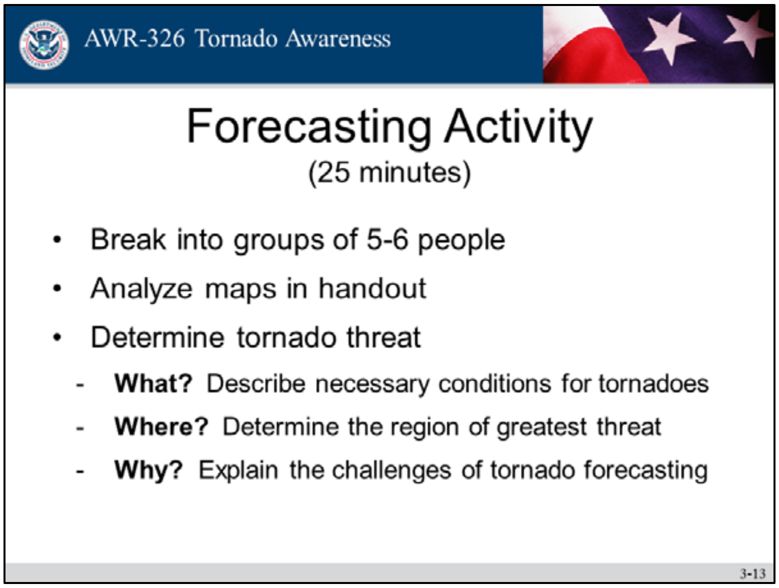

Slide 3-13. Forecasting Activity

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.

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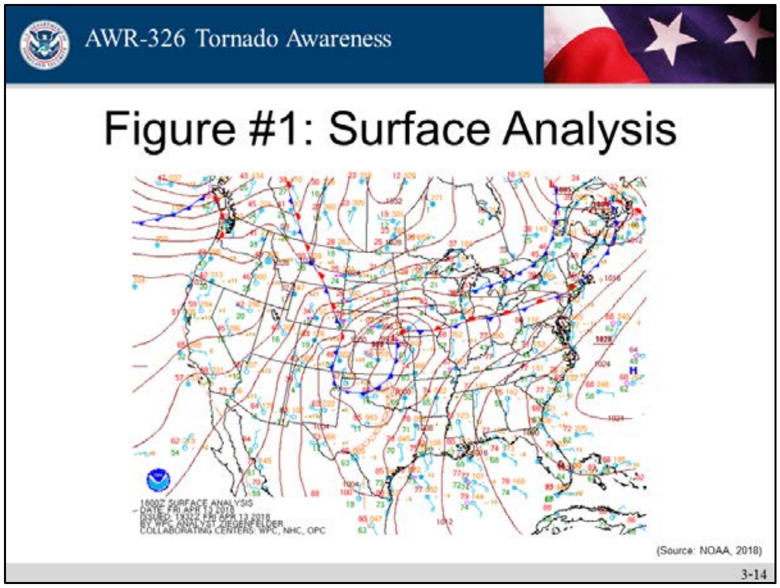

Slide 3-14. Figure #1: Surface Analysis

This surface analysis map depicts the weather systems that were in place across the continental United States at 18Z on April 13, 2018. Note the mid-latitude cyclone over the central Plains, with a frontal boundary draped through Kansas, Oklahoma, and Texas. Think about where severe weather is most likely in relation to these weather features.

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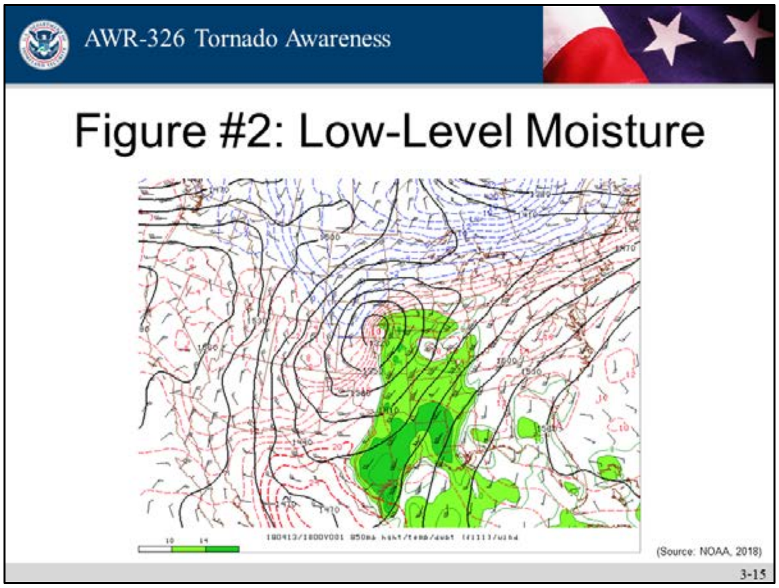
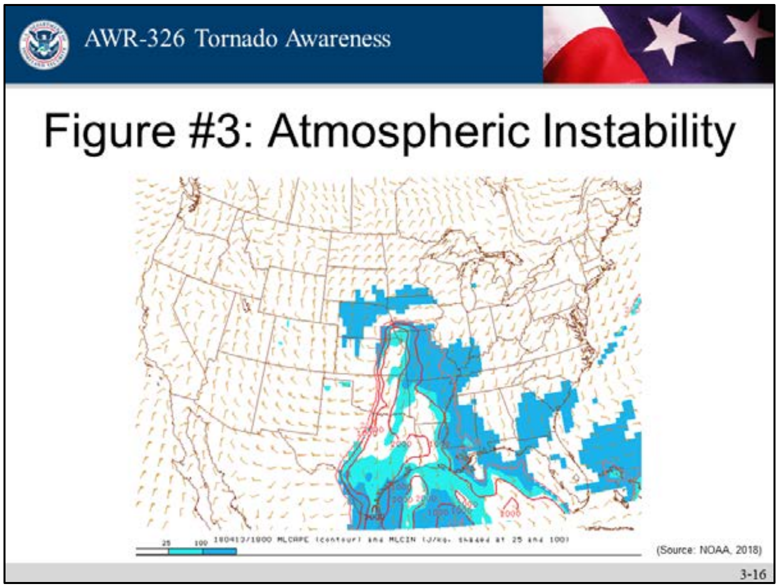


Slide 3-15. Figure #2: Low-Level Moisture

This is a map of low-level moisture, expressed as dew point 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.

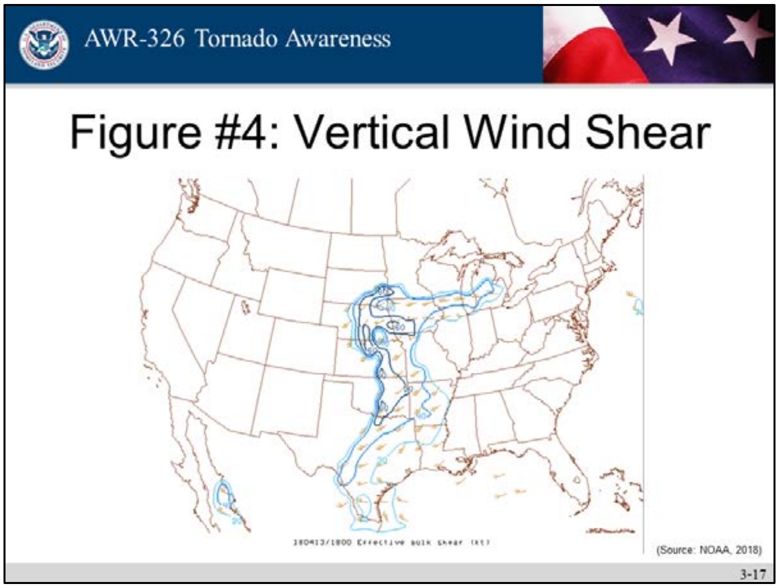
Particpant Notes:



Slide 3-16. 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.

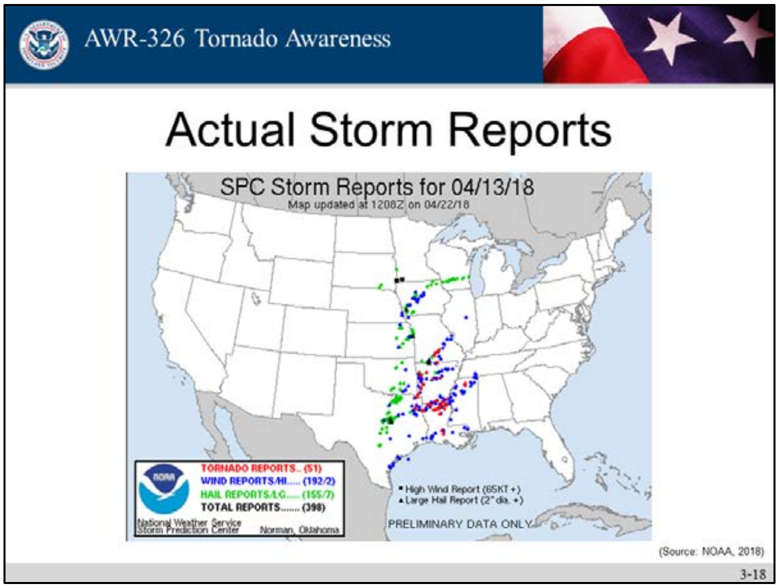
Particpant Notes:



Slide 3-17. 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.

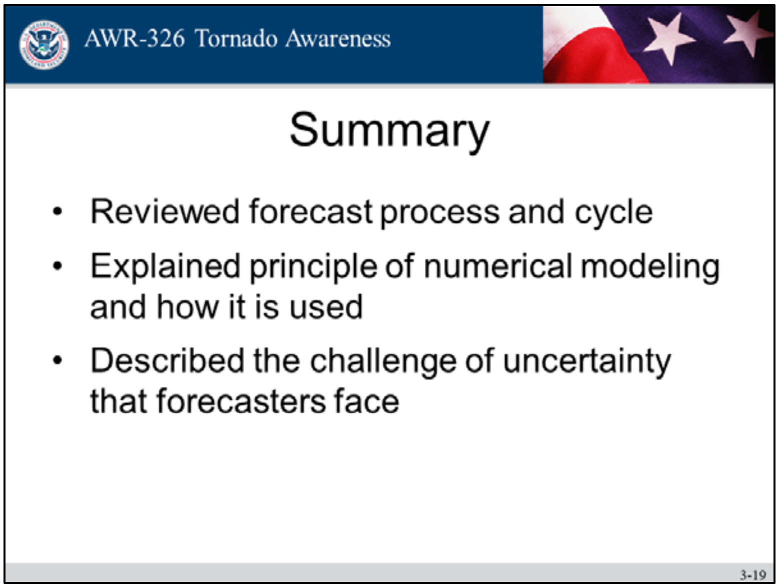
Particpant Notes:



Slide 3-18. Actual Storm Reports

These were the actual storm reports from the severe weather outbreak that occurred on April 13, 2018. Tornadoes were observed across the southern Plains and into the Midwest, along with severe hail and straight-line winds.

Particpant Notes:



Slide 3-19. 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.

AWR-326
Tornado Awareness

Module 4: Tornado Warning Process

Version 2.0

FEMA

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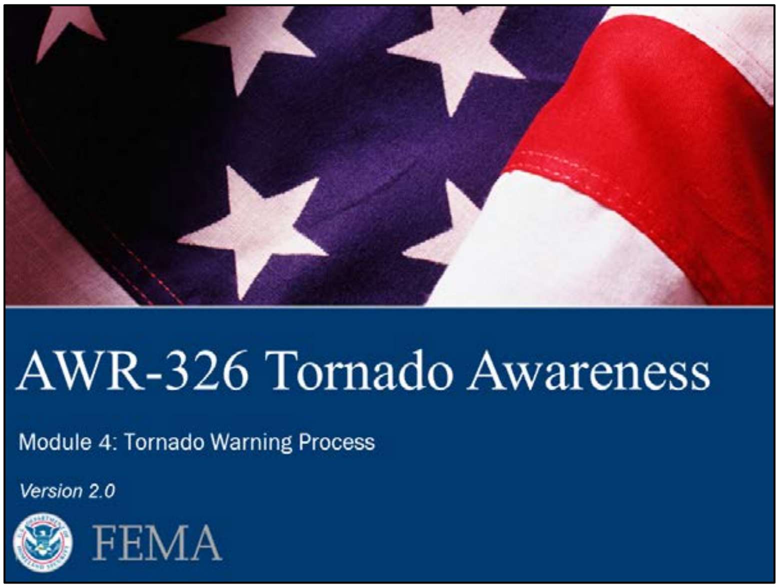
Module 4: Tornado Warning Process – Administration Page



Slide 4-1. Tornado Warning Process

Duration

55 minutes

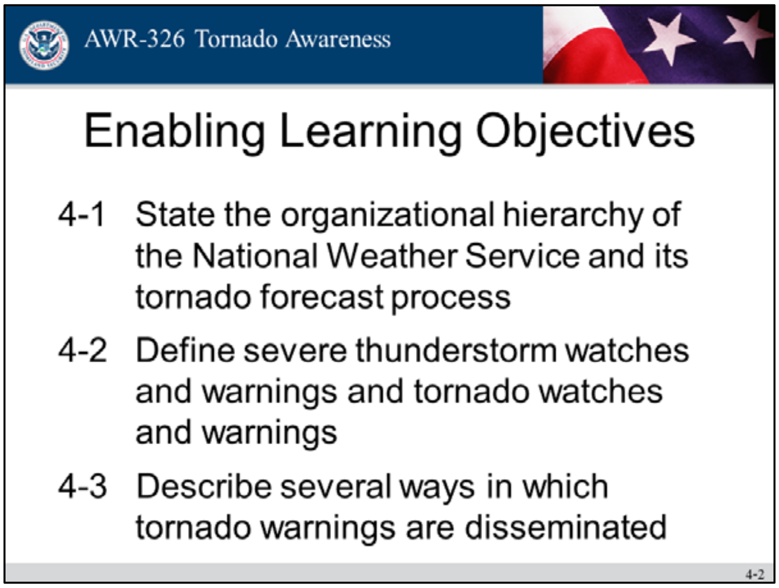
Scope Statement

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 https://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. Accessed 2018. https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-12-00147.1

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FEMA. 2015. *National Preparedness Goal, Second Edition.* September 2015. https://www.fema.gov/media-library-data/1443799615171-2aae90be55041740f97e8532fc680d40/National_Preparedness_Goal_2nd_Edition.pdf

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FEMA. 2018. *FEMA Strategic Plan 2018-2022*. https://www.fema.gov/media-library-data/1533052524696-b5137201a4614ade5e0129ef01cbf661/strat_plan.pdf

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

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

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. 2020. Accessed 2020. https://www.weather.gov/skywarn/

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

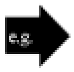
Assessment Strategy

- Instructor 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.



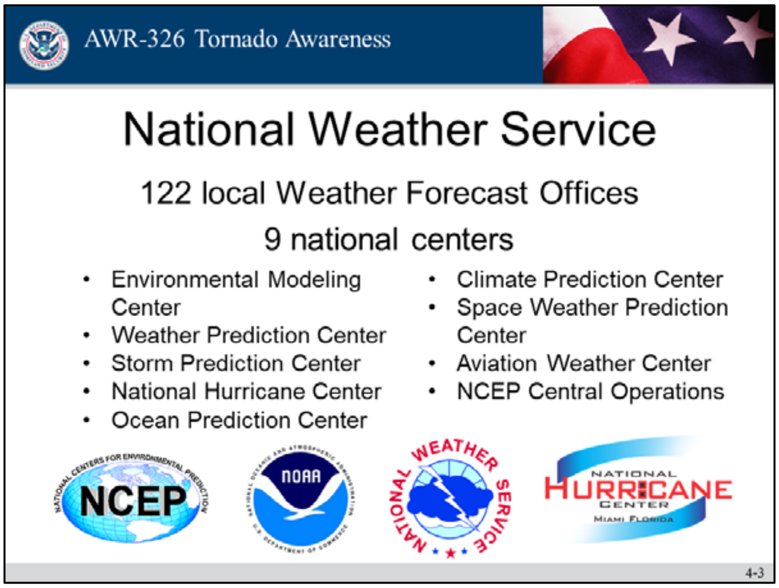
Example: Used when there is a descriptive illustration to show or explain.

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

Hint: Used to cover administrative items or instructional tips that aid in the flow of the instruction.

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.

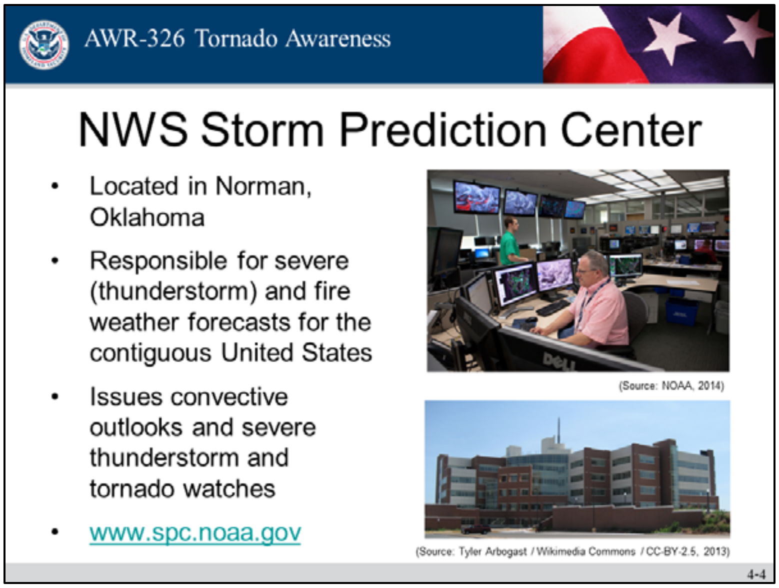
Particpant Notes:



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"**

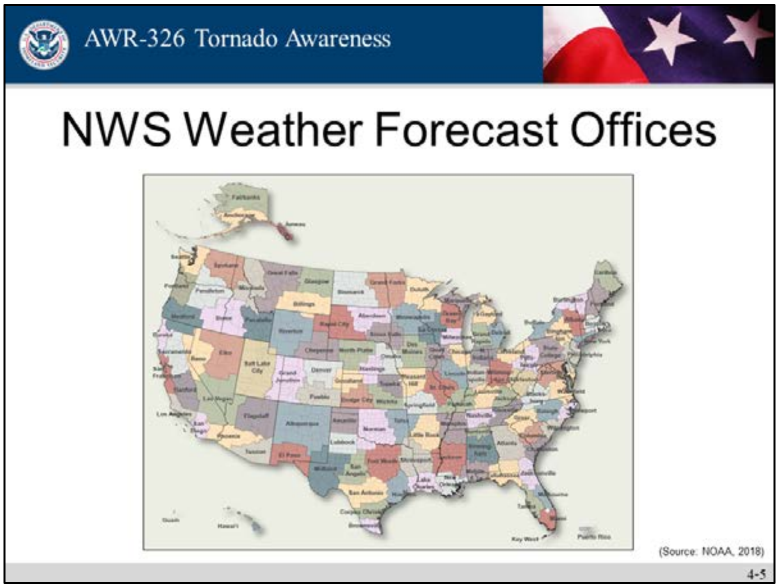


Slide 4-4. NWS Storm Prediction Center

Example: In the above slide, the top photo shows 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:

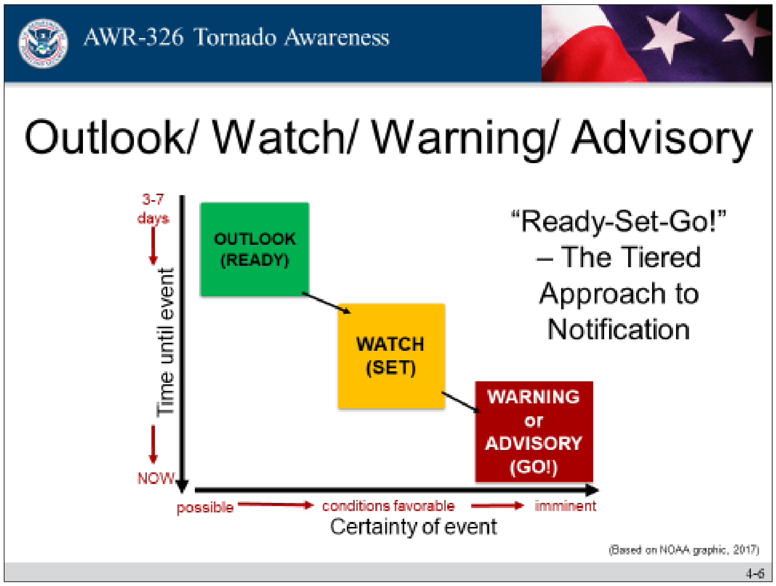
- Issues severe thunderstorm and tornado watches for this nation's 48 contiguous states;
- Issues mesoscale weather discussions and fire weather forecasts;
- Coordinates with local NWS Weather Forecast Offices during the issuance of severe weather watches; and
- Maintains 24-hour forecasting operations.



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.

Hint: To stimulate discussion, the instructors may ask participants why they think it is necessary to split the country into so many different CWAs and also point out that many of the CWA sizes are influenced by geography and population.



Slide 4-6. Outlook/ Watch/ Warning/ Advisory

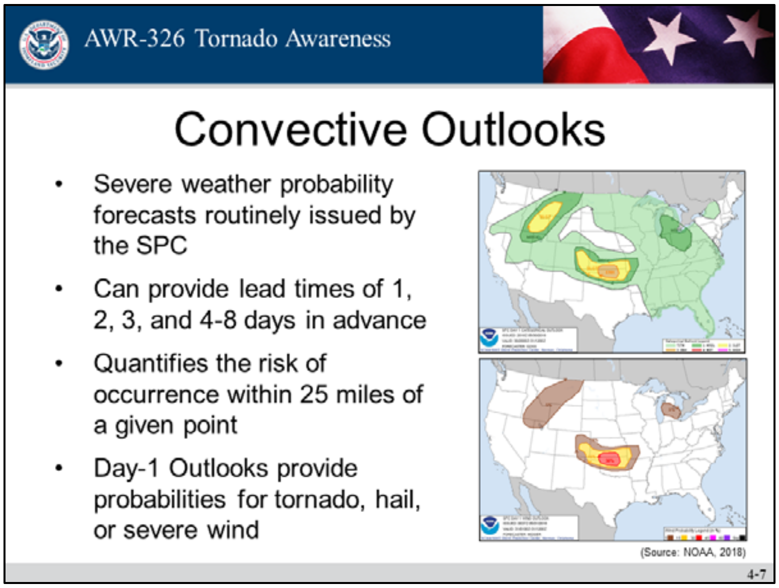
The NWS Glossary provides the following definitions:

"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."



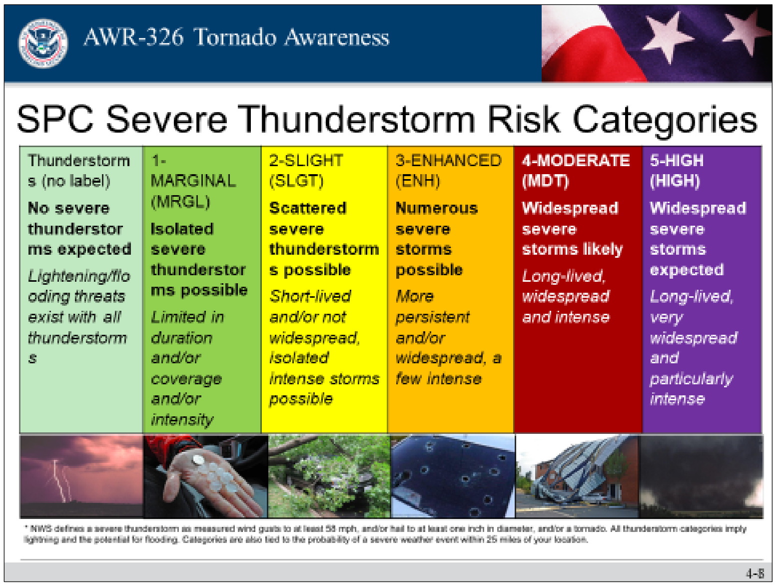
Slide 4-7. Convective Outlooks

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 one 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.

