AWR-331 Winter Weather Hazards: Science and Preparedness

Participant Guide

Version 1.0

FEMA

NATIONAL DISASTER PREPAREDNESS TRAINING CENTER

Copyright Information

AWR-331 Winter Weather Hazards: Science and Preparedness

This Printing: December 2015

Printed in the United States of America

This program was supported by Cooperative Agreement Number EMW-2013-CA-K00148, administered by the U.S. Department of Homeland Security, Training & Exercise Integration/Training Operations. Points of view or opinions in this program are those of the author(s) and do not represent the position or policies of the U.S. Department of Homeland Security.

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

Table of Contents

This page is intentionally left blank.

AWR-331 Winter Weather Hazards: Science and Preparedness

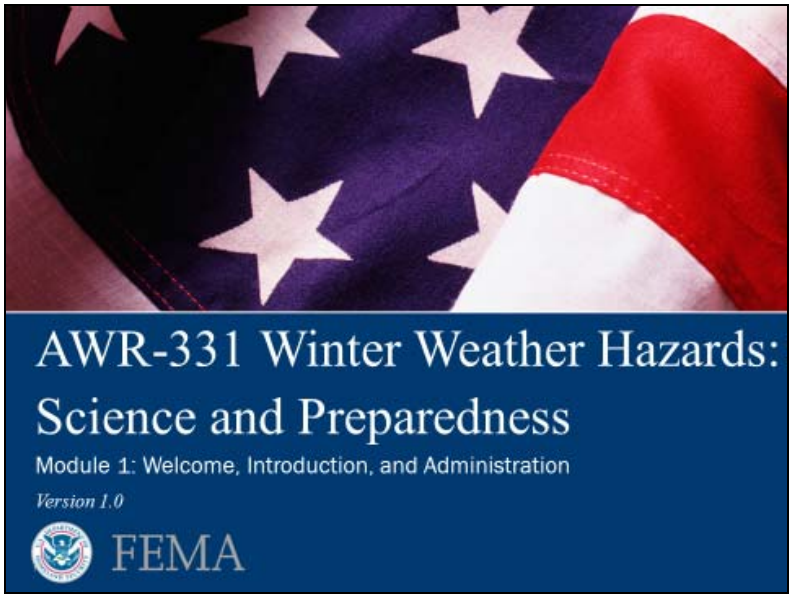
Module 1: Welcome, Introduction, and Administration

Version 1.0

FEMA

This page is intentionally left blank.

Module 1: Welcome, Introduction, and Administration – Administration Page



Slide 1-1. Welcome, Introduction, and Administration

Duration

50 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.

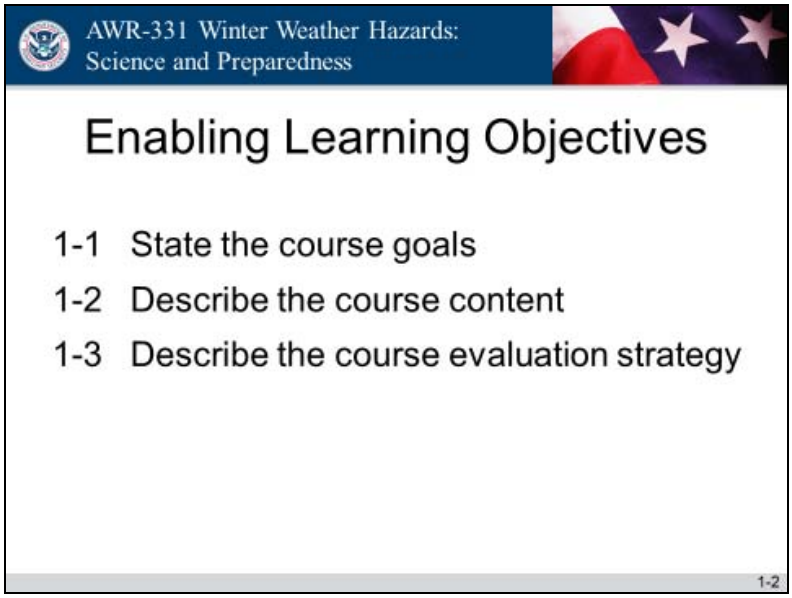
Next, the instructors will:

- 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 objectives.