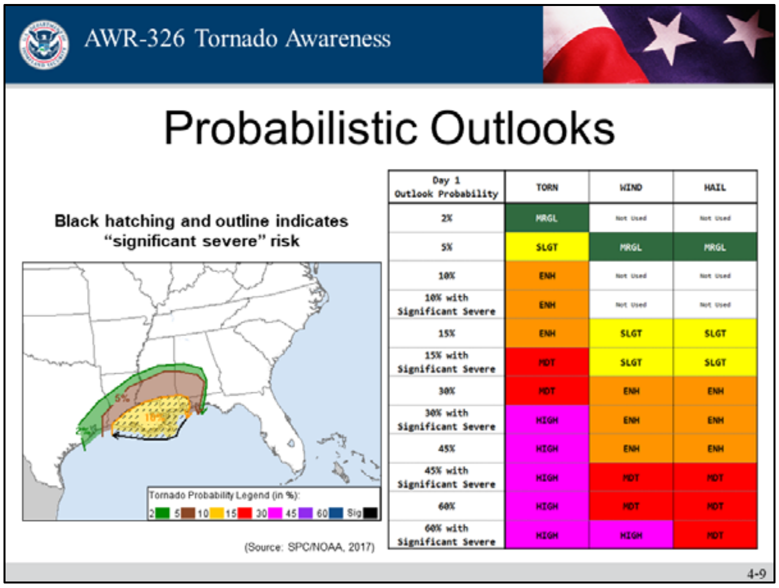
For more information about SPC products, including issuance/valid times, please visit: http://www.spc.noaa.gov/misc/about.html and http://www.spc.noaa.gov/faq/



Slide 4-8. SPC Severe Thunderstorm Risk Categories

At a lead time of one day (i.e., Day 1 Outlook), the probabilities are given for each type of hazard (e.g., hail, damaging wind, and tornado). Marginal, Slight, Enhanced, Moderate, and High risks represent progressively larger threats for organized severe storm episodes. These risks, along with their numerical, abbreviated labels, and colors (1-MRGL-dark green, 2-SLGT-yellow, 3-ENH-orange, 4-MDT-red, and 5-HIGH-magenta), are based directly on the numerical probabilities of severe weather that are provided with every outlook.

Note: 'High risks' are issued when forecasters have a high degree of confidence in a severe weather/tornado event/outbreak, and typically only issued a few times a year at most.



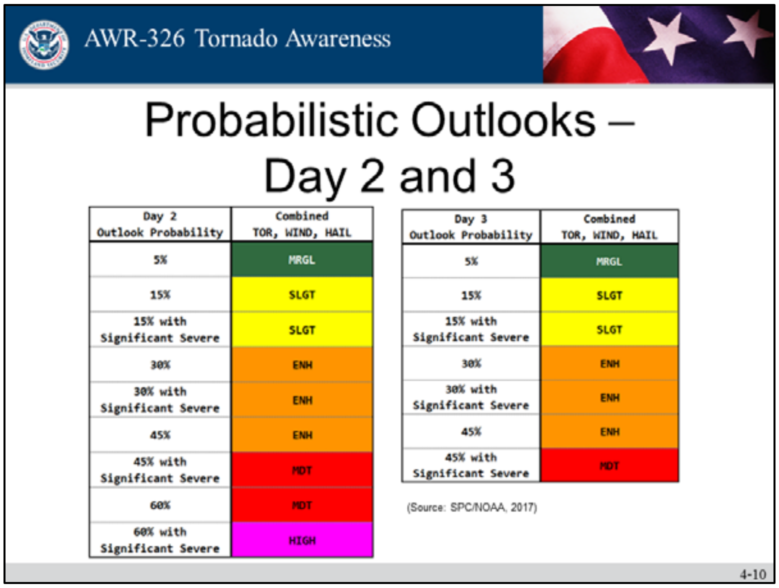
Day 1 Outlook Probability	TORN	WIND	HAIL
2%	MRGL	Not Used	Not Used
5%	SLGT	MRGL	MRGL
10%	ENH	Not Used	Not Used
10% with Significant Severe	ENH	Not Used	Not Used
15%	ENH	SLGT	SLGT
15% with Significant Severe	MDT	SLGT	SLGT
30%	MDT	ENH	ENH
30% with Significant Severe	HIGH	ENH	ENH
45%	HIGH	ENH	ENH
45% with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

Slide 4-9. Probabilistic Outlooks

The outlooks also include probability of occurrence maps. For Day 1, the percentage lines provide the chance that the given type of severe weather (tornado, hail, or damaging thunderstorm wind) will happen within about 25 miles of a point. Categorical (1-MRGL, 2-SLGT, 3-ENH, 4-MDT, and 5-HIGH) labels are tied directly to the probability numbers as defined in this table for Day 1.

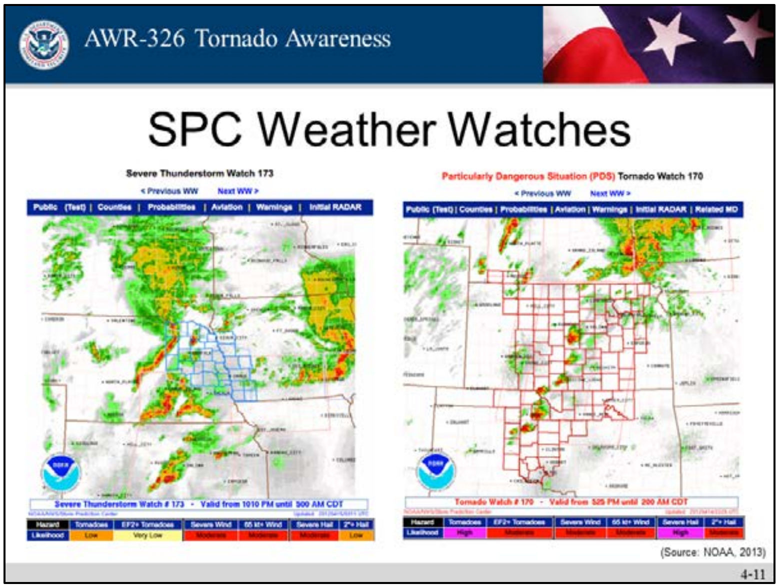
The probability values represent the chance of severe weather within about 25 miles of a point, which is about the size of a major metropolitan area. Though severe storms tend to receive a large amount of media coverage, severe weather is uncommon at any one location. Your chance of getting a tornado on any random day are very small, climatologically speaking. Put in that context, even a 10% chance of a tornado within 25 miles of a point means a much bigger threat than usual, and should be taken seriously.

Days 2 & 3 outlooks give probabilities for all-inclusive severe weather because the lead time is further, and forecasters have less information available to them to make the predictions. As lead time decreases, more information can be deciphered from the data and more detailed predictions can be made.



Slide 4-10. Probabilistic Outlooks – Day 2 and 3

For Day 2 and Day 3, the probabilities cover all severe storm hazards together. Categorical (1-MRGL, 2-SLGT, 3-ENH, 4-MDT, and 5-HIGH) labels are tied directly to the probability numbers as defined in these tables for Day 2 and Day 3 Convective Outlooks.

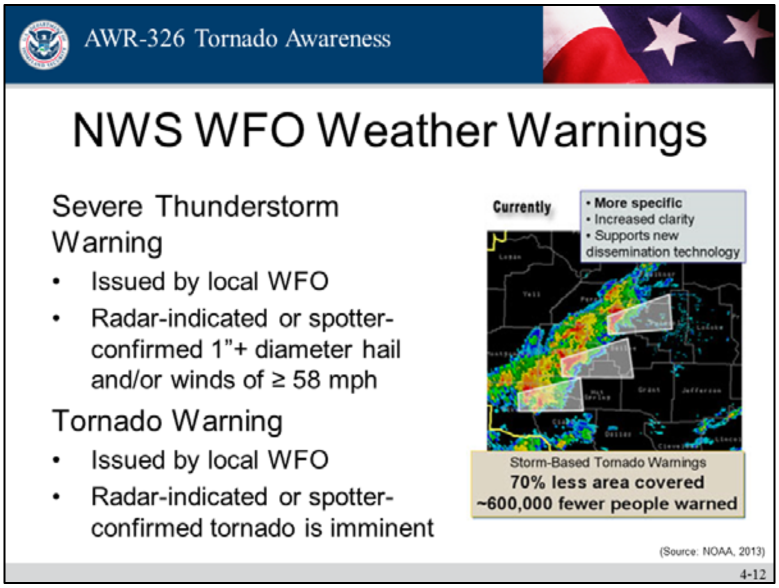


Slide 4-11. SPC Weather Watches

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/



Slide 4-12. 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.crh.noaa.gov/Image/dvn/downloads/backgrounder_DVN_Storm_based_warnings.pdf.

From the NWS Glossary (https://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 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.

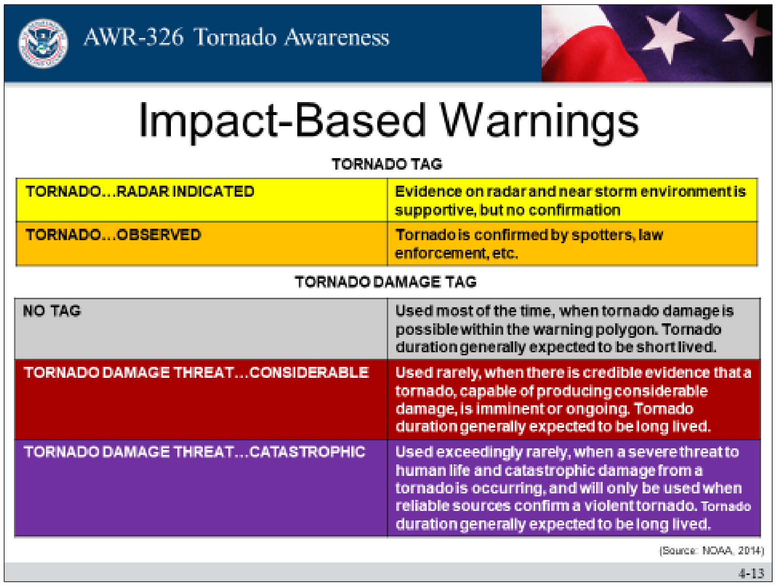
Tornado Warning

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.

The NWS can also issue what is called a “Tornado Emergency”. This rare type of warning is really an enhanced tornado warning but likely on a larger scale. They are typically issued when there is an imminent threat of significant, widespread tornadic damage and the potential for large loss of life either as a result of a strong tornado already on the ground or an outbreak of tornadoes.

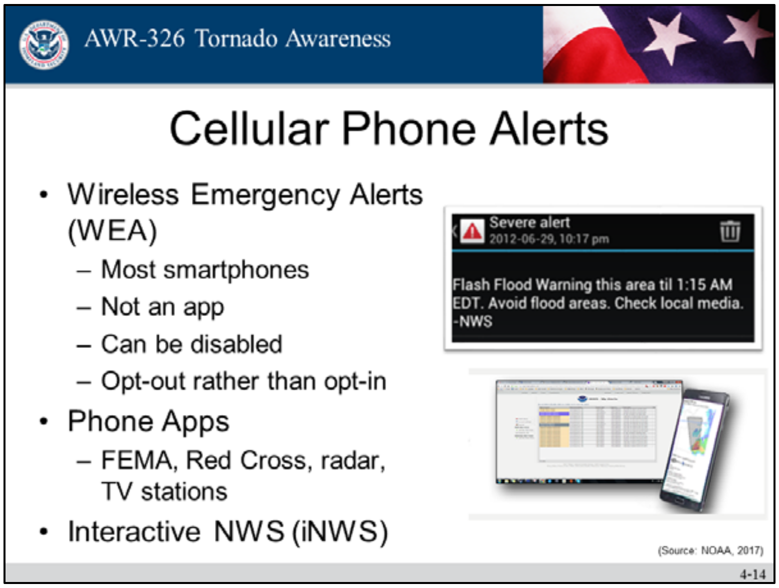


Slide 4-13. Impact-Based Warnings

The National Weather Service (NWS) communicates threats to partners and constituents via a product called the impact-based warning. The goal of this process is to focus on providing more information to media and emergency managers, facilitating improved public response and decision-making; and meeting societal needs in the most life-threatening weather events. The impact-based warning will have “event tags” at the bottom of each severe thunderstorm and tornado warning. The additional tornado event tags will have tornado threat information attached to them as a quick means to provide users and partners with potential high impact signals that prompt faster risk assessment and protective action.

Currently, all Weather Forecast Offices serving the contiguous United States are utilizing the impact-based warning format. More information concerning the look of the warnings is available in the Examples section.

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



Slide 4-14. Cellular Phone Alerts

"Wireless Emergency Alerts (WEA)," also known as "Commercial Mobile Alert System" or "Personal Localized Alerting Network," is 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.

The 360 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: https://www.fema.gov/emergency-managers/practitioners/integrated-public-alert-warning-system/broadcasters-wireless/commercial-mobile-service-providers.

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The FEMA app has a disaster reporter function with crowdsourcing. For more information on this, visit: http://www.fema.gov/smartphone-app

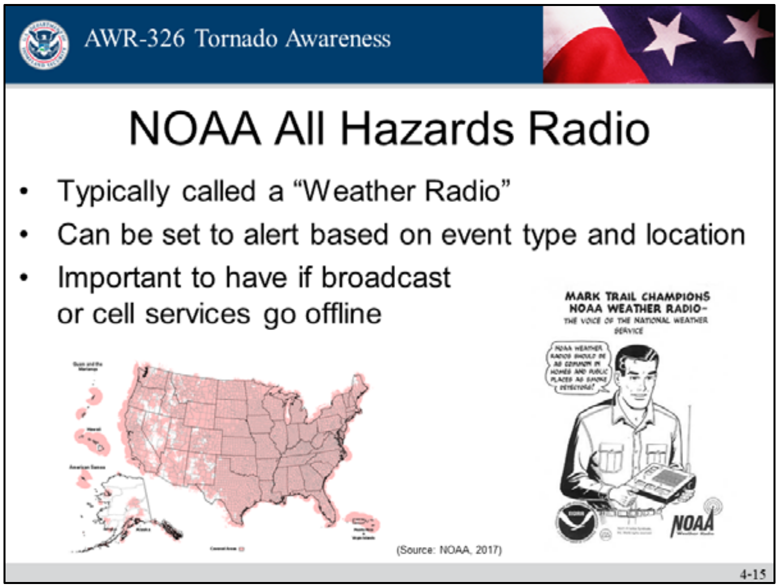
The American Red Cross also offers useful smart phone applications that can be used during different types of hazardous weather conditions. For more information on these applications, visit: http://www.redcross.org/prepare/mobile-apps

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 alert platform available for NWS partners: https://inws.ncep.noaa.gov/

For information on the Integrated Public Alert and Warning System, visit:http://www.fema.gov/integrated-public-alert-warning-system

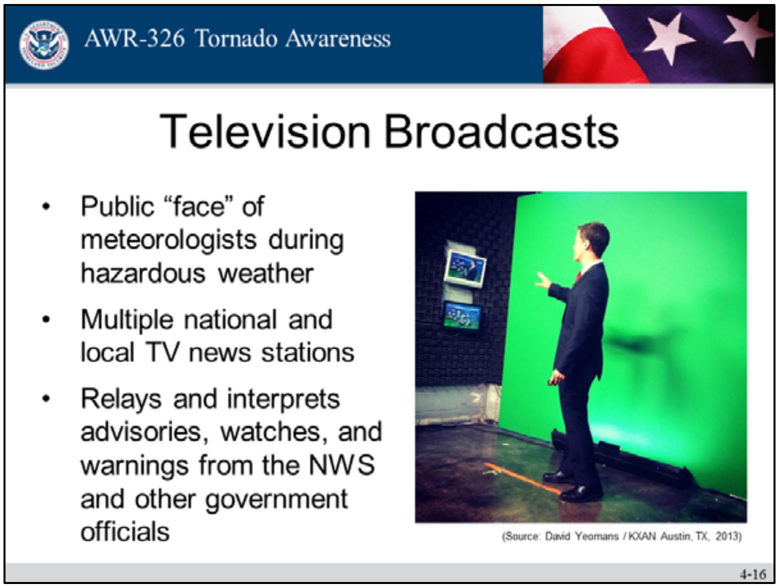
Some private applications can provide useful platforms for visualizing NWS radar data. Some of these include GRLevelX (Windows) and RadarScope (Apple and Android).



Slide 4-15. NOAA All-Hazards Radio

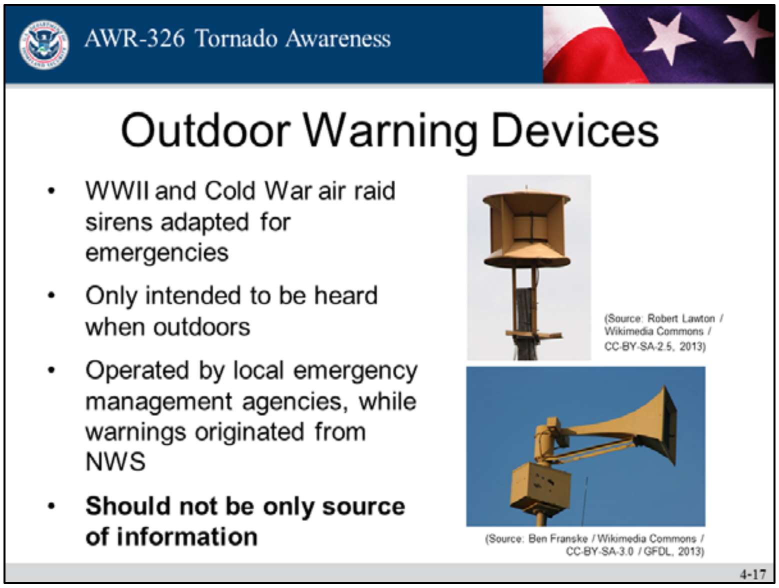
The "NOAA Weather Radio" is a continuous broadcast of weather forecasts and advisories originating from local NWS offices. Newer radios offer Specific Area Message Encoding (SAME) capability, which allow users to filter alerts based on the most relevant geographic area of interest. The weather radio 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.



Slide 4-16. Television Broadcasts

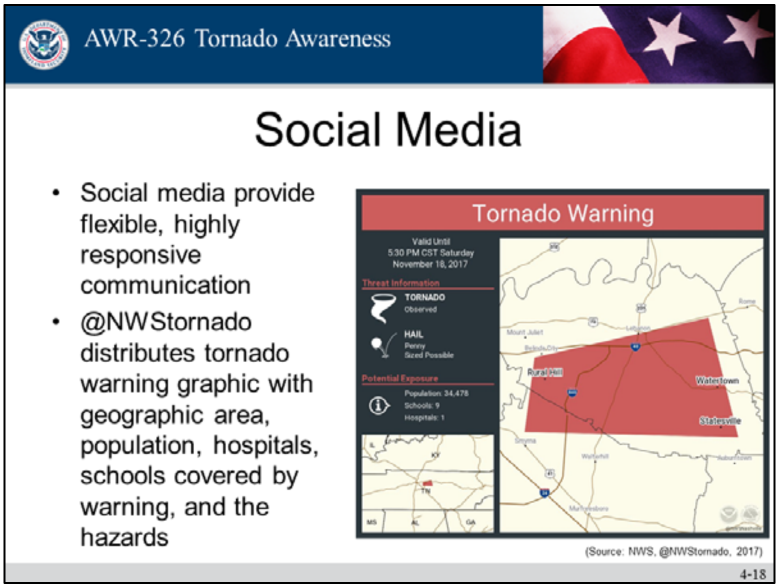
Television is one of the primary methods in which the public receives weather warnings. Most national and local news stations employ meteorologists on their staff whose sole purpose is to watch and broadcast the weather. While news stations are required to relay NWS alerts, they are also able to add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



Slide 4-17. 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.

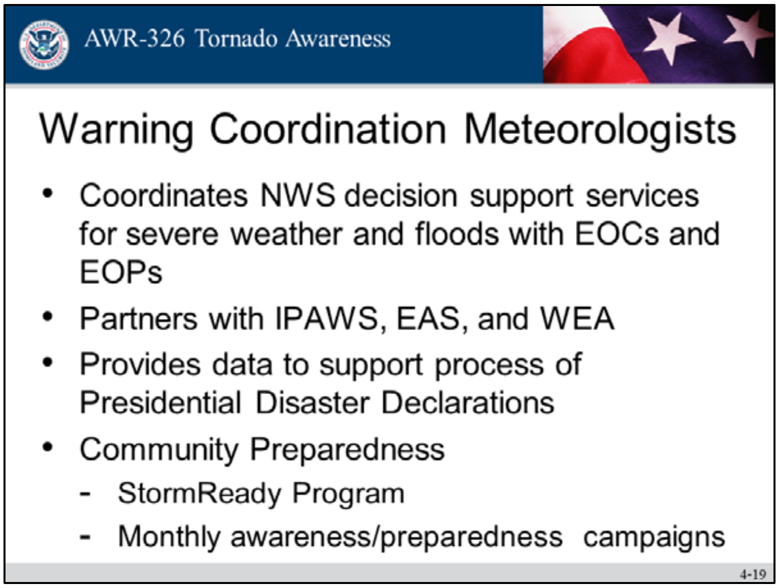
Key Point: It is critical to remember that sirens are only intended to be heard while outdoors. One should NEVER depend on sirens as a means of receiving tornado warnings while inside a building or a vehicle. Also, be sure to seek more information to clarify why the sirens are sounding.



Slide 4-18. Social 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.

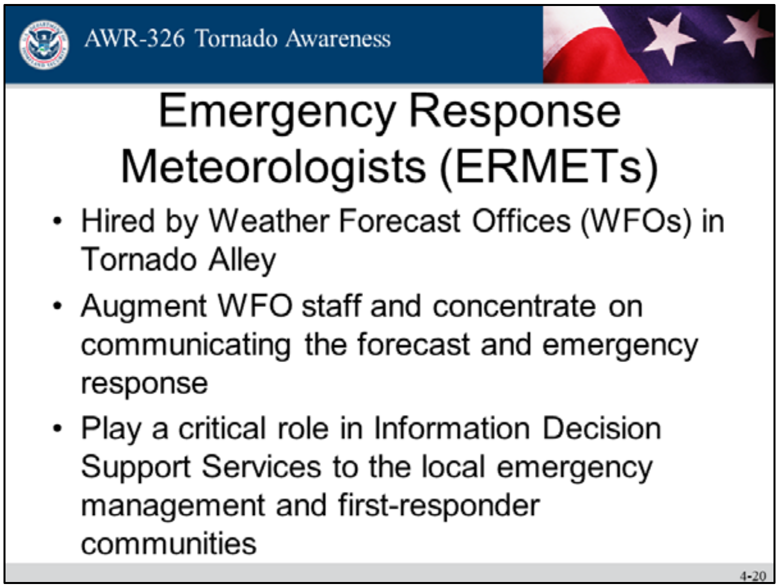
For more about social media, please refer to the National Disaster Preparedness Training Center's FEMA-certified PER-304 course, "Social Media for Natural Disaster Response and Recovery."



Slide 4-19. 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.



Slide 4-20. Emergency Response Meteorologists (ERMETs)

NWS Weather Forecast Offices located in tornado alley, along with regional operations centers, can employ Emergency Response Meteorologists (ERMETs). These meteorologists work to augment the WFO staff, especially leading up to and during a severe weather event. Some important tasks that ERMETs focus on include communicating the forecast to key partners and addressing any forecast concerns related to emergency response. ERMETs play a critical role in Information Decision Support Services (IDSS) provided by the NWS to emergency managers and first responders.

Slide 4-21. 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.

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.

Slide 4-22. Storm-Ready Communities

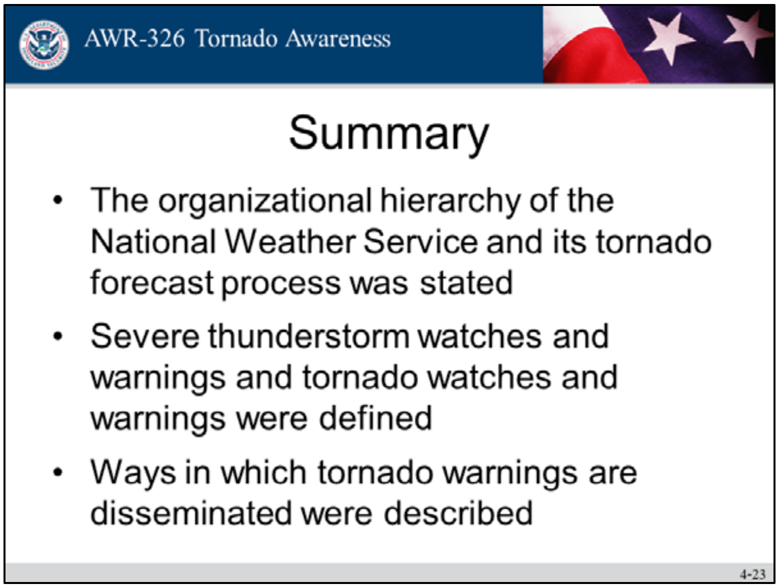
- Launched by NWS in August 2011
- Improving technology, forming partnerships, and increasing public awareness "to protect, mitigate, respond to, and recover from weather-related disasters"
- Better communication of risk and impacts
- More outreach to partners
- Risk and increase community resilience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

To be officially StormReady, a community must:

- Establish a 24-hour warning point and emergency operations center
- Have more than one way to receive severe weather warnings and forecasts and to alert the public
- Create a system that monitors weather conditions locally
- Promote the importance of public readiness through community seminars
- Develop a formal hazardous weather plan, which includes training severe weather spotters and holding emergency exercises

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: https://ndptc.basecamphq.com/projects/13081831/file/257279583/AWR326_PG_RC2019(2)19Jun20.docx://www.nws.noaa.gov/com/weatherreadynation/.



Slide 4-23. 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.

AWR-326
Tornado Awareness

Module 5: Tornado Safety

Version 2.0

FEMA

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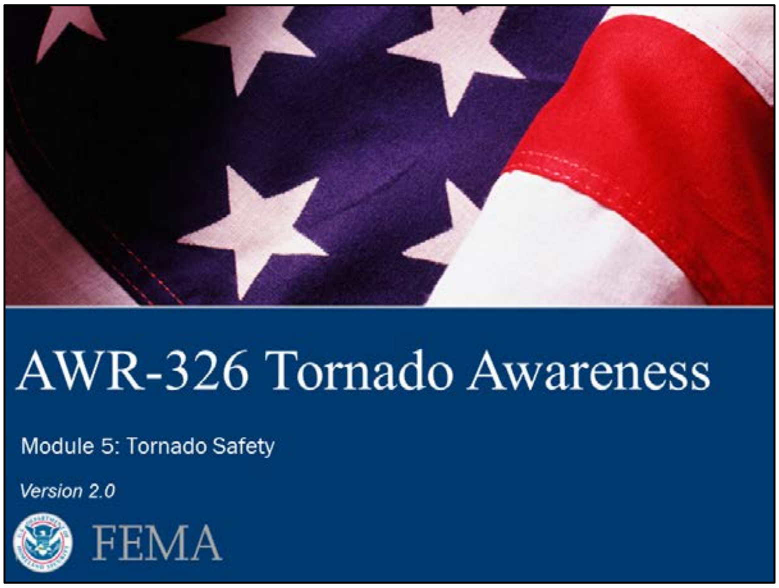
Module 5: Tornado Safety – Administration Page



Slide 5-1. Tornado Safety

Duration

120 minutes

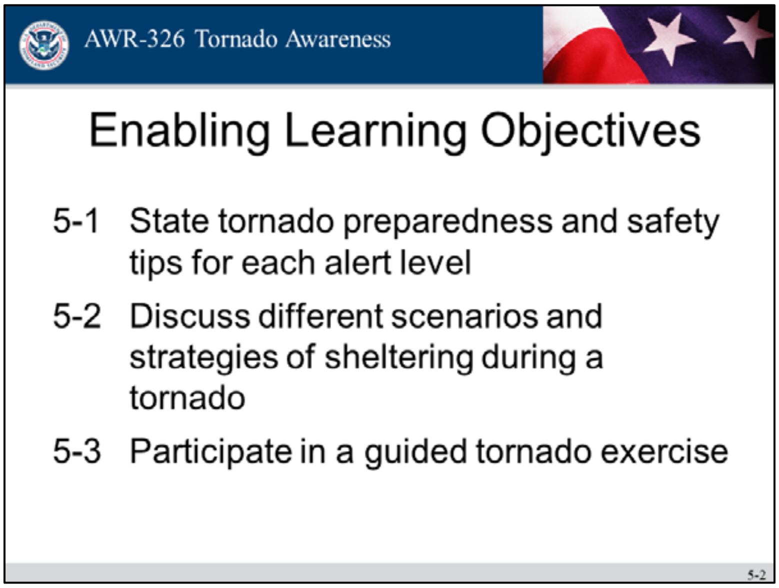
Scope Statement

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 https://ndptc.basecamphq.com/projects/13081831/file/257279583/AWR326_PG_RC2019(2)19Jun20.docxs://ndptc.hawaii.edu/
    - Participant Handout

Instructor-to-Participant Ratio

2:40

Reference List

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National Weather Service (NWS) WFO: Chicago, Illinois. 2015. April 9, 2015 Tornado Event, Including Rochelle/Fairdale EF-4 Tornado. Accessed 2018. https://www.weather.gov/lot/15apr09

Mersereau, Dennis. 2015. Here's an In-Depth Look at the Tornado That Destroyed Fairdale, Illinois. April 14, 2015. Accessed 2018. http://thevane.gawker.com/heres-an-in-depth-look-at-the-tornado-that-destroyed-fa-1697075704

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

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

Tornado Awareness

Icon Map

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

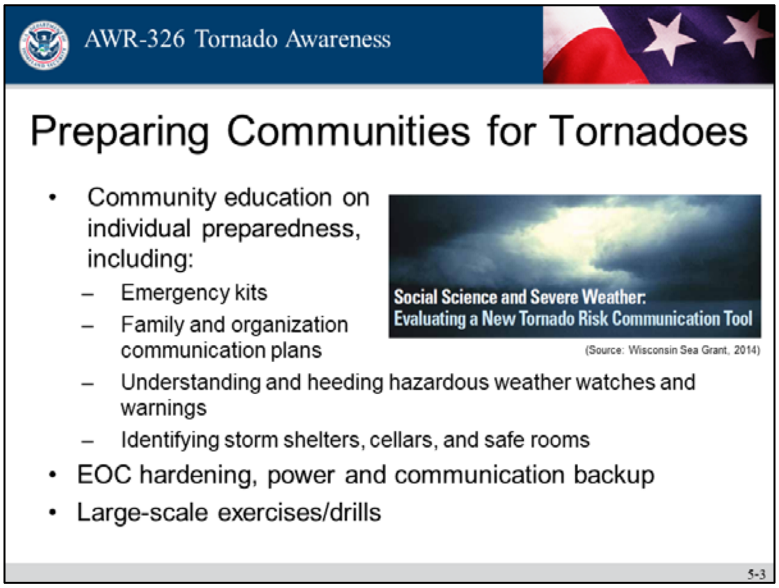
Example: Used when there is a descriptive illustration to show or explain.

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

Hint: Used to cover administrative items or instructional tips that aid in the flow of the instruction.

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.

Particpant Notes:

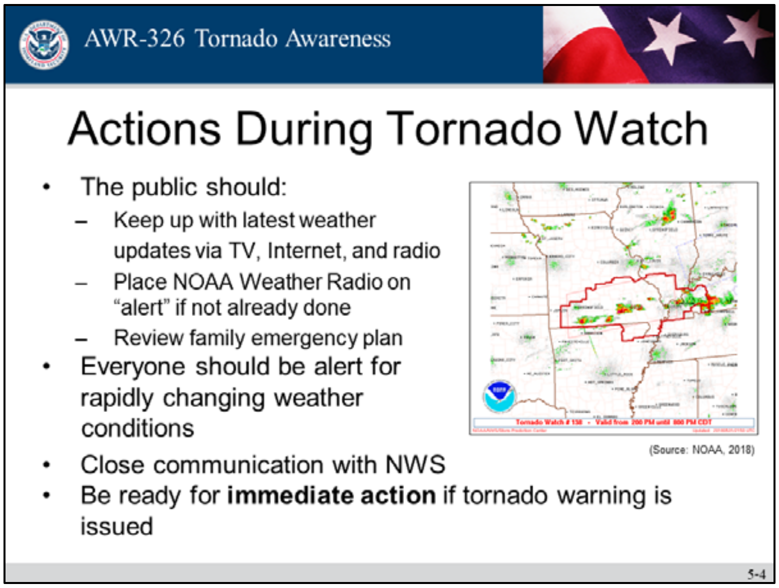


Slide 5-3. Preparing Communities for Tornadoes

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

Participant Notes:

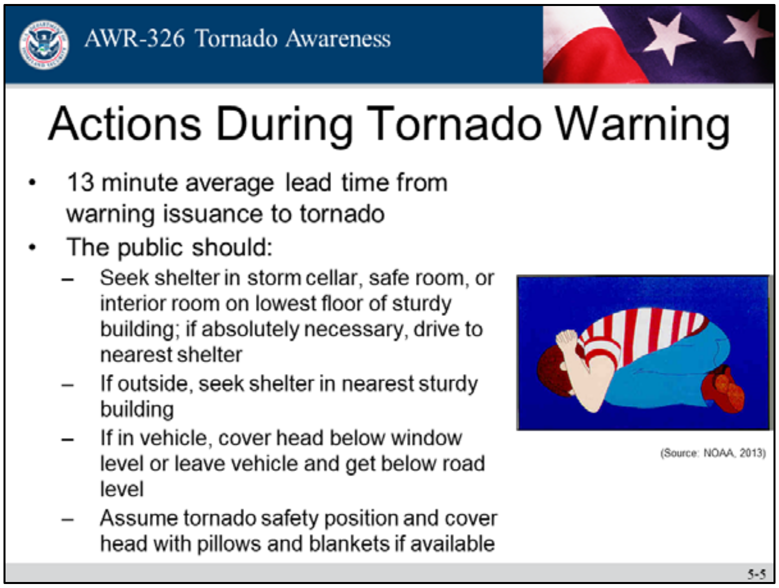


Slide 5-4. Actions During Tornado Watch

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?
  - Where will you shelter in the event of a tornado warning?

Participant Notes:



Slide 5-5. Actions During Tornado Warning

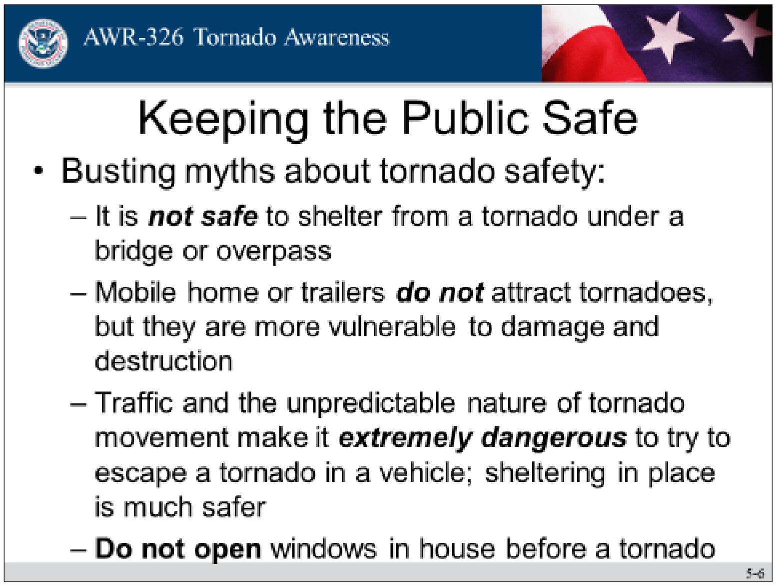
The average tornado warning lead time is 13 minutes. However, this can vary greatly depending on how "classic" the structure of a supercell thunderstorm is. Non-classic cases can result in much less lead time. When a tornado warning is issued for a particular area, individuals should follow the actions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

- Seek shelter in storm cellar, safe room, or interior room on lowest floor of sturdy building, to include a basement if available;
- 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. Keeping the Public Safe

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.
    a. Do not open the windows in your house. It is a myth that doing so would help to balance the pressure between the inside and outside of the house, possibly preventing destruction of the structure. Windows should be kept shut.
2. Abandon mobiles homes since they are not safe in a tornado, even if they are securely tied down. Best advice is to go to a shelter, if possible.
3. 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:

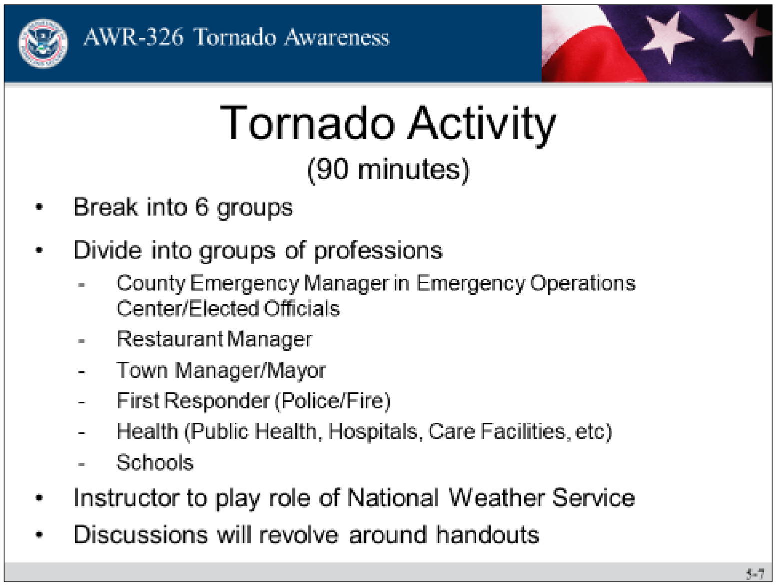
- Wear long pants, a long sleeve shirt, and real shoes (not flip flops or sandals!);
- Charge and take cell phones to the shelter; and
- Make a plan for your pets including finding their leashes and carriers.

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

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 is 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:

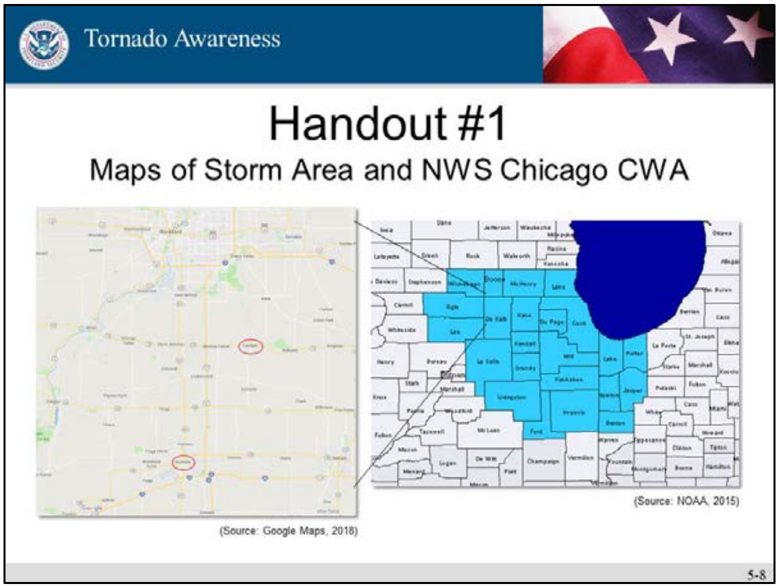


Slide 5-7. Tornado Activity

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:



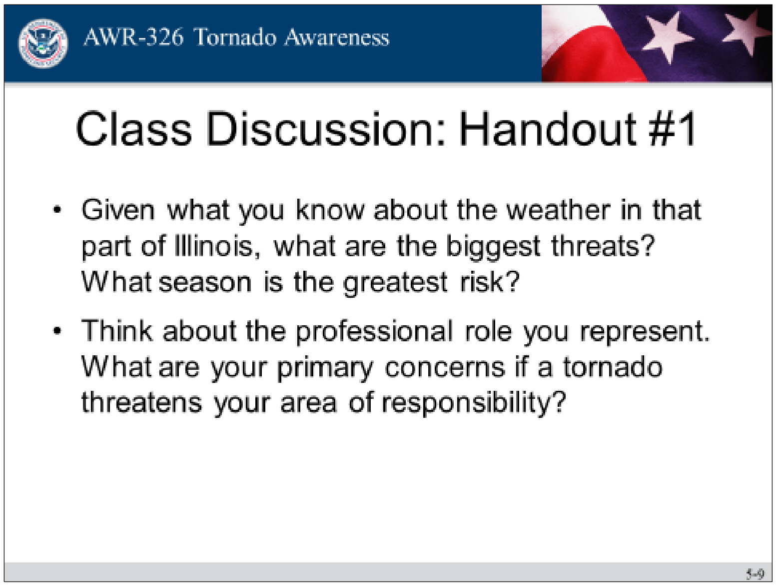
Slide 5-8. Handout #1
Maps of Storm Area and NWS Chicago CWA

Module 5: Handout #1 (page 1 of 5) is a map of the storm area with important landmarks labeled.

Module 5: Handout #1 (page 2 of 5) is a map of the NWS Chicago CWA (right).

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

Participant Notes:

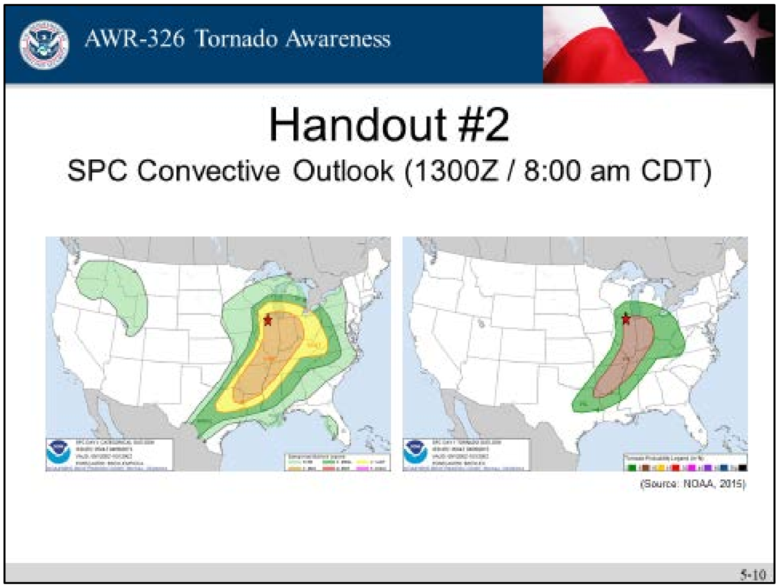


Slide 5-9. Class Discussion: Handout #1

Given what you know about the weather in this part of Illinois, what are the biggest threats? What season is the greatest risk?

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

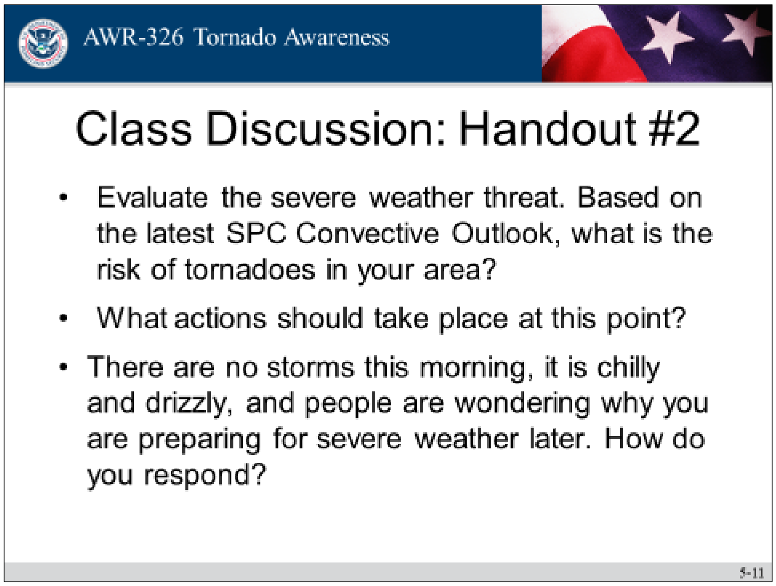
Participant Notes:



Slide 5-10. 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 left figure shows the categorical outlook, with a slight severe weather risk (yellow) extending from Texas northeastward toward the upper Midwest. An enhanced severe weather risk (orange) extends from east Texas through Wisconsin.

Participant Notes:



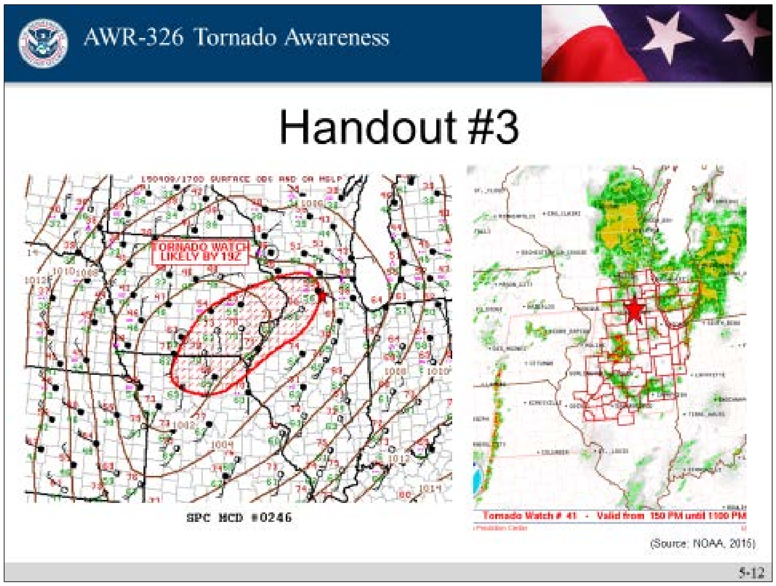
Slide 5-11. Class Discussion: Handout #2

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

What actions should take place at this point?

There are no storms this morning, it is chilly and drizzly, and people are wondering why you are preparing for severe weather later. How do you respond?

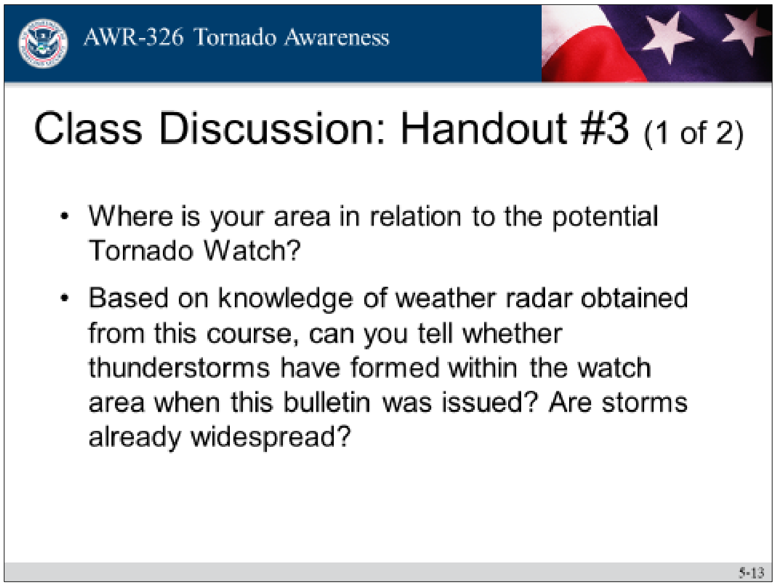
Participant Notes:



Slide 5-12. 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 mesoscale discussion 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 northern Illinois, southeastern Wisconsin, and northwestern Indiana.

Participant Notes:



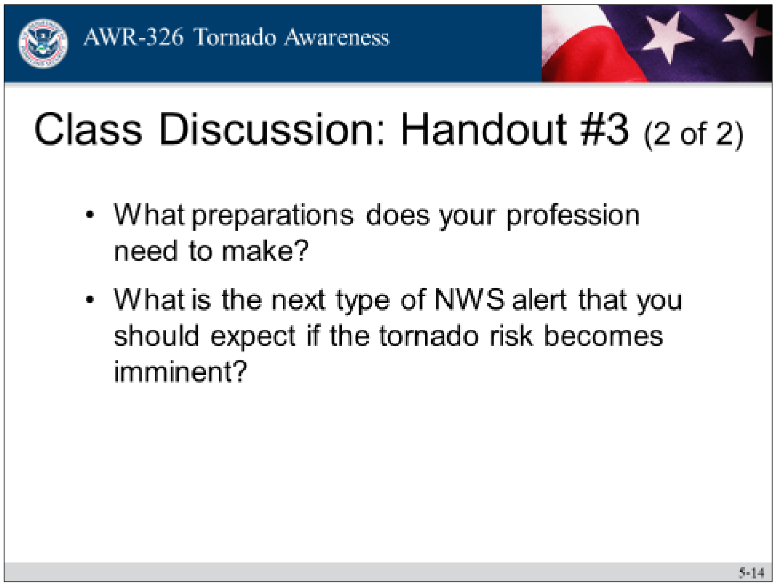
Slide 5-13. Class Discussion: Handout #3 (1 of 2)

Where is your area in relation to this potential 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?