Enabling Learning Objectives (ELOs)



Slide 1-2. Enabling Learning Objectives

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

1-1 State the course goals;
1-2 Describe the course content; and
1-3 Describe the course evaluation strategy.

Resources

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

- 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

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Accessed 2014. http://www.ipcc.ch/report/ar5/wg1/

The Weather Channel. 2014. The Science Behind Naming Winter Storms at The Weather Channel. Accessed 2014. http://www.weather.com/news/news/science-behind-naming-winter-storms-weather-channel-20140121

Practical Exercise Statement

Not applicable

Assessment Strategy

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

Winter Weather Hazards: Science and Preparedness

Icon Map

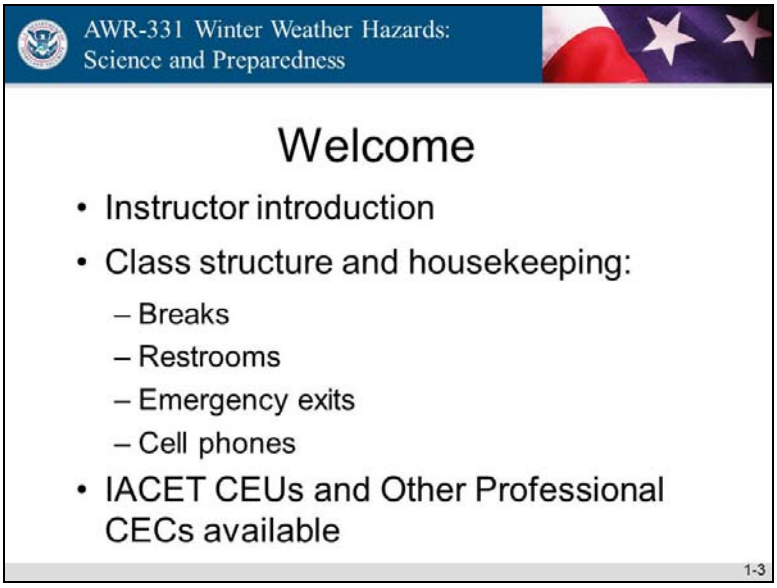
Knowledge Check: Used when it is time to assess participant understanding.

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

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

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

Participant Notes:

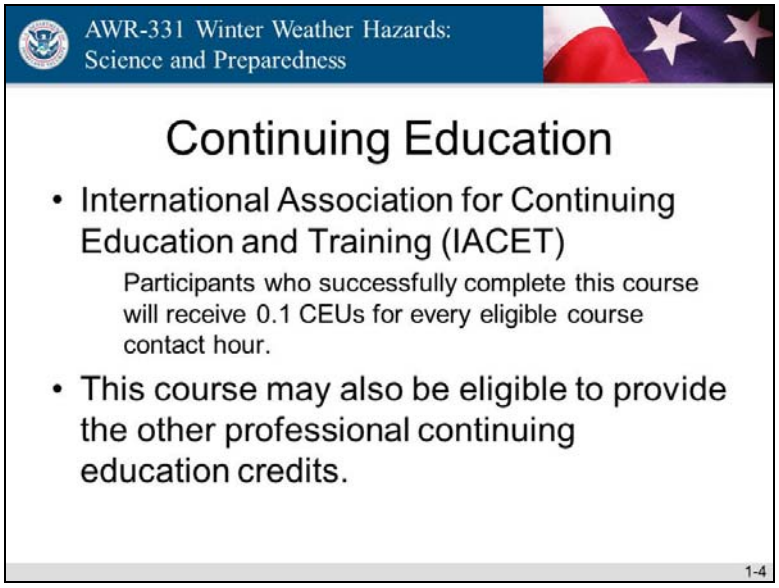


Slide 1-3. Welcome

The 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.