What preparations does your profession need to make?

Participant Notes:

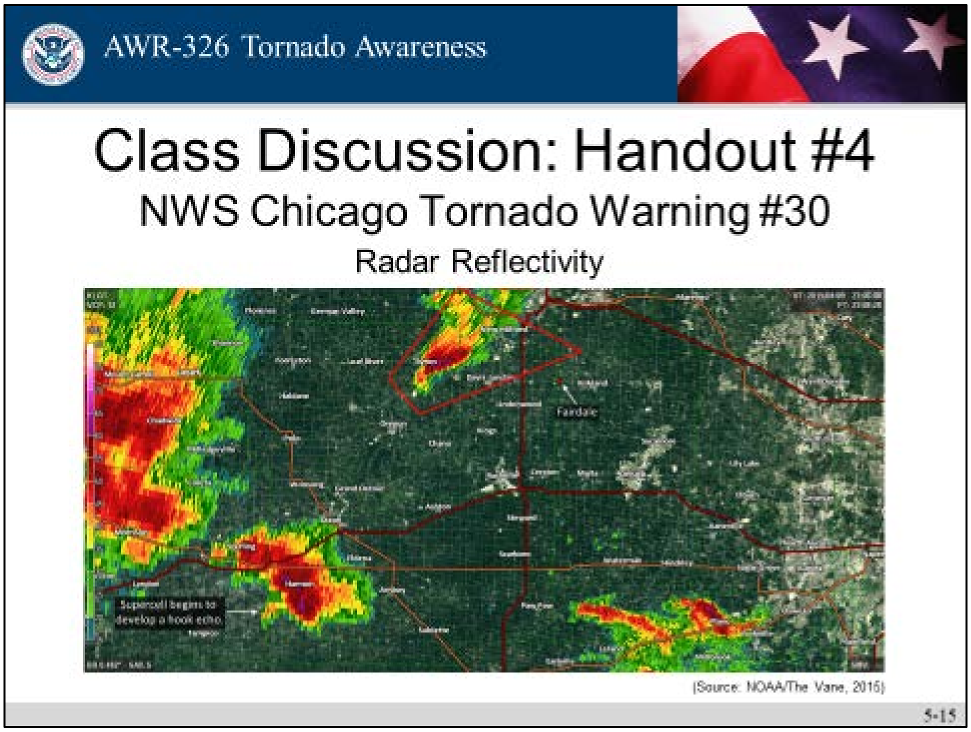


Slide 5-14. Class Discussion: Handout #3 (2 of 2)

What preparations does your profession need to make?

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

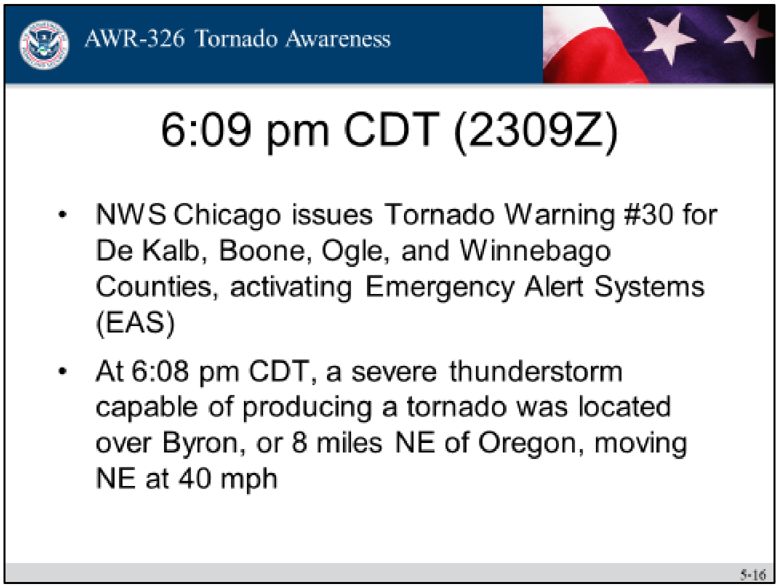
Participant Notes:



Slide 5-15. Class Discussion: Handout #4
NWS Chicago Tornado Warning #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 Fairdale.

Participant Notes:

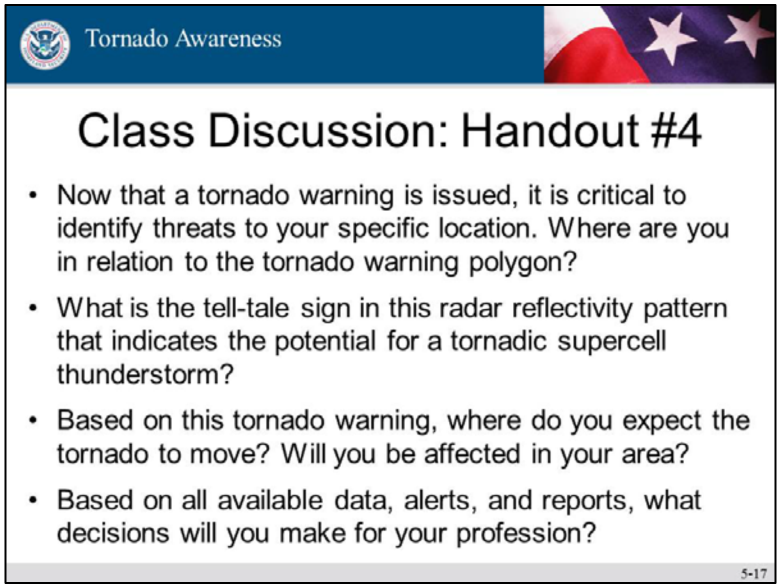


Slide 5-18. 6:09 pm CDT (2309Z)

At 6:09 pm CDT, the NWS WFO Chicago issued a tornado warning for NW De Kalb County in north central Illinois, SW Boone County in north central Illinois, NE Ogle County in north central Illinois, and SE Winnebago County in north central Illinois.

Radar indicated the hazard of tornadoes and quarter-size hail from a severe thunderstorm located over Byron. This was located to the NW of the area of interest.

Participant Notes:



Slide 5-17. Class Discussion: Handout #4

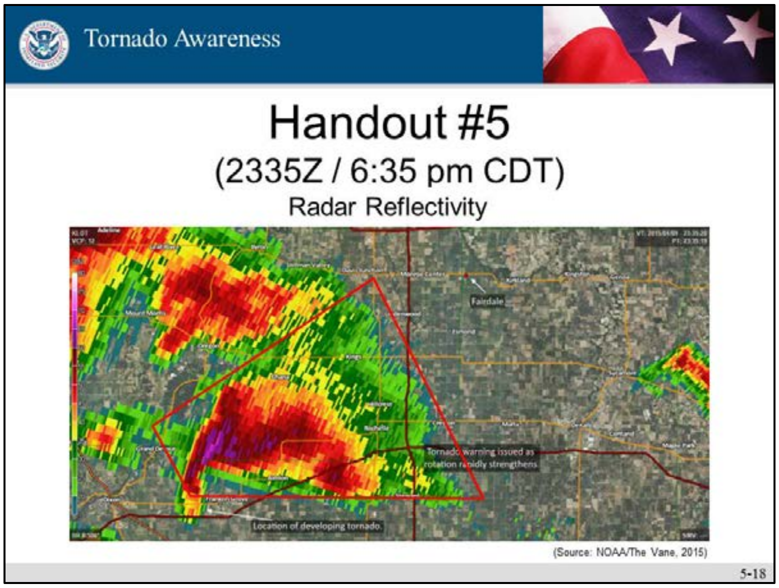
Now that a tornado threat is issued, it is critical to identify threats to your specific location. Where are you in relation to the tornado warning polygon?

What is 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 area?

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

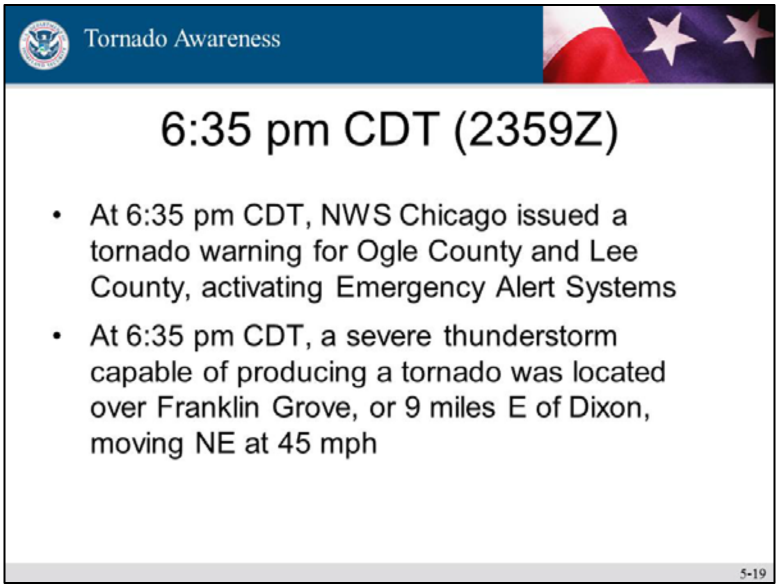
Participant Notes:



**Slide 5-18. Handout #5
(2335Z / 6:35 pm CDT)**

Module 5: Handout #5 (page 1 of 4) depicts a new tornado warning that was issued at 5:17 pm CDT (2217Z). This time, the warning includes the area of interest. The reflectivity shows a new hook echo developing to the southwest of the initial storm. 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 5-19. 6:35 pm CDT (2359Z)

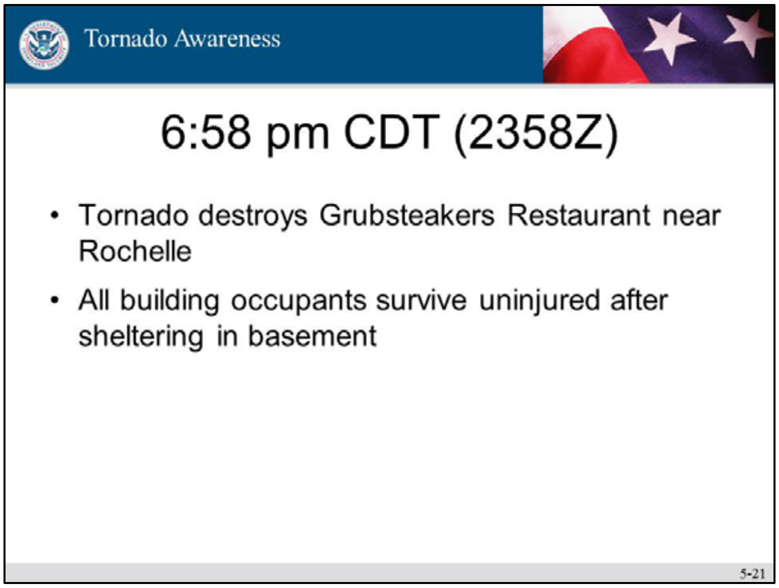
At 6:35 pm CDT, NWS Chicago issued a tornado warning for SE Ogle County and NE Lee County in north central Illinois.

Participant Notes:

Slide 5-20. Tornado Near I-39

This photo shows the large EF-4 tornado that developed SW of Rochelle, Illinois.

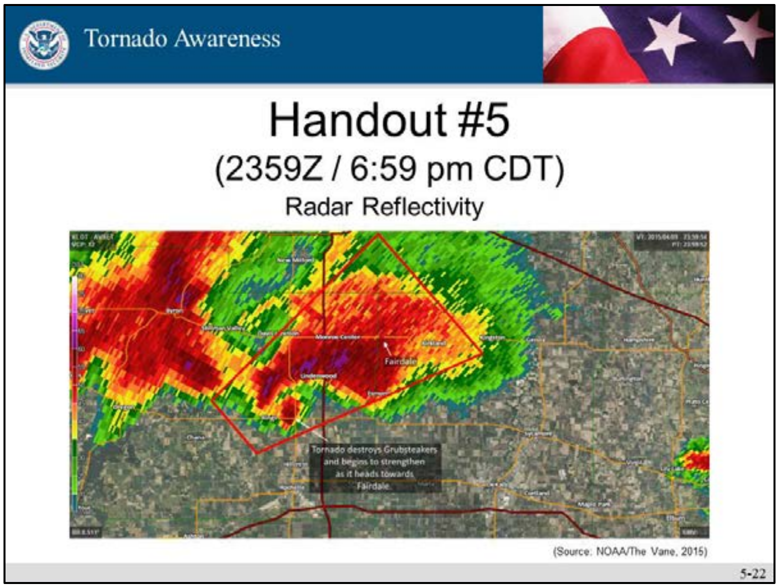
Participant Notes:



Slide 5-21. 6:58 pm CDT (2358Z)

At 5:58 pm CDT, the tornado approached Rochelle, Illinois, and destroyed the restaurant called Grubsteakers. Twelve people occupied the building including staff and customers. After the tornado warning, the restaurant owner immediately instructed everyone into the basement of the building, which was a storm cellar. Soon after, the tornado struck the building and destroyed it. The group was trapped in the basement by storm debris for two hours. After first responders arrived and removed the debris, all 12 survivors emerged uninjured.

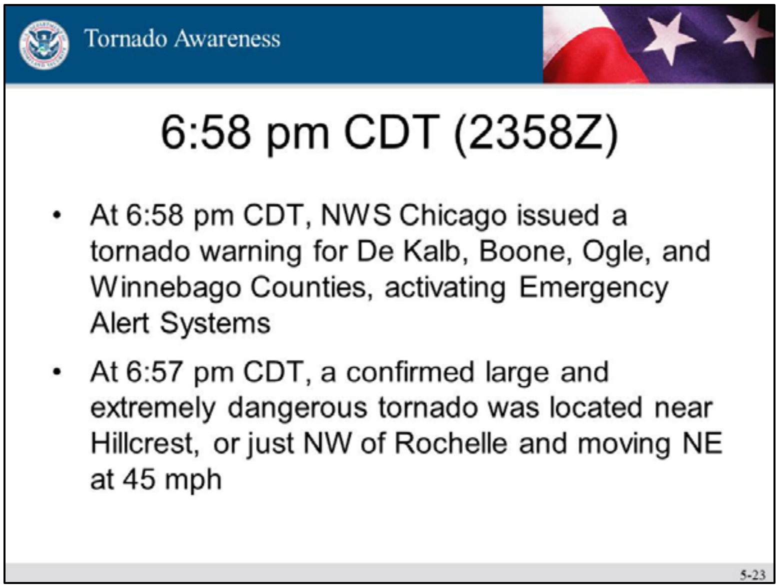
Participant Notes:



Slide 5-22. Handout #5
(2359Z / 6:59 pm CDT)

At 6:59 pm CDT, the tornado remained on the ground and moving NE towards Fairdale.

Participant Notes:



Slide 5-23. 6:58 pm CDT (2358Z)

At 6:58 pm CDT, NWS Chicago issued a tornado warning for NW De Kalb County, SW Boone County, SE Ogle County, and SE Winnebago County in north central Illinois. The warning text included:

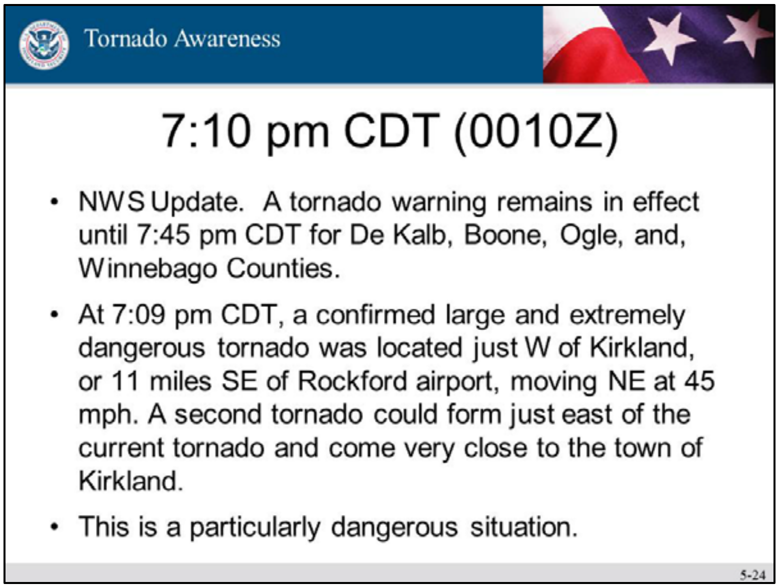
AT 657 PM CDT...A CONFIRMED LARGE AND EXTREMELY DANGEROUS TORNADO WAS LOCATED NEAR HILLCREST...OR JUST NORTHWEST OF ROCHELLE AND MOVING NORTHEAST AT 45 MPH.

THIS IS A PARTICULARLY DANGEROUS SITUATION.

IMPACT...YOU ARE IN A LIFE THREATENING SITUATION. FLYING DEBRIS MAY BE DEADLY TO THOSE CAUGHT WITHOUT SHELTER. MOBILE HOMES WILL BE DESTROYED. CONSIDERABLE DAMAGE TO HOMES...BUSINESSES AND VEHICLES IS LIKELY AND COMPLETE DESTRUCTION IS POSSIBLE.

A LARGE AND EXTREMELY DANGEROUS TORNADO IS ON THE GROUND. TAKE IMMEDIATE TORNADO PRECAUTIONS. THIS IS AN EMERGENCY SITUATION.

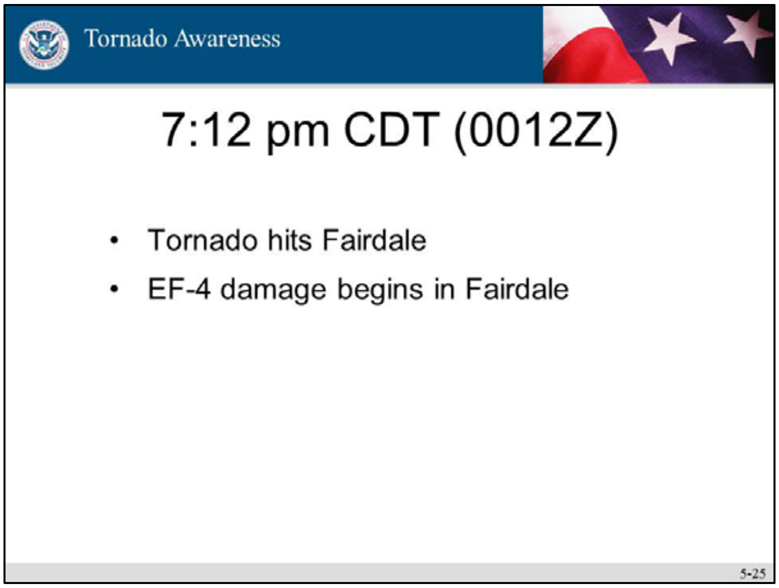
Participant Notes:



Slide 5-24. 7:10 pm CDT (0010Z)

The tornado continues moving toward Kirkland and Fairdale.

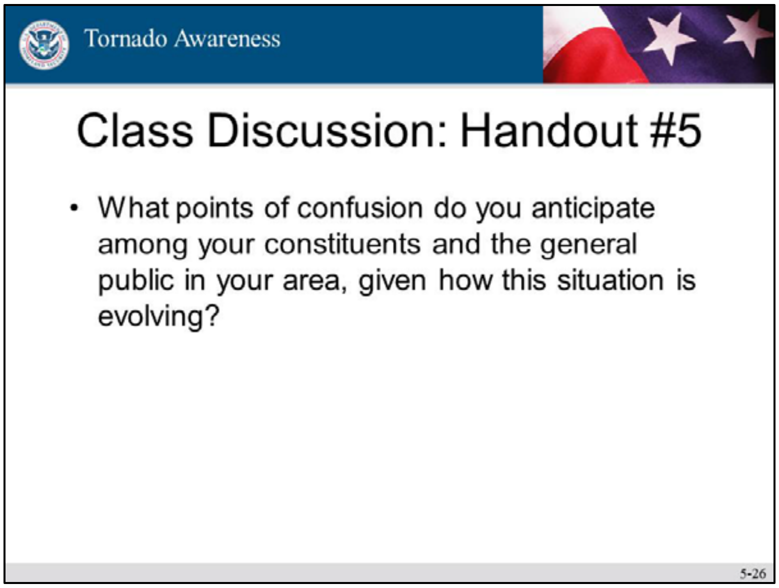
Participant Notes:



Slide 5-25. 7:12 pm CDT (0012Z)

At 7:12 pm CDT, the tornado enters Fairdale Illinois and EF-4 damage begins.

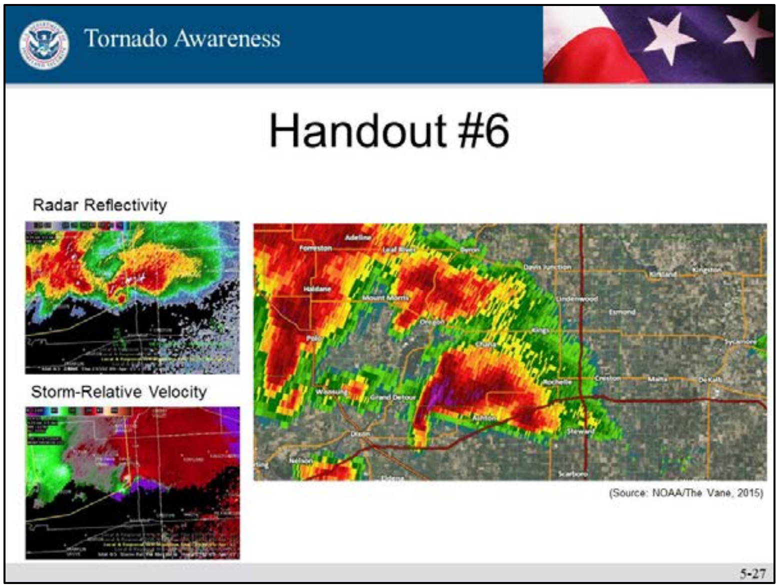
Participant Notes:



Slide 5-26. Class Discussion: Handout #5

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

Participant Notes:

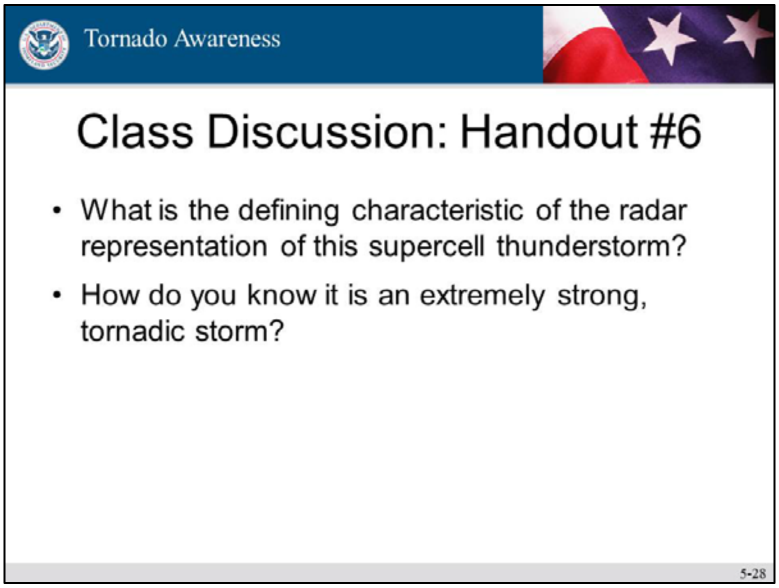


Slide 5-27. Handout #6

The final handout Module 5: Handout #6 (page 1 of 4) shows the radar reflectivity and storm-relative velocity as it approached Fairdale Illinois.

A base reflectivity radar animation of the storm event shows the progression of storms from southwest to northeast on that day.

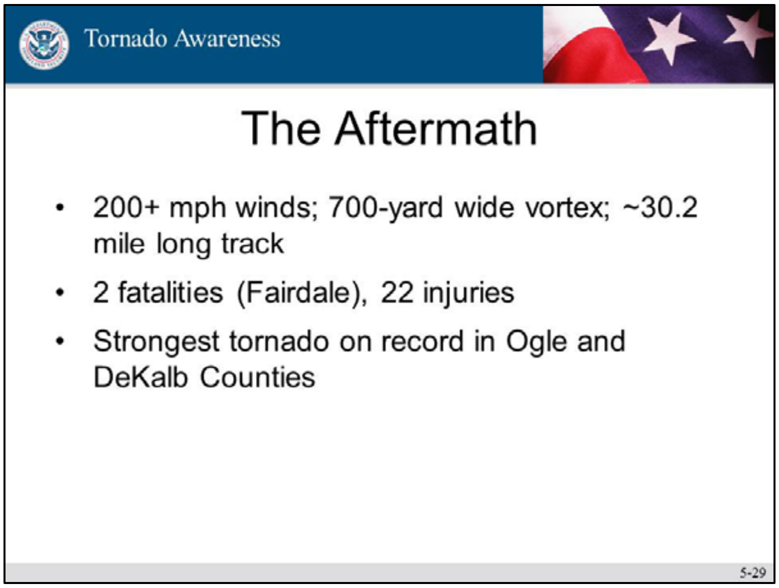
Participant Notes:



Slide 5-28. Class Discussion: Handout #6

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

Participant Notes:

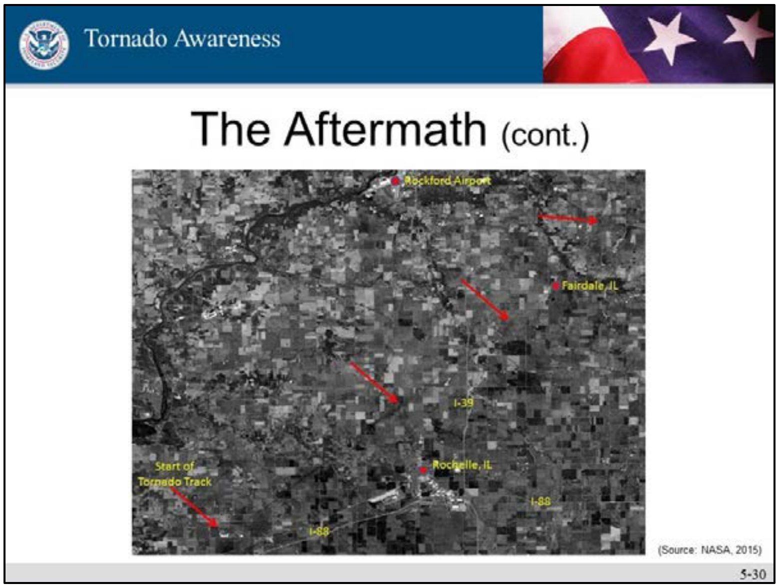


Slide 5-29. The Aftermath

Details regarding the aftermath are listed below:

- 200+ mph winds, 700 yard wide vortex, ~30.2 mile long track
- 2 fatalities, 22 injuries
- Strongest tornado on record in Ogle and DeKalb Counties

Participant Notes:

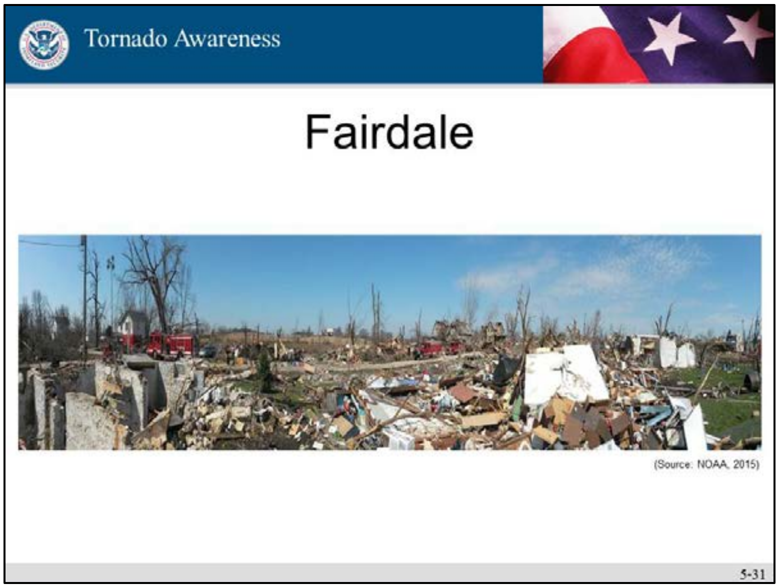


Slide 5-30. The Aftermath (continued)

Additional details of the aftermath are listed below:

- The image shown is a NASA satellite image of the area after the tornado. The tornado track can be seen starting southwest of Rochelle Illinois and stretching northeast all the way through Fairdale Illinois.

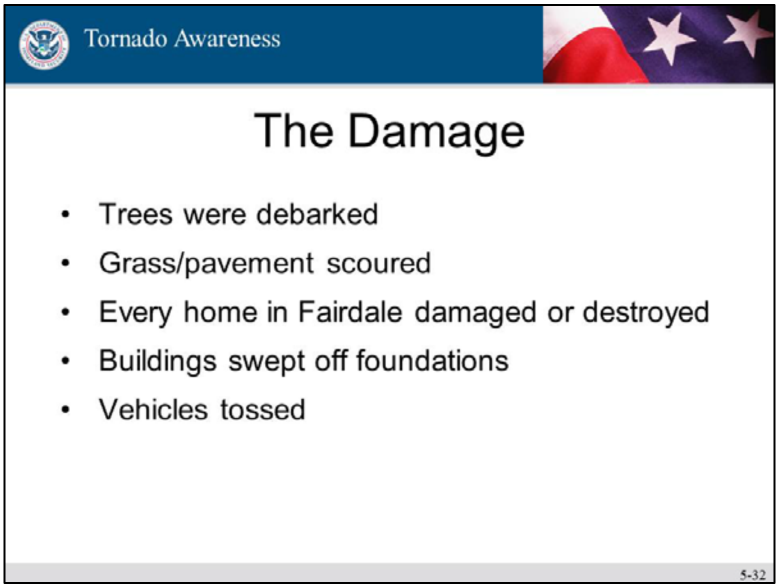
Participant Notes:



Slide 5-31. Fairdale

The town of Fairdale Illinois was devastated, sustaining EF-4 damage.

Participant Notes:

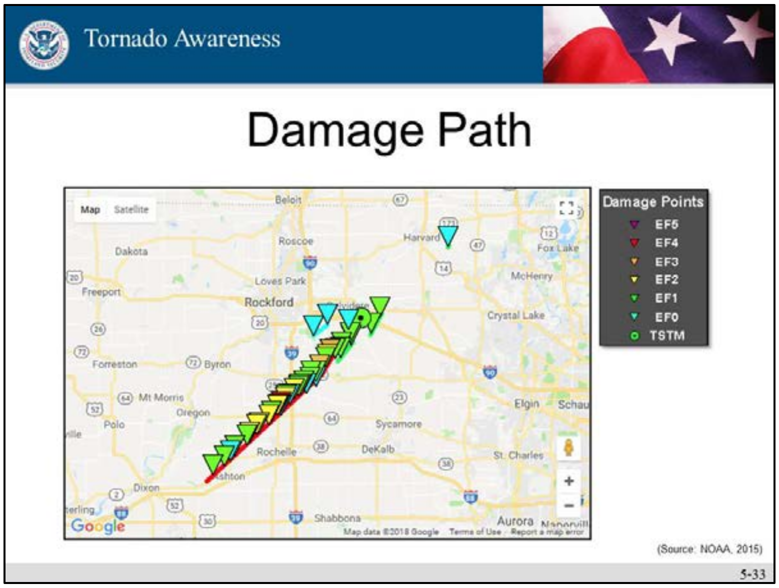


Slide 5-32. The Damage

Evidence of damage from the EF-4 tornado included the following:

- Trees were debarked
- Grass/pavement were scoured
- Every home in Fairdale Illinois was damaged or destroyed
- Buildings were swept off foundations
- Vehicles were tossed

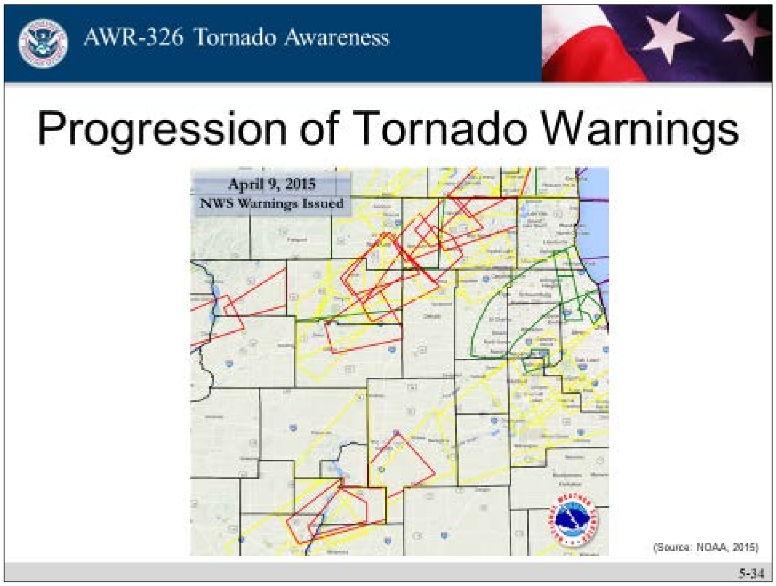
Participant Notes:



Slide 5-33. Damage Path

The post-storm damage survey conducted by the National Weather Service showed a swath of EF-4 damage ranging from Rochelle Illinois to Fairdale Illinois. The same storm also went on to produce an EF-1 tornado after the initial EF-4 tornado lifted.

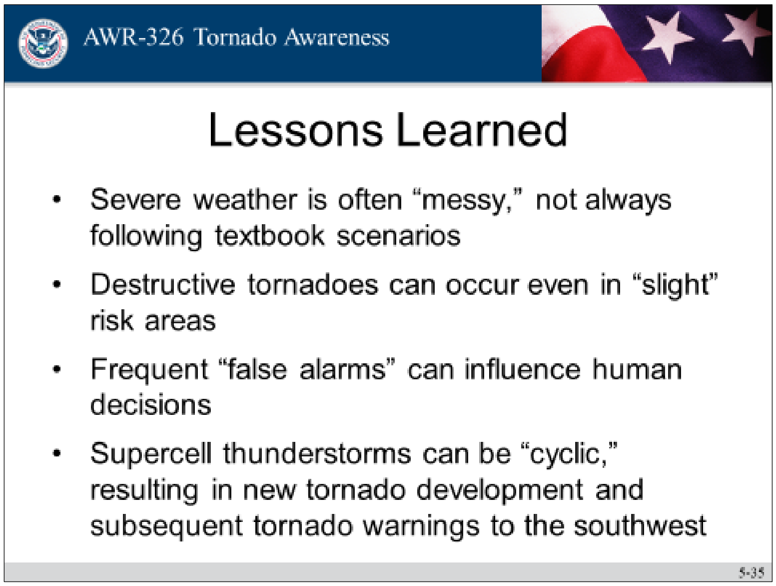
Participant Notes:



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:

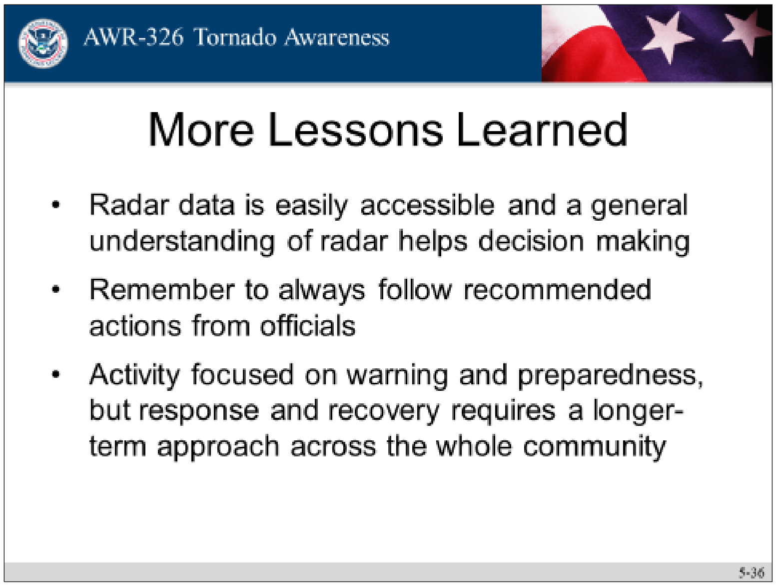


Slide 5-35. Lessons Learned

Some of the lessons learned included the following points:

- Severe weather is often “messy,” and does not always follow textbook scenarios.
- Destructive tornadoes can occur even in “slight” risk areas.
- Frequent “false alarms” can influence human decisions.
- Supercell thunderstorms can be “cyclic,” resulting in new tornado development and subsequent tornado warnings.

Participant Notes:



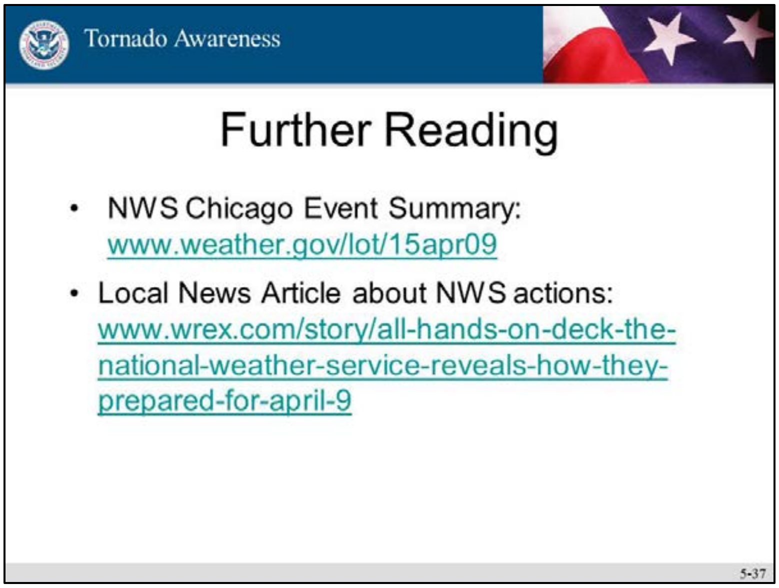
Slide 5-36. More Lessons Learned

Additional lessons from this event are provided below:

- Radar data is easily accessible and a general understanding of radar helps decision-making.
- Remember to always follow recommended actions from officials.
- 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 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:

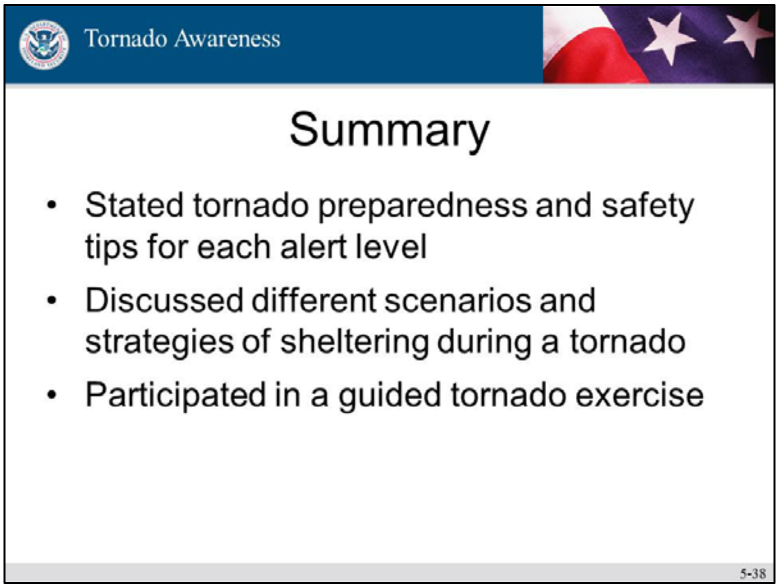


Slide 5-37. Further Reading

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 Chicago Event Summary: https://www.weather.gov/lot/15apr09
- Local News Article about NWS actions: http://www.wrex.com/story/31682517/2016/04/09/all-hands-on-deck-the-national-weather-service-reveals-how-they-prepared-for-april-9

Participant Notes:



Slide 5-38. 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.

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AWR-326
Tornado Awareness

Module 6: Evaluation and Conclusion

Version 2.0

U.S. DEPARTMENT OF HOMELAND SECURITY

FEMA

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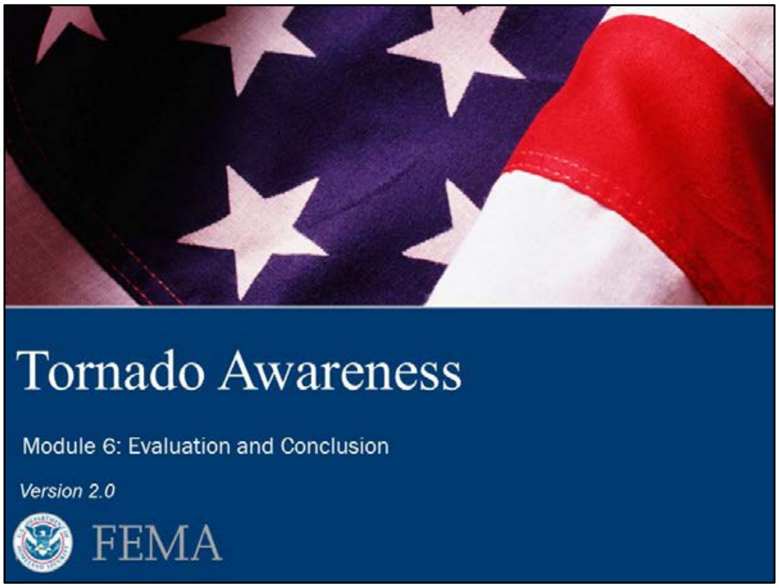
Module 6: Evaluation and Conclusion – Administration Page



Slide 6-1. Evaluation and Conclusion

Duration

45 minutes

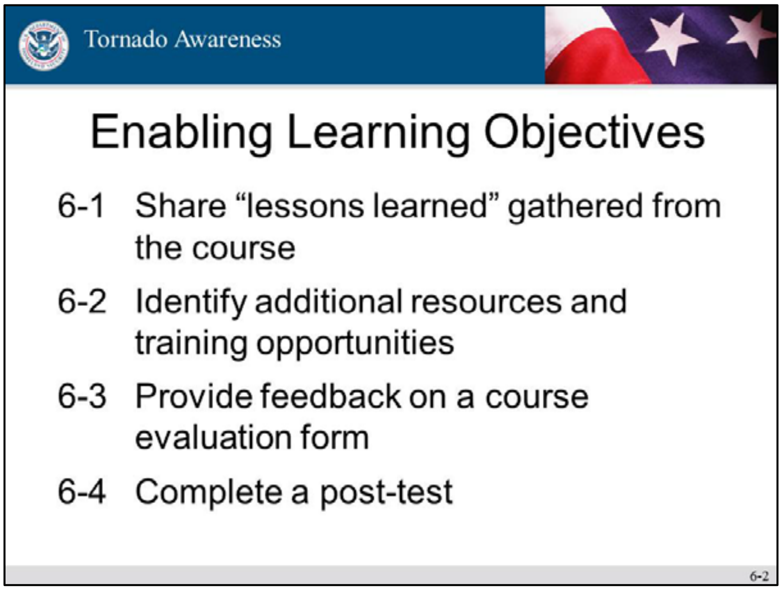
Scope Statement

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

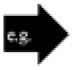
Assessment Strategy

- Instructor observation of participant involvement in classroom discussion
- Instructor 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.

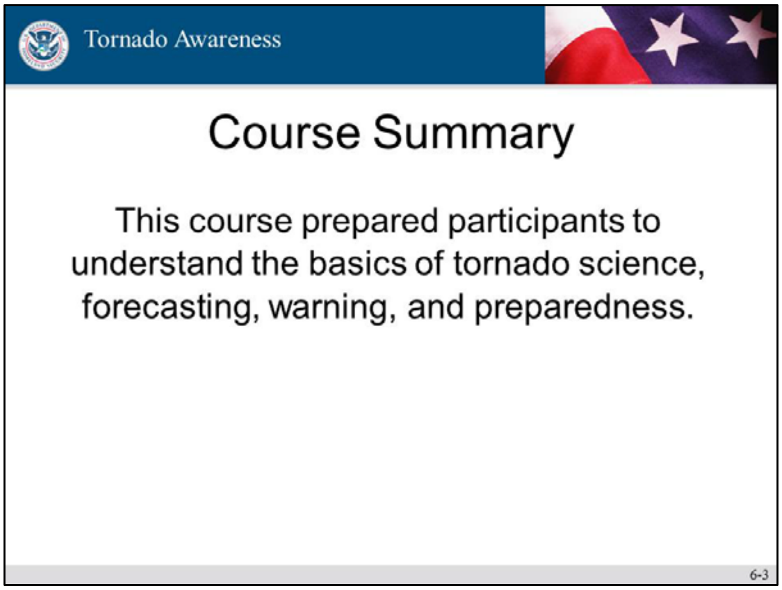
**Example**: Used when there is a descriptive illustration to show or explain.

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

**Hint**: Used to cover administrative items or instructional tips that aid in the flow of the instruction.

**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.

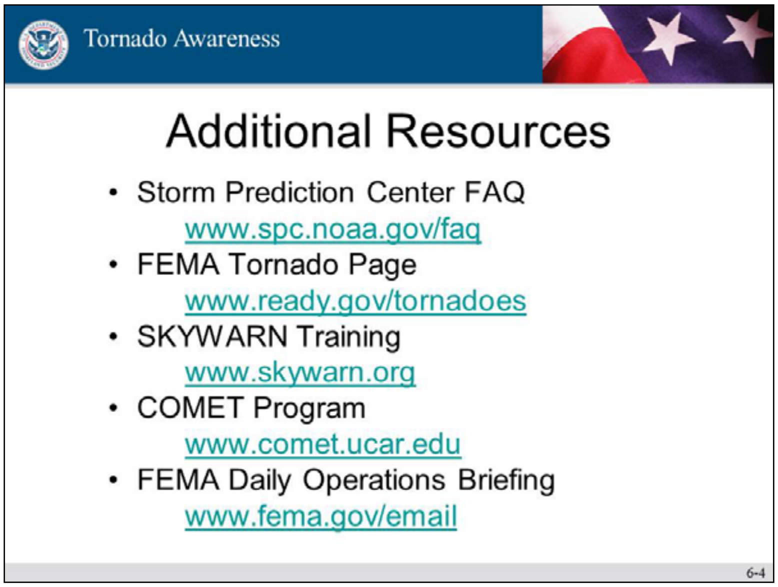
Participant Notes:



Slide 6-3. Course Summary

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

Participant Notes:

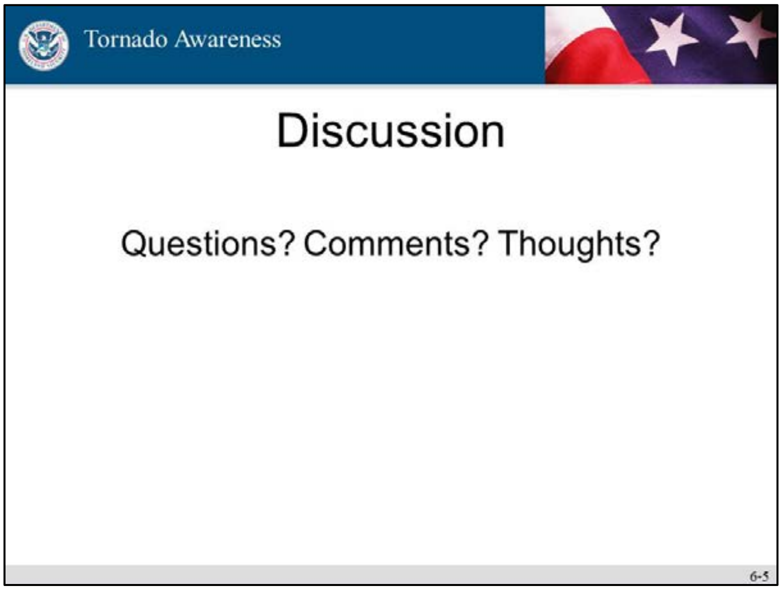


Slide 6-4. Additional Resources

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

- Storm Prediction Center FAQ, https://ndptc.basecamphq.com/projects/13081831/file/257279583/AWR326_PG_RC2019(2)19Jun20.docxhttps://ndptc.basecamphq.com/projects/13081831/file/257279583/AWR326_PG_RC2019(2)19Jun20.docx://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, https://www.fema.gov/email

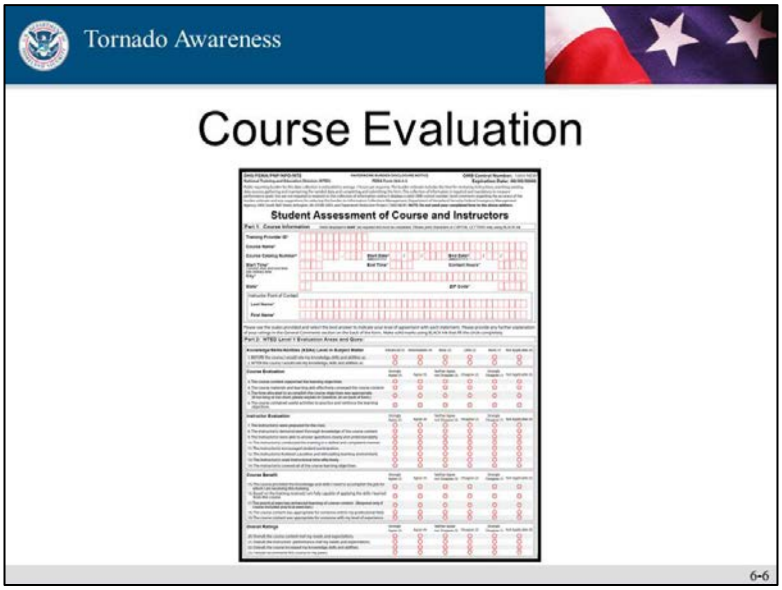
Participant Notes:



Slide 6-5. Discussion

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

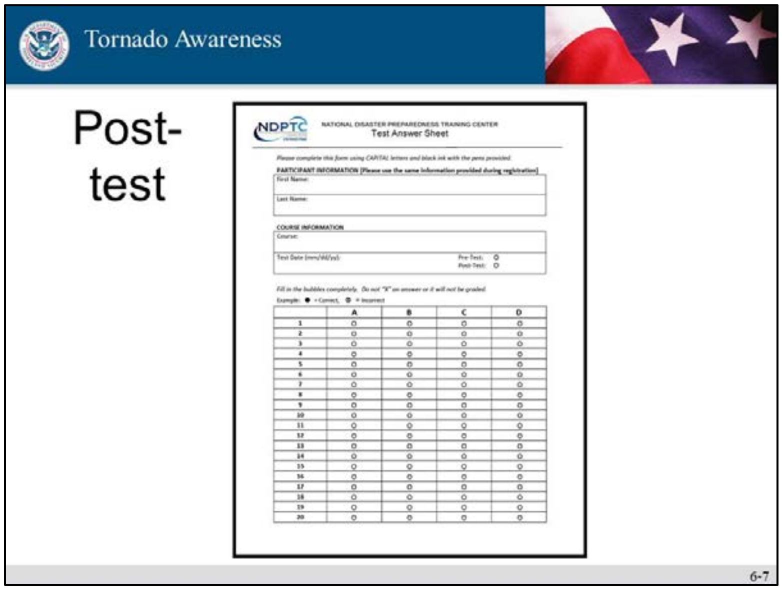
Participant Notes:



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:

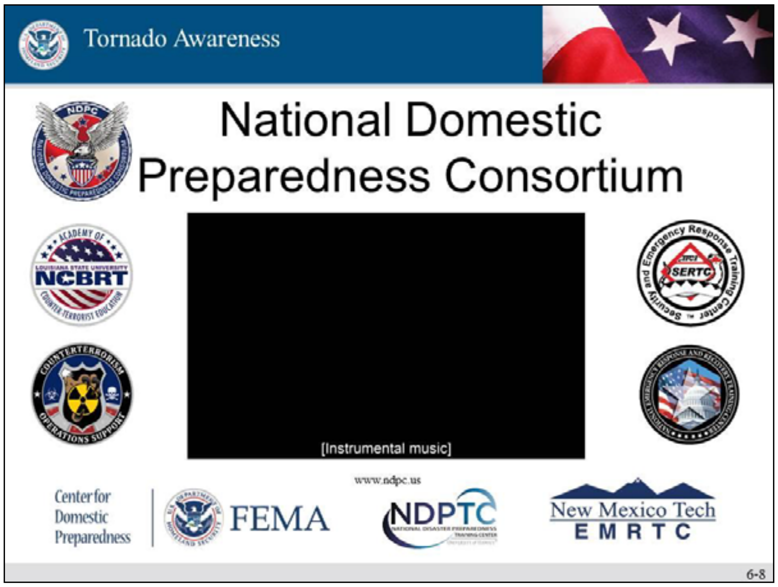


Slide 6-7. Post-test

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 National Domestic Preparedness Consortium (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);
- U.S. Department of Energy Nevada Test Site: Counter-Terrorism Operations Support; and
- Transportation Technology Center, Inc./Security and Emergency Response Training Center.

Each member brings a unique set of assets to the domestic preparedness program.

Unofficial Video Transcript
[Instrumental Music]
Preparing the Nation Through Training

National Center for Biomedical Research and Training:
Law Enforcement, Biological, and Food and Agricultural Training

Participant Notes:

Center for Radiological/Nuclear Training:
Prevention and Response to Radiological/Nuclear Attacks

Energetic Materials Research and Testing Center:
Explosive and Incendiary Attacks

National Disaster Preparedness Training Center:
Natural Disasters, Coastal Communities
Islands/Territories/Underserved at Risk Populations
Leveraging Technology

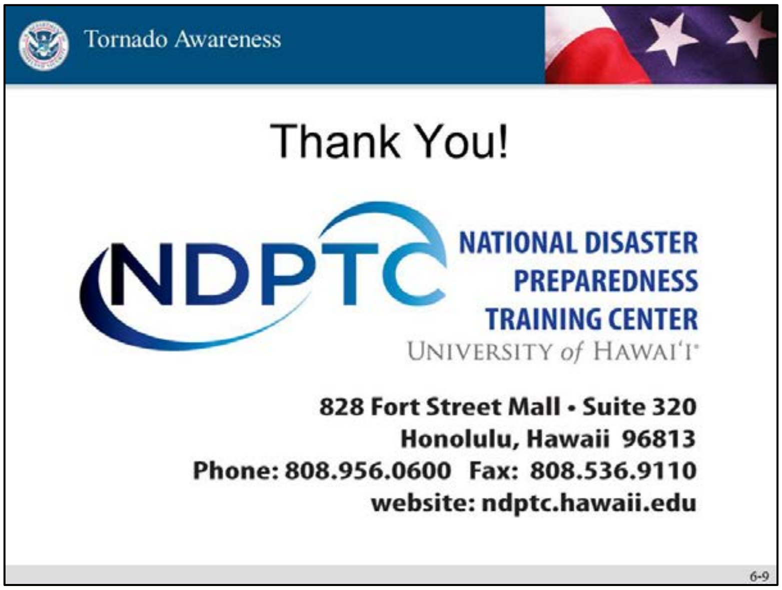
Security and Emergency Response Training Center:
Surface Transportation Response to Hazmat/WMD
Emergency Event Planning for Surface Transportation

FEMA Center for Domestic Preparedness:
Prevention, Deterrence and Response to CBRNE Hazards
Healthcare/Public Health Mass Casualty

National Emergency Response and Recovery Training Center:
Executive Officials/Crisis Communication
Infrastructure Protection, Threat and Risk Assessment
Search and Rescue, Sport Event Management Cybersecurity
Hazmat, Public Health/Medical Services, Incident Management

Partners Preparing the Nation Through Training
www.ndpc.us

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

Appendices

Version 2.0

FEMA

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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

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

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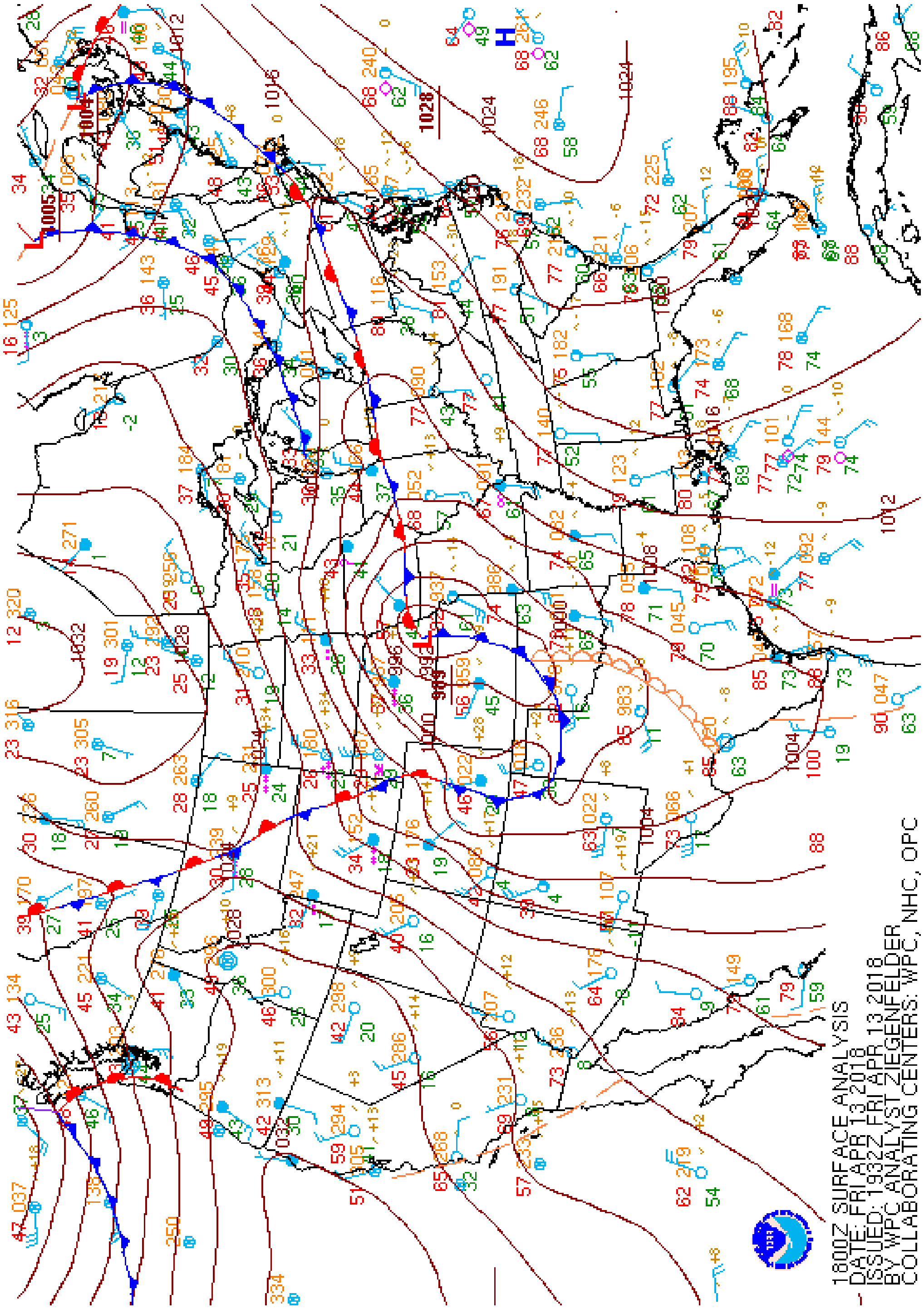
Module 3: Handout #1
Surface Analysis Map
(page 1 of 10)

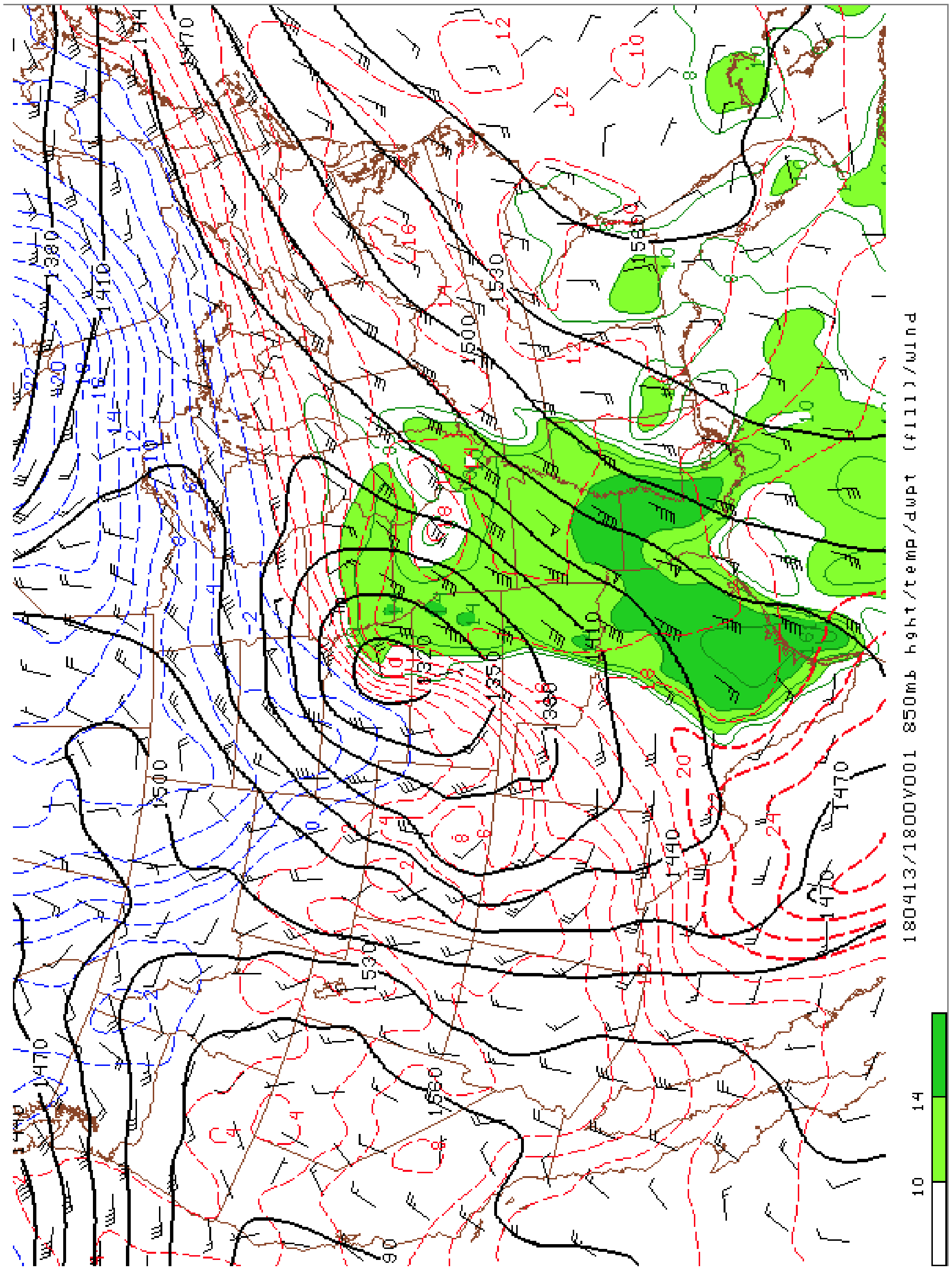


(Source: NOAA, 2018)

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 April 13, 2018. Note the mid-latitude cyclone over the northern Plains, with a frontal boundary draped through Kansas, Oklahoma, and Texas. 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)



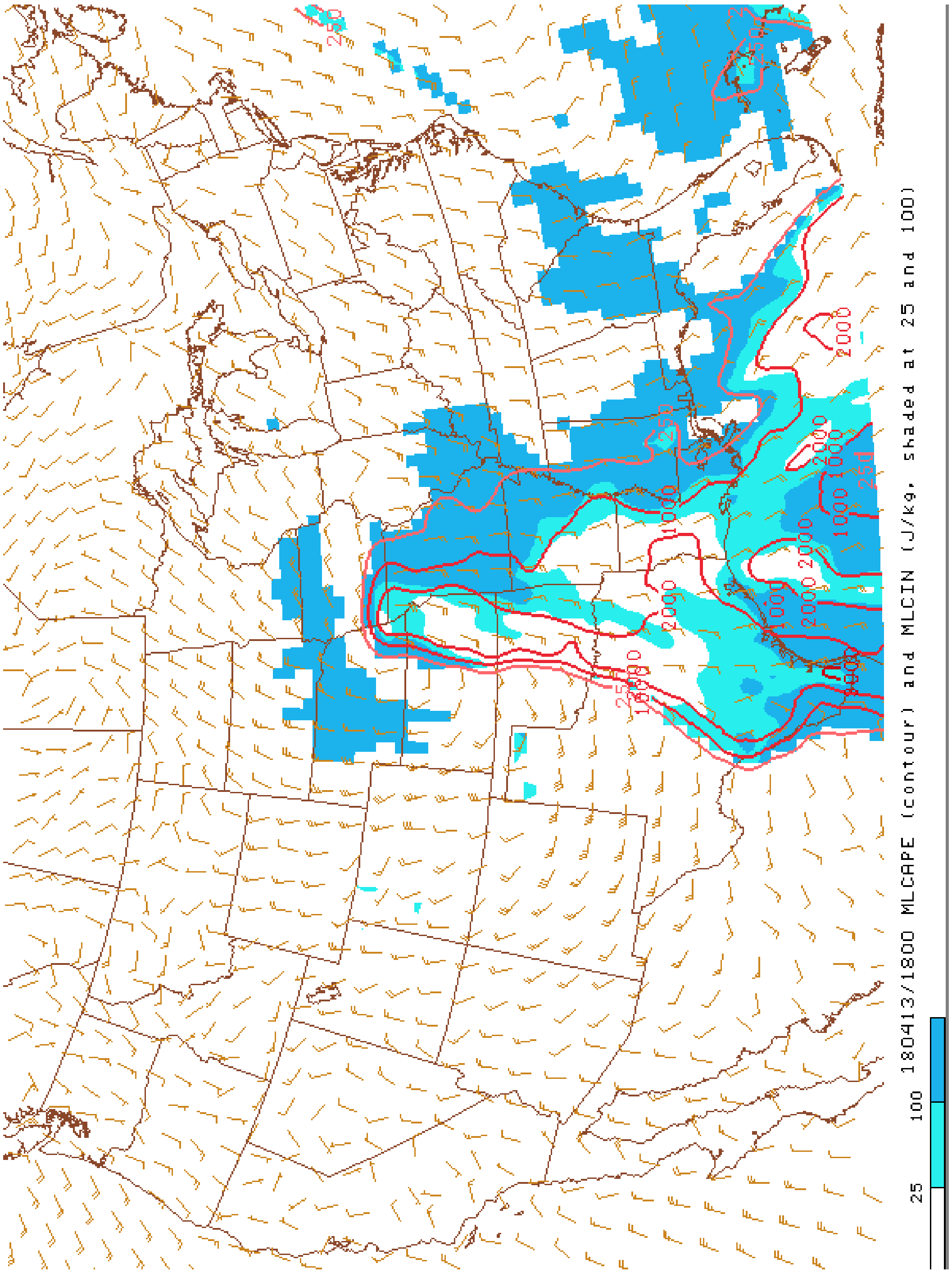
(Source: NOAA, 2018)

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)



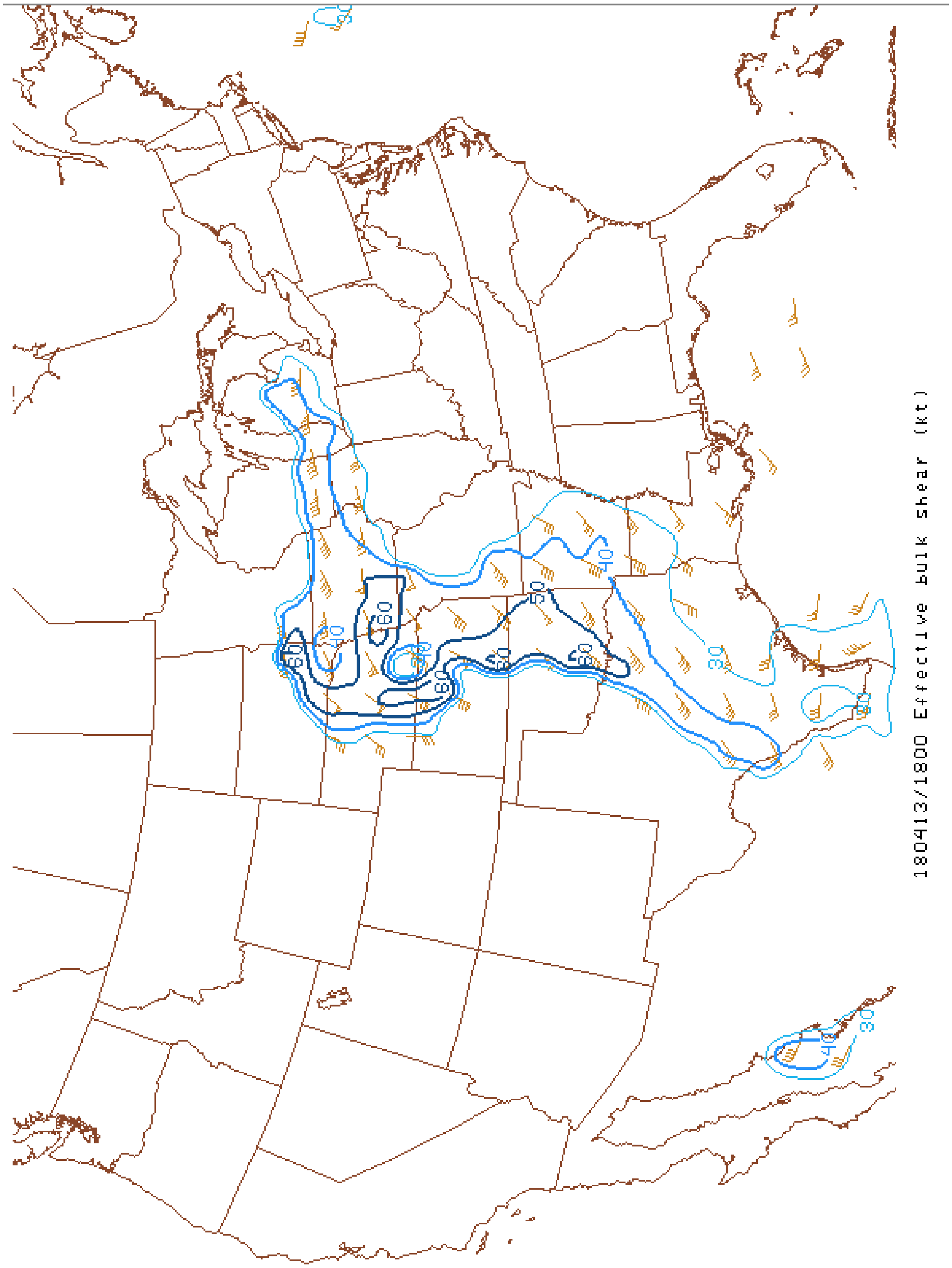
(Source: NOAA, 2018)

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, 2018)

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.

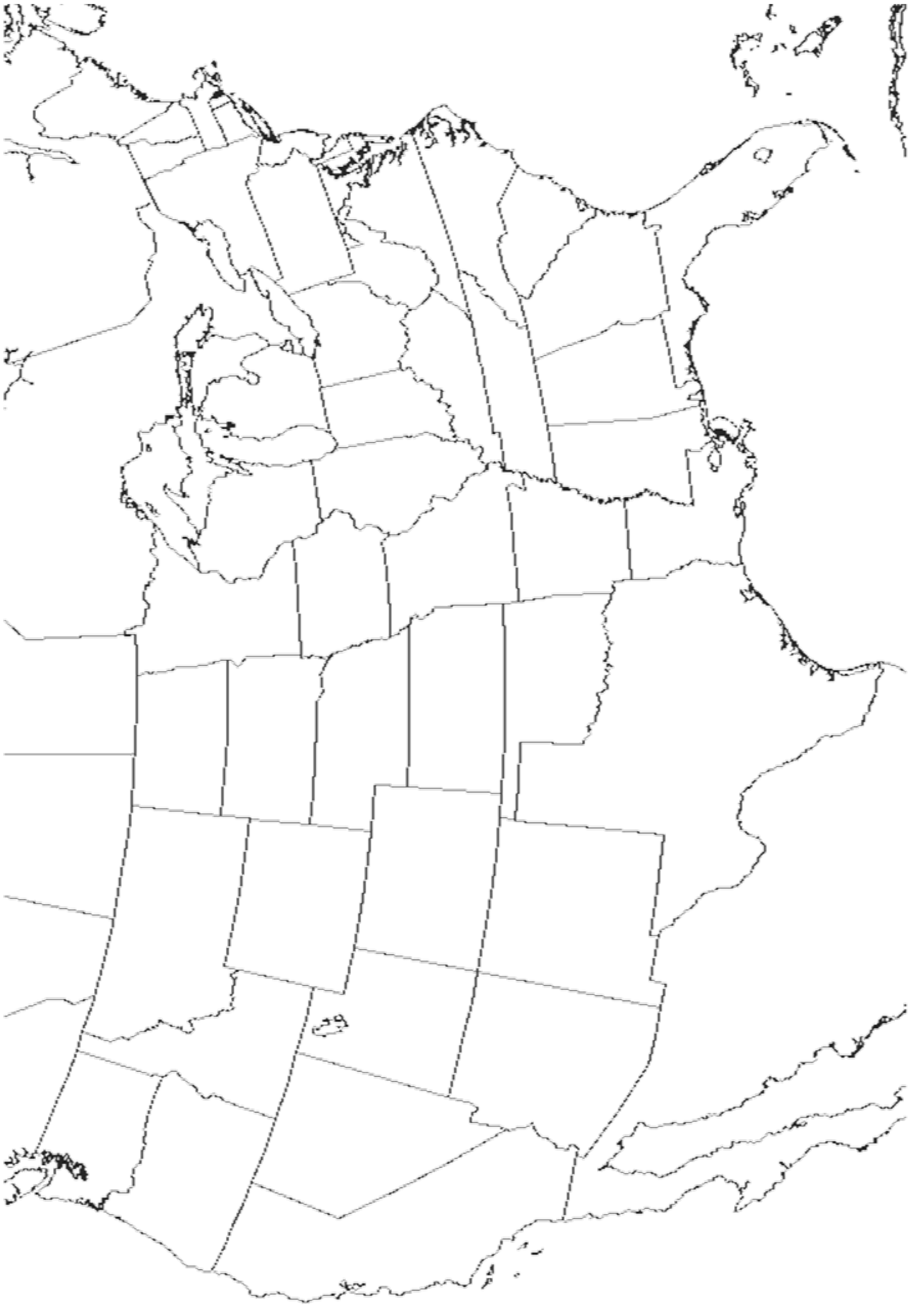
Module 3: Handout #1
Questions
(page 9 of 10)

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

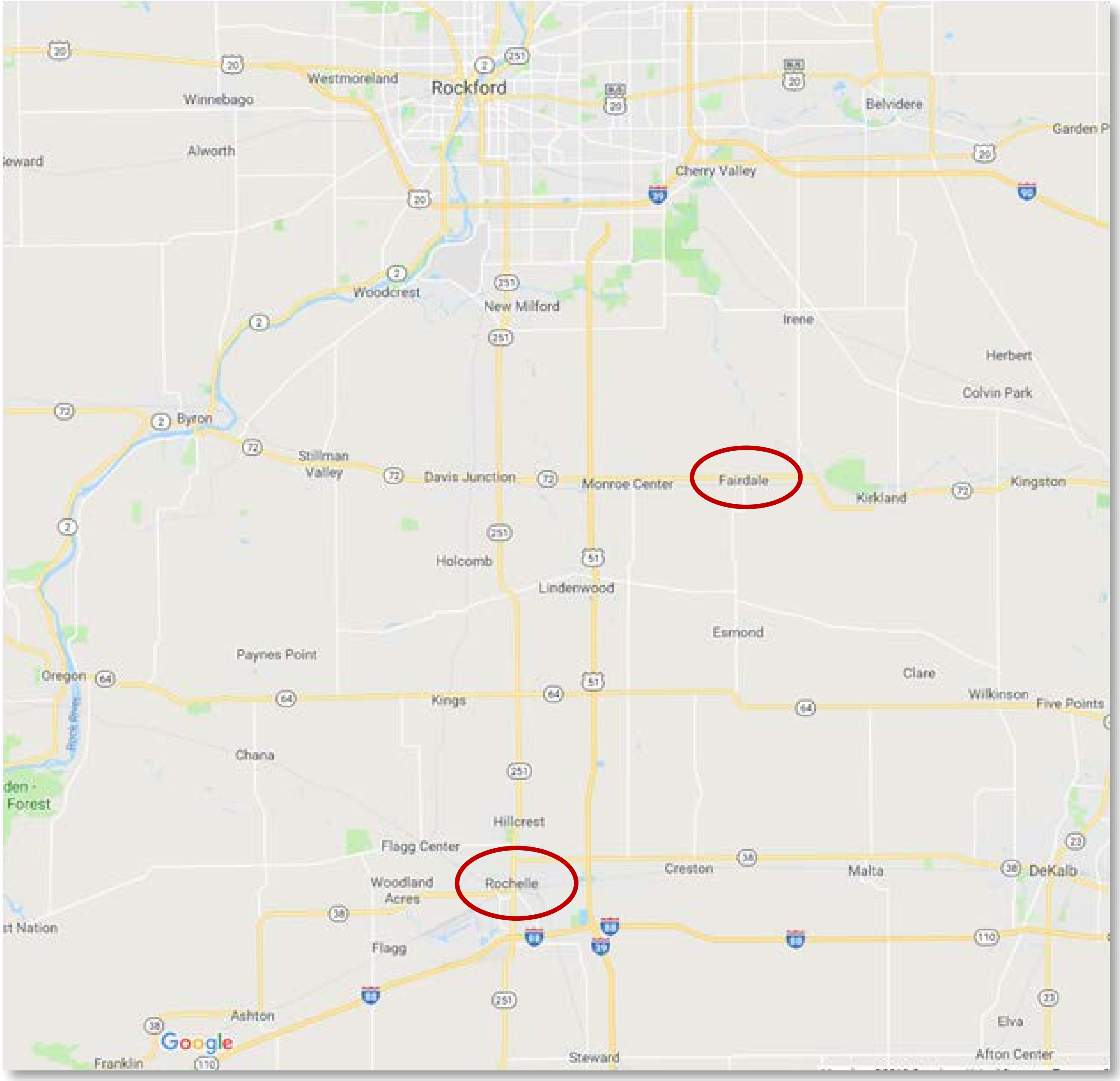
2. From your basic understanding of the science of tornadoes, assume you are a tornado forecaster. What parts of the country would you advise people to be prepared for tornadoes later in the day? Shade in the area of concern on the map on the next page.

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 Storm Area
(page 1 of 5)

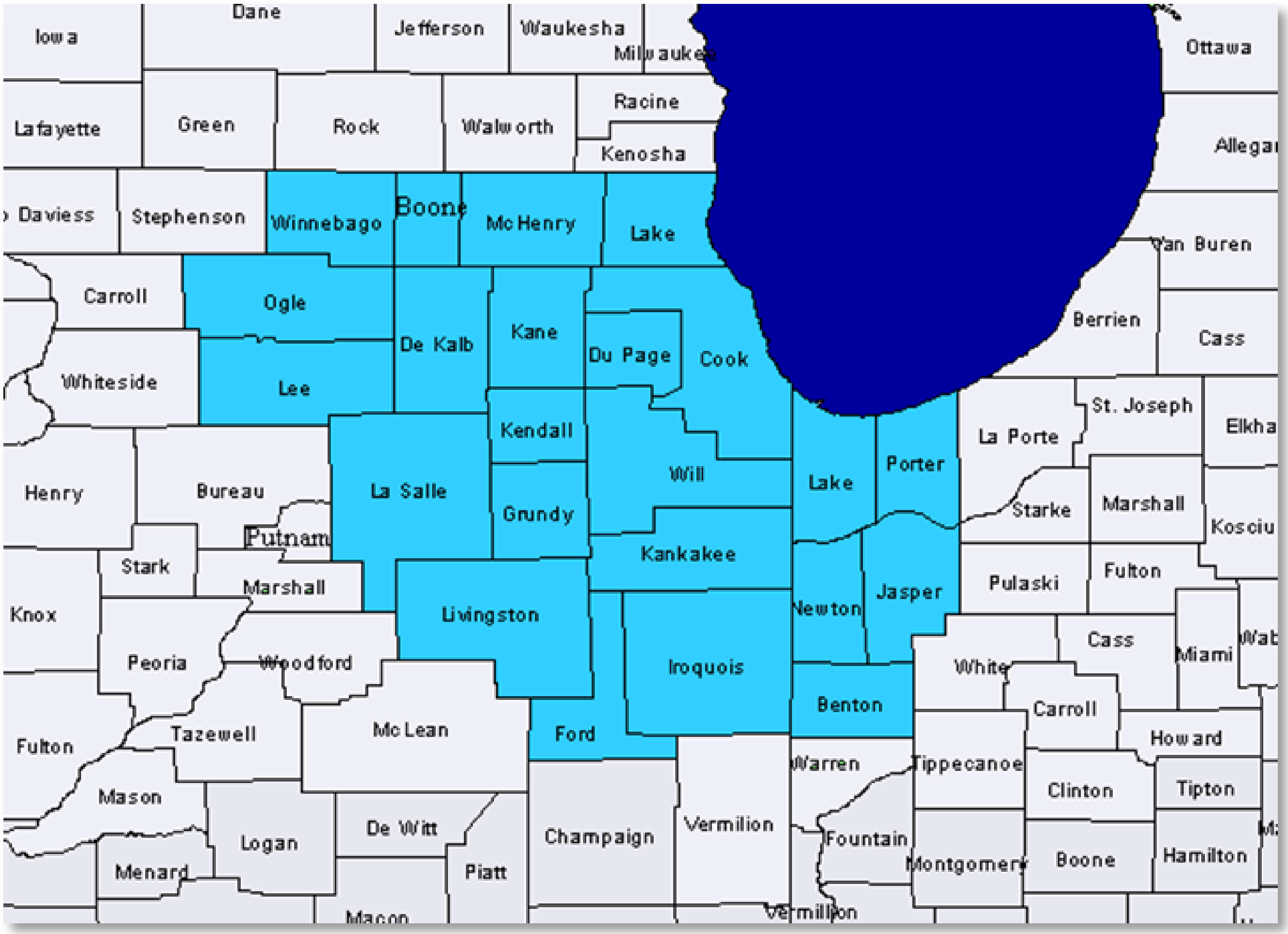


(Source: Google Maps, 2013)

Module 5: Handout #1
Map of Storm Area
(page 2 of 5)

Map of the storm area of interest. The towns of Rochelle and Fairdale in Illinois are circled.

Module 5: Handout #1
County Warning Area of Chicago, Illinois
(page 3 of 5)



(Source: NOAA, 2015)

Module 5: Handout #1
County Warning Area of Chicago, IL
(page 4 of 5)

Map of NWS WFO Chicago, Illinois, county warning area (CWA), showing Ogle and DeKalb Counties located in the northwestern portion 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?

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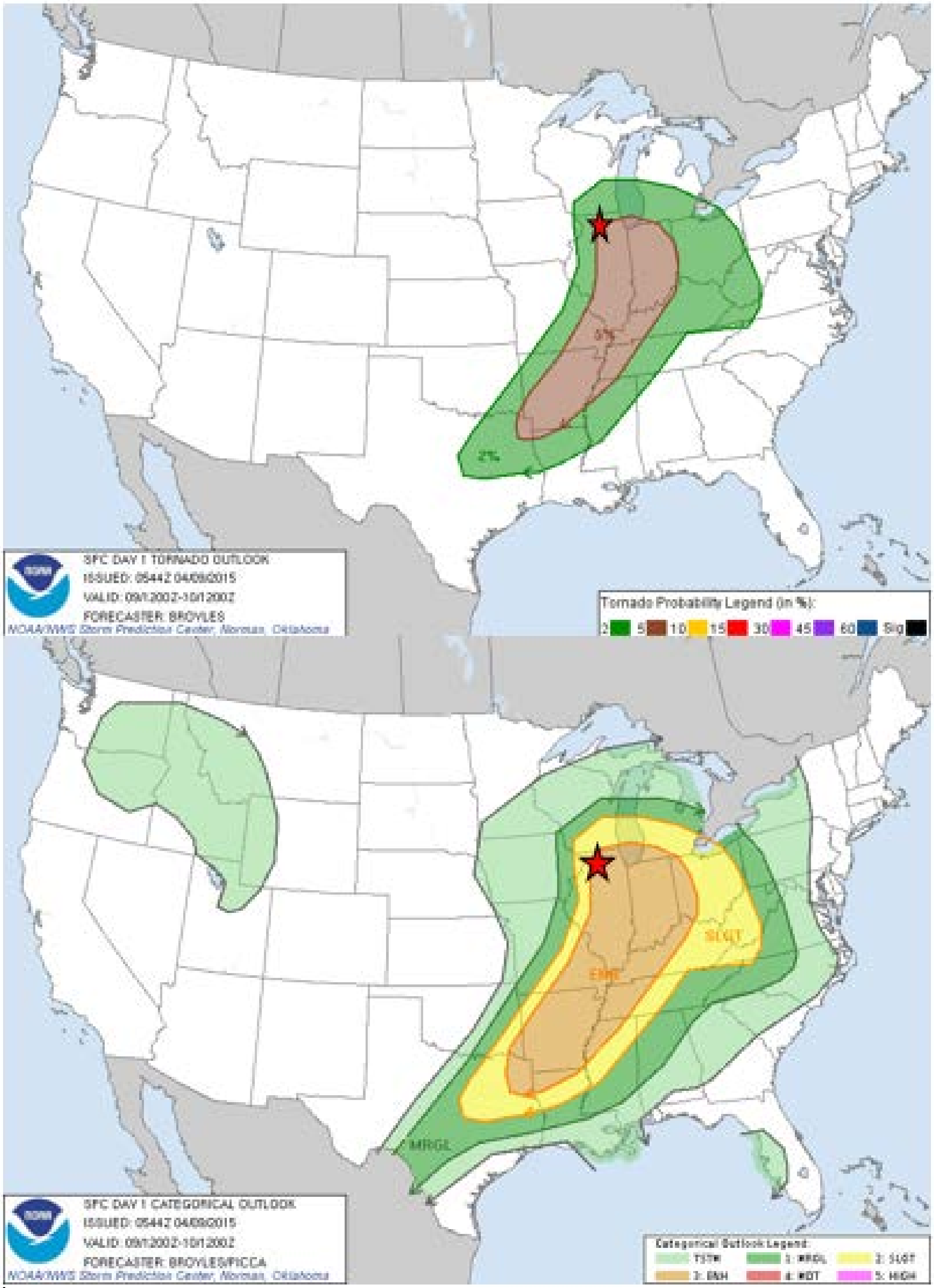
Module 5: Handout #2
SPC Convective Outlook (1300Z / 8:00 am CDT)

(page 1 of 4)



(Source: NOAA, 2015)

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

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. An enhanced severe weather risk (orange) extends from east Texas through Wisconsin.

Module 5: Handout #2

(page 3 of 4)

```
DAY 1 CONVECTIVE OUTLOOK
   NWS STORM PREDICTION CENTER NORMAN OK
  0800 AM CDT THU APR 09 2015

   VALID 1300Z - 1400Z

   ...THERE IS AN ENH RISK OF SVR TSTMS ACROSS PARTS OF NE TX...FAR SE
   OK...NRN LA...AR...NW MS...WRN TN...KY...SE MO...IL...FAR SRN
   WI...IND AND WRN OH...

   ...THERE IS A SLGT RISK OF SVR TSTMS ACROSS PARTS OF THE SRN
   PLAINS...LOWER TO MID MS VALLEY...OZARKS...OH VALLEY...SRN GREAT
   LAKES AND CNTRL APPALACHIAN MTNS...

   ...THERE IS A MRGL RISK OF SVR TSTMS ACROSS PARTS OF THE SRN
   PLAINS...LOWER TO MID MS VALLEY...OZARKS...TN VALLEY...OH
   VALLEY...SRN GREAT LAKES AND CNTRL APPALACHIANS...

   ...SUMMARY...
   SEVERE THUNDERSTORMS ARE LIKELY TODAY INTO TONIGHT FROM PARTS OF THE
   SOUTHERN PLAINS...NORTHEASTWARD INTO THE LOWER TO MID MISSISSIPPI
   VALLEY...OHIO VALLEY AND SOUTHERN GREAT LAKES REGION.  THIS WILL
   INCLUDE THE RISK FOR DAMAGING WIND GUSTS AND LARGE HAIL. A FEW
   TORNADOES MAY OCCUR WITH A STRONG TORNADO POSSIBLE.

   ...OH VALLEY/SRN GREAT LAKES/CNTRL APPALACHIANS...
   AN UPPER-LEVEL TROUGH WILL MOVE QUICKLY EWD ACROSS THE CNTRL AND NRN
   PLAINS TODAY AS A SFC LOW MOVES NEWD INTO THE UPPER MS VALLEY. A
   TRAILING COLD FRONT WILL MOVE EWD INTO THE MID MS VALLEY THIS
   AFTERNOON. A WARM FRONT IS FORECAST TO MOVE NWD INTO THE SRN GREAT
   LAKES...ALONG WHICH SCATTERED THUNDERSTORMS MAY BE ONGOING THIS
   MORNING. CONVECTIVE COVERAGE SHOULD GRADUALLY INCREASE ACROSS THE OH
   VALLEY AND SRN GREAT LAKES REGION DURING THE DAY AS A LOW-LEVEL JET
   MOVES INTO THE REGION FROM THE SOUTHWEST. STRENGTHENING WARM
   ADVECTION AND SFC HEATING MAY RESULT IN POCKETS OF MODERATE
   INSTABILITY BY EARLY AFTERNOON. AS THE COLD FRONT SWEEPS EWD ACROSS
   THE MID MS VALLEY THIS AFTERNOON...SFC-BASED THUNDERSTORMS SHOULD
   DEVELOP ALONG AND AHEAD OF THE FRONT WITH OTHER CELLS INITIATING EWD
   ACROSS THE WARM SECTOR IN THE OH VALLEY. THE DEVELOPMENT OF SEVERAL
   LINE SEGMENTS OR A SEMI-CONTINUOUS SQUALL LINE MAY OCCUR FROM THE
   LATE AFTERNOON INTO THE EVENING ACROSS THE REGION.

   NAM FORECAST SOUNDINGS AT 00Z/FRIDAY FROM ST LOUIS NEWD TO
   INDIANAPOLIS SHOW MLCAPE VALUES OF 1000 TO 1500 J/KG WITH SFC
   DEWPOINTS IN THE LOWER 60S F. THIS COMBINED WITH 40 TO 50 KT OF FLOW
   JUST ABOVE THE BOUNDARY LAYER SHOULD SUPPORT SEVERE STORMS WITH WIND
   DAMAGE POTENTIAL. LINE SEGMENTS THAT CAN ORGANIZE IN AREAS WHERE
   INSTABILITY BECOMES MAXIMIZED COULD DEVELOP AN ENHANCED WIND-DAMAGE
   THREAT. THE SHEAR ENVIRONMENT SHOULD ALSO SUPPORT SUPERCELL
   DEVELOPMENT BUT THIS WILL DEPEND UPON THE PREFERRED STORM MODE. THE
   MOST FAVORABLE AREA FOR SUPERCELLS WOULD BE IN CNTRL AND NRN IL
   WHERE THE LOW AND MID-LEVEL JET IS FORECAST TO COUPLE JUST AHEAD OF
   A VORTICITY MAX. ANOTHER AREA OF POTENTIAL FOR SUPERCELLS COULD BE
   ACROSS THE OH VALLEY WHERE CELLS MAY TEND TO BE DISCRETE AND MODELS
   FORECAST A POCKET OF MODERATE INSTABILITY. ANY SUPERCELL THAT CAN
   ORGANIZE WILL HAVE POTENTIAL FOR HAIL AND POSSIBLY TORNADOES. A
   STRONG TORNADO CAN NOT BE RULED OUT ACROSS THE REGION BUT THIS
   SHOULD DEPEND ON MESOSCALE FACTORS. DUE TO UNCERTAINTY CONCERNING
   THE LOCATION...WILL DEFER TO LATER OUTLOOKS.
```

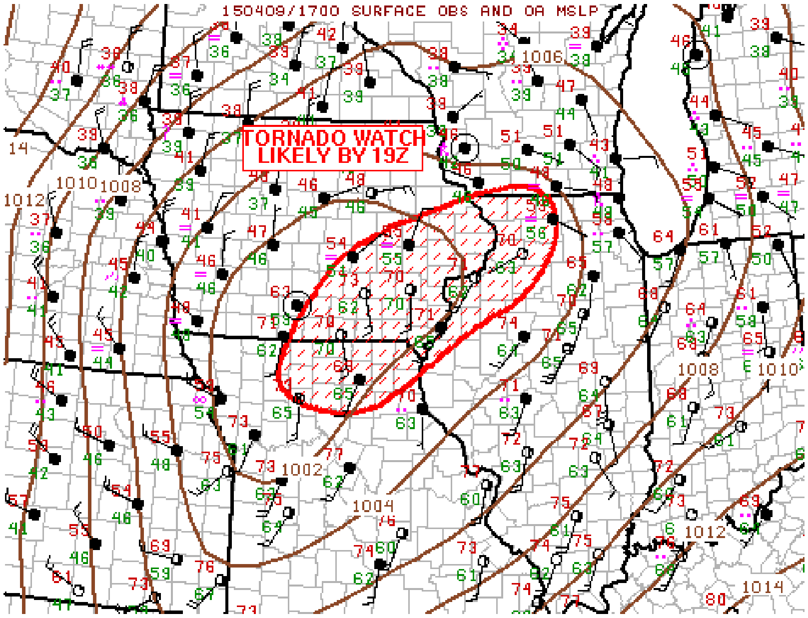
Module 5: Handout #2
Discussion Questions
(page 4 of 4)

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. There are no storms this morning, it is chilly and drizzly, and people are wondering why you are preparing for severe weather later. How do you respond?

Module 5: Handout #3
SPC Mesoscale Discussion (1729Z / 12:29 pm CDT)
(page 1 of 3)



SPC MCD #0246

Graphical update to the tornado watch showing a continuing threat in the area.

MESOSCALE DISCUSSION 0246
NWS STORM PREDICTION CENTER NORMAN OK
1229 PM CDT THU APR 09 2015

AREAS AFFECTED...NERN MO...SRN/ERN IA...NWRN IL

CONCERNING...SEVERE POTENTIAL...TORNADO WATCH LIKELY

VALID 091729Z - 091900Z

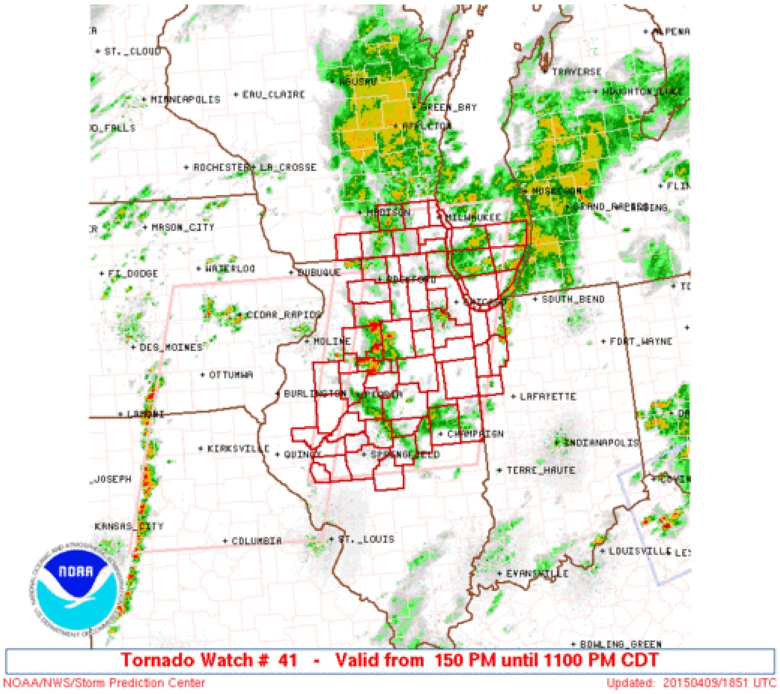
PROBABILITY OF WATCH ISSUANCE...95 PERCENT

SUMMARY...TORNADO WATCH WILL LIKELY BE ISSUED BY 19Z FROM NORTHERN MO INTO NWRN IL.

DISCUSSION...INTENSE MID-LEVEL HEIGHT FALLS ARE EXPECTED TO DEVELOP/SPREAD ACROSS IA INTO SRN WI/NRN IL LATER THIS EVENING. THIS SHOULD ENCOURAGE/FOCUS ASCENT AHEAD OF DEEPENING SFC LOW AS IT TRACKS FROM NWRN MO...INTO SERN IA BY 21Z. LATEST VIS IMAGERY DEPICTS DEEPENING THERMALS ALONG N-S WIND SHIFT OVER IA/MO AND THIS IS SUPPORTED BY RECENT INCREASE IN SHOWERS FROM NORTH OF MCI TO NEAR LWD. AS BOUNDARY LAYER CONTINUES TO WARM THERE IS INCREASING CONFIDENCE THAT CONVECTION WILL DEEPEN AND TSTMS SHOULD DEVELOP. STRONG SHEAR WILL LEAD TO DISCRETE SUPERCELLS EARLY IN THE CONVECTIVE CYCLE. FORECAST STORM MOTIONS APPEAR FAVORABLE FOR CONVECTION TO UTILIZE SHEAR ALONG E-W BOUNDARY DRAPED ACROSS IA/NRN IL AND TORNADOES MAY BE NOTED WITH THE MOST INTENSE STRUCTURES.

TORNADO THREAT SHOULD INCREASE DOWNSTREAM ACROSS NRN IL LATER THIS AFTERNOON AND THIS THREAT WILL BE ADDRESSED WITHIN A FEW HOURS.

Module 5: Handout #3
SPC Tornado Watch (1850Z / 1:50 pm CDT)
(page 2 of 3)



Map showing a tornado watch extending over northern Illinois

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URGENT - IMMEDIATE BROADCAST REQUESTED
   TORNADO WATCH NUMBER 41
   NWS STORM PREDICTION CENTER NORMAN OK
   150 PM CDT THU APR 9 2015

   THE NWS STORM PREDICTION CENTER HAS ISSUED A

   * TORNADO WATCH FOR PORTIONS OF
     NORTHERN AND CENTRAL ILLINOIS
     FAR NORTHWEST INDIANA
     FAR SOUTHERN WISCONSIN
     LAKE MICHIGAN

   * EFFECTIVE THIS THURSDAY AFTERNOON AND EVENING FROM 150 PM UNTIL
     1100 PM CDT.

   * PRIMARY THREATS INCLUDE...
     A FEW TORNADOES LIKELY WITH A COUPLE INTENSE TORNADOES POSSIBLE
     SCATTERED DAMAGING WINDS LIKELY WITH ISOLATED SIGNIFICANT GUSTS
       TO 80 MPH POSSIBLE
     SCATTERED LARGE HAIL AND ISOLATED VERY LARGE HAIL EVENTS TO 2.5
       INCHES IN DIAMETER POSSIBLE

DISCUSSION...TWO ROUNDS OF SEVERE CONVECTION ARE EXPECTED WITH
   INITIAL STORMS IN CENTRAL ILLINOIS DEVELOPING E/NE AND ADDITIONAL
   STORMS ALONG A FRONTAL ZONE. BOTH AREAS WILL HAVE STRONG DEEP-LAYER
   SHEAR SUPPORTING RISKS FOR A FEW TORNADOES...LARGE HAIL AND DAMAGING
   WINDS.
```

(Source: NOAA, 2015)

Module 5: Handout #3

Discussion Questions

(page 3 of 3)

1. Where is your area in relation to this potential 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 within the tornado watch area?

3. What preparations does your profession need to make?

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

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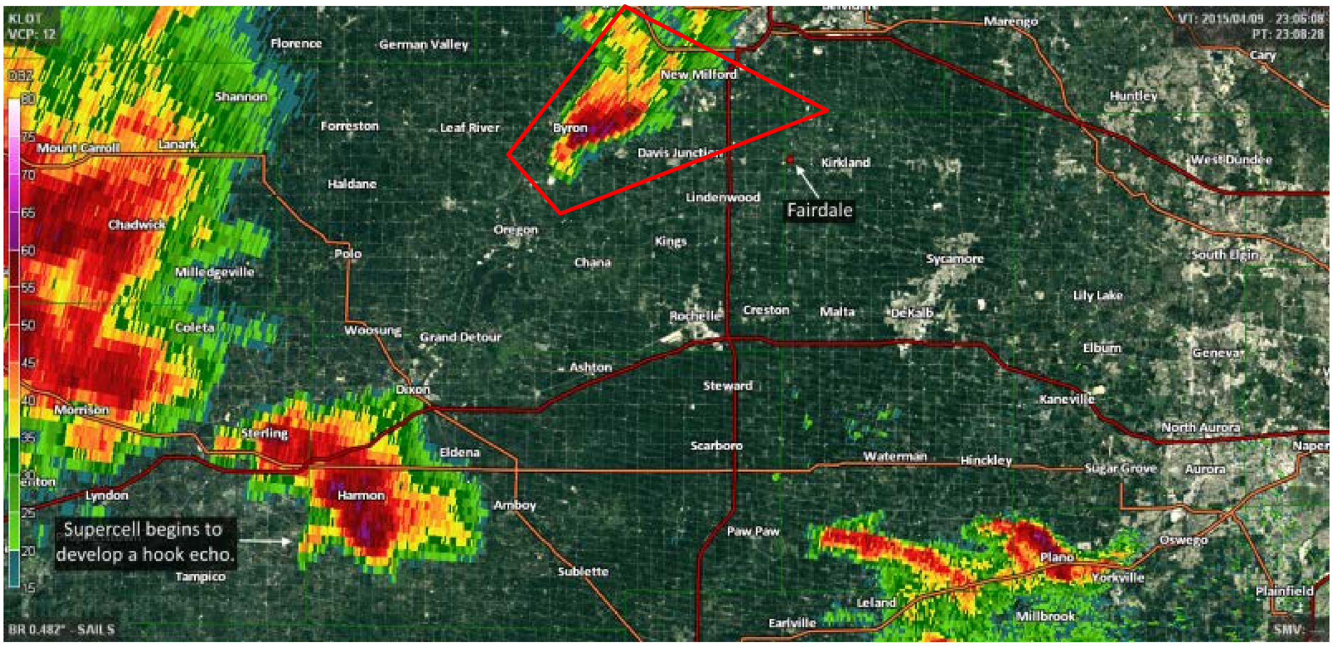
Module 5: Handout #4
NWS LOT Tornado Warning #30
(6:09 pm CDT (2309Z))
(page 1 of 3)

Map showing radar reflectivity 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 Fairdale.

(Source: NOAA/The Vane, 2015)



Module 5: Handout #4
NWS LOT Tornado Warning #30
(6:09 pm CDT (2309Z))
(page 2 of 3)

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BULLETIN - EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE CHICAGO/ROMEOVILLE IL
609 PM CDT THU APR 9 2015

THE NATIONAL WEATHER SERVICE IN CHICAGO  HAS ISSUED A

* TORNADO WARNING FOR...
  NORTHWESTERN DE KALB COUNTY IN NORTH CENTRAL ILLINOIS...
  SOUTHWESTERN BOONE COUNTY IN NORTH CENTRAL ILLINOIS...
  NORTHEASTERN OGLE COUNTY IN NORTH CENTRAL ILLINOIS...
  SOUTHEASTERN WINNEBAGO COUNTY IN NORTH CENTRAL ILLINOIS...

* UNTIL 645 PM CDT

* AT 608 PM CDT...A SEVERE THUNDERSTORM CAPABLE OF PRODUCING A
  TORNADO WAS LOCATED OVER BYRON...OR 8 MILES NORTHEAST OF OREGON...
  MOVING NORTHEAST AT 40 MPH.

  HAZARD...TORNADO AND QUARTER SIZE HAIL.

  SOURCE...RADAR INDICATED ROTATION.

  IMPACT...FLYING DEBRIS WILL BE DANGEROUS TO THOSE CAUGHT WITHOUT
           SHELTER. MOBILE HOMES WILL BE DAMAGED OR DESTROYED.
           DAMAGE TO ROOFS...WINDOWS AND VEHICLES WILL OCCUR.  TREE
           DAMAGE IS LIKELY.

* THIS DANGEROUS STORM WILL BE NEAR...
  ROCKFORD AIRPORT AROUND 620 PM CDT.
  CHERRY VALLEY AROUND 635 PM CDT.
  LOVES PARK AROUND 640 PM CDT.

OTHER LOCATIONS IMPACTED BY THIS TORNADIC THUNDERSTORM INCLUDE NEW
MILLFORD AND DAVIS JUNCTION.

INCLUDING THE FOLLOWING INTERSTATES...
 I-39 BETWEEN MILE MARKERS 111 AND 123.
 I-90 BETWEEN MILE MARKERS 61 AND 63.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

TAKE COVER NOW! MOVE TO A BASEMENT OR AN INTERIOR ROOM ON THE LOWEST
FLOOR OF A STURDY BUILDING. AVOID WINDOWS. IF YOU ARE OUTDOORS...IN A
MOBILE HOME...OR IN A VEHICLE...MOVE TO THE CLOSEST SUBSTANTIAL
SHELTER AND PROTECT YOURSELF FROM FLYING DEBRIS.
```

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

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

2. What is 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 area?

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

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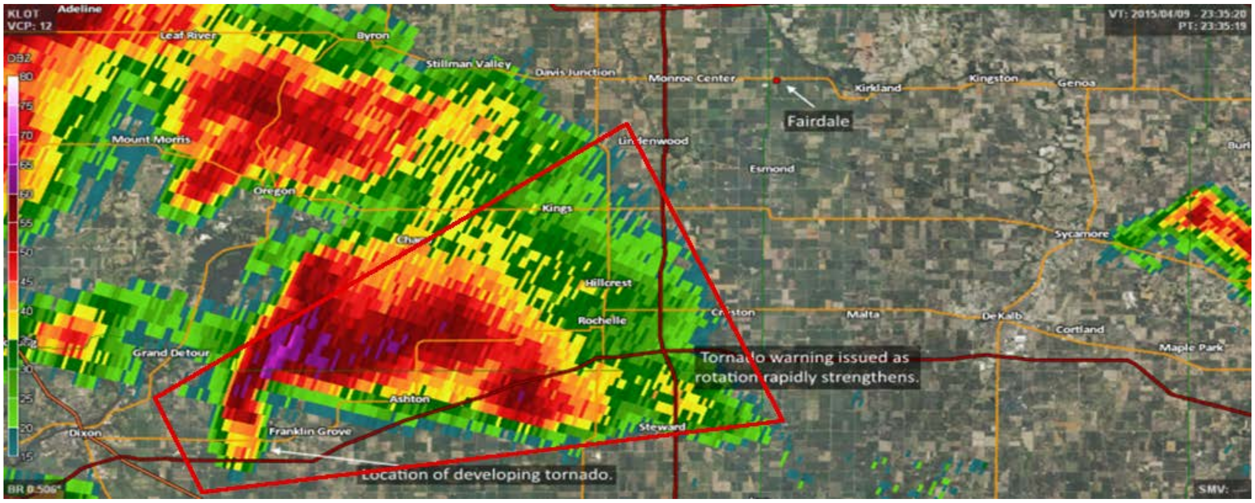
Module 5: Handout #5
NWS LOT Tornado Warning #31
(2335Z / 6:35 pm CDT)

(page 1 of 4)



Radar image depicts a new tornado warning that was issued at 6:35 pm CDT (2335Z). This time, the warning includes the area of interest. The reflectivity shows a new hook echo developing to the southwest of the initial storm. 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.
(Source: NOAA/The Vane, 2015)

Module 5: Handout #5
NWS LOT Tornado Warning #31
(2335Z / 6:35 pm CDT)
(page 2 of 4)

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BULLETIN - EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE CHICAGO/ROMEOVILLE IL
635 PM CDT THU APR 9 2015

THE NATIONAL WEATHER SERVICE IN CHICAGO  HAS ISSUED A

* TORNADO WARNING FOR...
  SOUTHEASTERN OGLE COUNTY IN NORTH CENTRAL ILLINOIS...
  NORTHEASTERN LEE COUNTY IN NORTH CENTRAL ILLINOIS...

* UNTIL 700 PM CDT

* AT 635 PM CDT...A SEVERE THUNDERSTORM CAPABLE OF PRODUCING A
  TORNADO WAS LOCATED OVER FRANKLIN GROVE...OR 9 MILES EAST OF
  DIXON...MOVING NORTHEAST AT 45 MPH.

  HAZARD...TORNADO AND HAIL UP TO TWO INCHES IN DIAMETER.

  SOURCE...RADAR INDICATED ROTATION.

  IMPACT...FLYING DEBRIS WILL BE DANGEROUS TO THOSE CAUGHT WITHOUT
           SHELTER. MOBILE HOMES WILL BE DAMAGED OR DESTROYED.
           DAMAGE TO ROOFS...WINDOWS AND VEHICLES WILL OCCUR.  TREE
                            DAMAGE IS LIKELY.
```

Module 5: Handout #5
NWS LOT Tornado Warning -- UPDATES
(page 3 of 4)

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SEVERE WEATHER STATEMENT
NATIONAL WEATHER SERVICE CHICAGO/ROMEOVILLE IL
643 PM CDT THU APR 9 2015

...A TORNADO WARNING REMAINS IN EFFECT UNTIL 700 PM CDT FOR
SOUTHEASTERN OGLE AND NORTHEASTERN LEE COUNTIES...

AT 643 PM CDT...A CONFIRMED TORNADO WAS LOCATED NEAR ASHTON...OR 9
MILES WEST OF ROCHELLE...MOVING NORTHEAST AT 40 MPH.

HAZARD...DAMAGING TORNADO AND TENNIS BALL SIZE HAIL.

SOURCE...WEATHER SPOTTERS CONFIRMED TORNADO.

IMPACT...FLYING DEBRIS WILL BE DANGEROUS TO THOSE CAUGHT WITHOUT
         SHELTER. MOBILE HOMES WILL BE DAMAGED OR DESTROYED. DAMAGE
         TO ROOFS...WINDOWS AND VEHICLES WILL OCCUR.  TREE DAMAGE IS
         LIKELY.

THIS TORNADO WILL BE NEAR...
  ROCHELLE AND HILLCREST AROUND 700 PM CDT.

OTHER LOCATIONS IMPACTED BY THIS TORNADIC THUNDERSTORM INCLUDE
STEWARD.

INCLUDING THE FOLLOWING INTERSTATES...
 I-39 BETWEEN MILE MARKERS 92 AND 102.
 I-88 BETWEEN MILE MARKERS 61 AND 81.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

TO REPEAT...A TORNADO IS ON THE GROUND. TAKE COVER NOW! MOVE TO A
BASEMENT OR AN INTERIOR ROOM ON THE LOWEST FLOOR OF A STURDY
BUILDING. AVOID WINDOWS. IF YOU ARE OUTDOORS...IN A MOBILE HOME...OR
IN A VEHICLE...MOVE TO THE CLOSEST SUBSTANTIAL SHELTER AND PROTECT
YOURSELF FROM FLYING DEBRIS.
```

Severe Weather Statement

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SEVERE WEATHER STATEMENT
NATIONAL WEATHER SERVICE CHICAGO/ROMEOVILLE IL
647 PM CDT THU APR 9 2015

...A TORNADO WARNING REMAINS IN EFFECT UNTIL 700 PM CDT FOR
SOUTHEASTERN OGLE AND NORTHEASTERN LEE COUNTIES...

AT 646 PM CDT...A CONFIRMED LARGE AND DANGEROUS TORNADO WAS LOCATED
OVER ASHTON...OR 7 MILES WEST OF ROCHELLE...MOVING NORTHEAST AT 40
MPH.

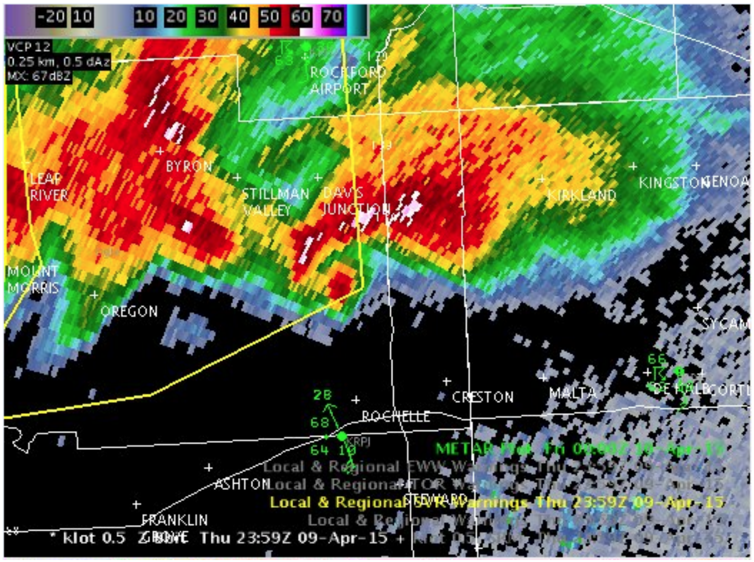
THIS IS A PARTICULARLY DANGEROUS SITUATION.
```

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

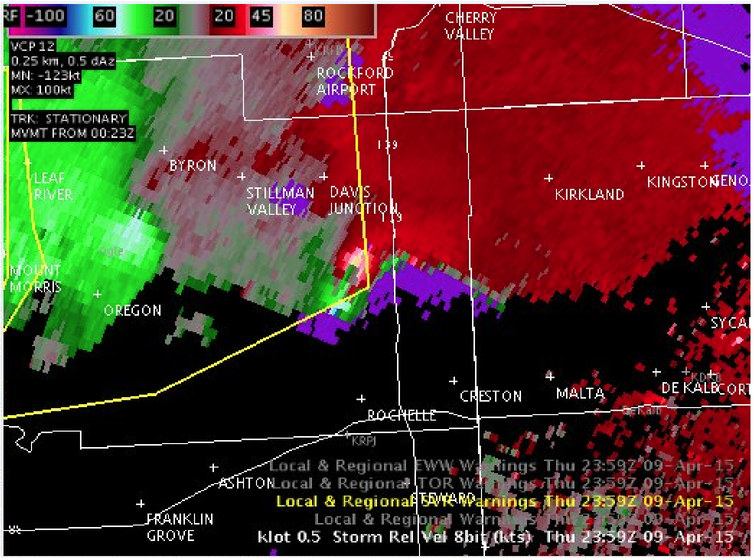
1. What points of confusion do you anticipate among your constituents and the general public in your area, given how this situation is evolving?

Module 5: Handout #6
NWS LOT Tornado Warning #32
(0005-0045Z / 7:05-7:45 pm CDT)

(page 1 of 4)



Radar reflectivity



Storm-relative velocity

(Source: NOAA/The Vane, 2015)

Module 5: Handout #6
NWS LOT Tornado Warning #32
(0005-0045Z / 7:05-7:45 pm CDT)
(page 2 of 4)

Map showing radar reflectivity and storm-relative velocity. Both the radar reflectivity and storm-relative velocity maps indicate intense rotation as the tornado approached Fairdale.

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 is an extremely strong, tornadic storm?

Module 5: Handout #6
NWS LOT Tornado Warning #32
(0005-0045Z / 7:05-7:45 pm CDT)

(page 4 of 4)

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BULLETIN - EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE CHICAGO/ROMEOVILLE IL
705 PM CDT THU APR 9 2015

                           THE NATIONAL WEATHER SERVICE IN CHICAGO  HAS ISSUED A

* TORNADO WARNING FOR...
  SOUTHWESTERN BOONE COUNTY IN NORTH CENTRAL ILLINOIS...
  NORTHEASTERN OGLE COUNTY IN NORTH CENTRAL ILLINOIS...
  SOUTHEASTERN WINNEBAGO COUNTY IN NORTH CENTRAL ILLINOIS...

* UNTIL 745 PM CDT

* AT 705 PM CDT...A SEVERE THUNDERSTORM CAPABLE OF PRODUCING A
  TORNADO WAS LOCATED OVER STILLMAN VALLEY...OR 8 MILES NORTHEAST OF
  OREGON...MOVING EAST AT 40 MPH.

  HAZARD...TORNADO.

  SOURCE...RADAR INDICATED ROTATION.

  IMPACT...FLYING DEBRIS WILL BE DANGEROUS TO THOSE CAUGHT WITHOUT
           SHELTER. MOBILE HOMES WILL BE DAMAGED OR DESTROYED.
           DAMAGE TO ROOFS...WINDOWS AND VEHICLES WILL OCCUR.  TREE
           DAMAGE IS LIKELY.

* THIS DANGEROUS STORM WILL BE NEAR...
  ROCKFORD AIRPORT AROUND 715 PM CDT.
  CHERRY VALLEY AROUND 730 PM CDT.

OTHER LOCATIONS IMPACTED BY THIS TORNADIC THUNDERSTORM INCLUDE NEW
MILLFORD AND DAVIS JUNCTION.

INCLUDING THE FOLLOWING INTERSTATES...
 I-39 BETWEEN MILE MARKERS 110 AND 123.
 I-90 BETWEEN MILE MARKERS 61 AND 62.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

TAKE COVER NOW! MOVE TO A BASEMENT OR AN INTERIOR ROOM ON THE LOWEST
FLOOR OF A STURDY BUILDING. AVOID WINDOWS. IF YOU ARE OUTDOORS...IN A
MOBILE HOME...OR IN A VEHICLE...MOVE TO THE CLOSEST SUBSTANTIAL
SHELTER AND PROTECT YOURSELF FROM FLYING DEBRIS.
```

Appendix C: Best Practices for Outdoor Warning Sirens

Recommended Best Practices for the Activation of Outdoor Warning Sirens

Developed by the Workgroup for Warning Systems

Chair- Rob Dale rdale@skywatch.org

Best Practices

Siren Testing

- Warning Siren testing shall be done on a regular schedule (but not more than once a month) using the standard “ALERT” (steady) sound.
- Testing of Sirens should not be done if conditions are in the area (non-severe storms, etc.) could confuse the public, and should not be rescheduled.
    - Notify the public of the cancellation as soon as possible.

Siren Alerting

- ONLY the “ALERT” (steady) Sound is to be used, lasting for at least 3 minutes.
- 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” tine WILL NOT be used.

Siren Activation

- When the National Weather Service issues or re-issues a Tornado Warning.
    - *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 continuous as possible while the tornado is still in the area.*

Or…

- During a Severe Thunderstorm Warning ONLY IF:
    - Destructive winds of 80mph or greater are observed by a trained spotter or indicated in the National Weather Service warning statements.

Or…

- Without a warning, when reliable reports from TRAINED weather spotter or indicated in the National Weather Service warning statements.
    - Immediately notify the National Weather Service and local media.
    - Preferably use NWSChat to let all know why sirens were activated.

Source: "Best Practices for Outdoor Warning Sirens." *Developed by the Workgroup for Warning Systems*, skywatch.org, n.d. Web. 2 Jun. 2015 http://skywatch.org/ows.pdf.

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 NO intended to remove a jurisdiction's obligation or responsibility to alert or warn its community if a situation falls outside of the parameters of these recommendations.

Outdoor warning sirens represent only one part of a broader public emergency notification system. Other components include: NOAA All-Hazards Weather Radio, Wireless Emergency Alerts (WEA), mass notification systems, emergency management, private sector meteorologists and the media. Sirens are used to alert citizens of an imminent hazard, which should 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 United States will minimize confusion in emergency situations. Establishing a standard will also enable communities to partner in area-wide public education campaigns regarding sirens.

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 various 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 from the main document or that we felt needed clarification are included below.

In 2015 this project was incorporated into the International Association of Emergency Managers (IAEM) Caucus on Climate, Weather, and Water, as well as the American Meteorological Society (AMS) Committee on Emergency Management.

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. With the number of warnings being issued on a steady rise over the past decade, reducing the coverage of siren alerts to areas truly threatened by the storm is crucial. Additional information on the storm-based polygon warnings is available at http://tinyurl.com/nws-polygon.

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 flash floods.

We originally considered using very large hail (2" or more) as a trigger point, but those hail sizes are often very isolated and short-lived, 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, using that criteria may be of use.

Bad Practices

Many "bad practices" exist in the alerting policies nationwide, and the intent of this document was just as much geared towards removing those as it was towards adding anything new.
Do not use an "all-clear" alert. Tis does nothing but add confusion to the public. Outdoor warning sirens are simply used to notify citizens that something hazardous could be approaching, so they need to go to a place of safety and find out that the storm has passed, so there is no reason for sounding an all-clear.
Some communities sound their sirens for warnings in neighboring counties (that do not include them directly) 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 the 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 notify the NWS, media outlets and neighboring jurisdictions immediately, which allows one unified message to be disseminated and provides the confirmation that the public need 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 50-60 mph 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 straight-line winds. Therefore we deemed receiving reports of confirmed 80 mph winds and/or extreme damage from downburst winds as activation criteria. There is a proposal to automatically alert cellphones through the Wireless Emergency Alert (WEA) system when a severe thunderstorm warning indicates winds of 80 mph or higher are included, so this would match the two systems. 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.