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:



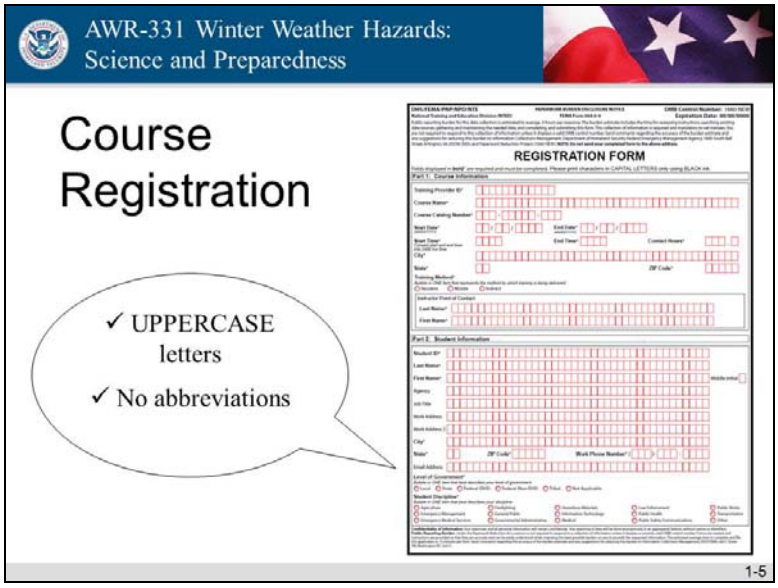
Slide 1-4. Continuing Education

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.

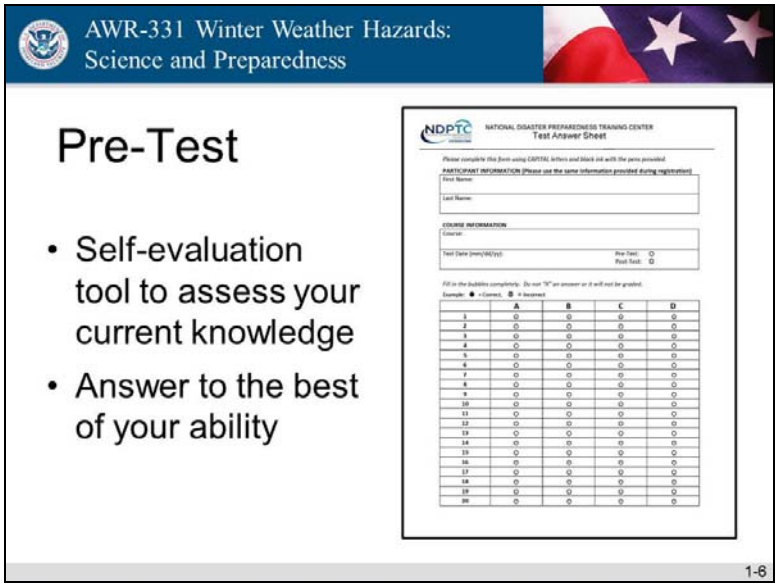
Participant Notes:



Slide 1-5. 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 1-6. Pre-Test

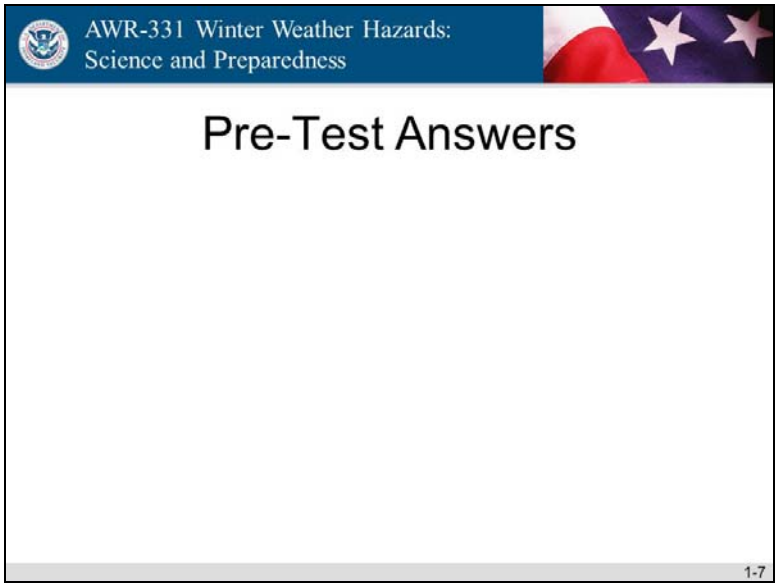
Participants should note the following:

- The pre-test is important because it provides a self-measure of knowledge as well as assumptions on the topics. It also illustrates the course 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.

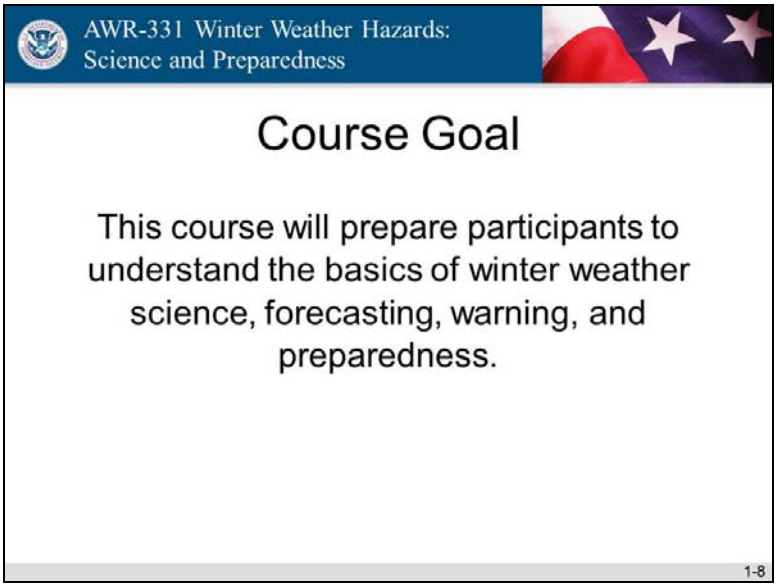
Participant Notes:



Slide 1-7. 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:



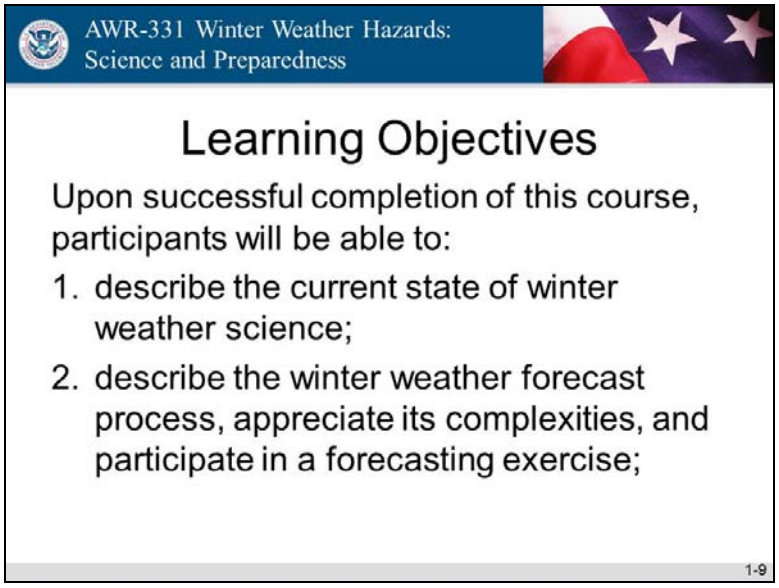
Slide 1-8. Course Goal

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

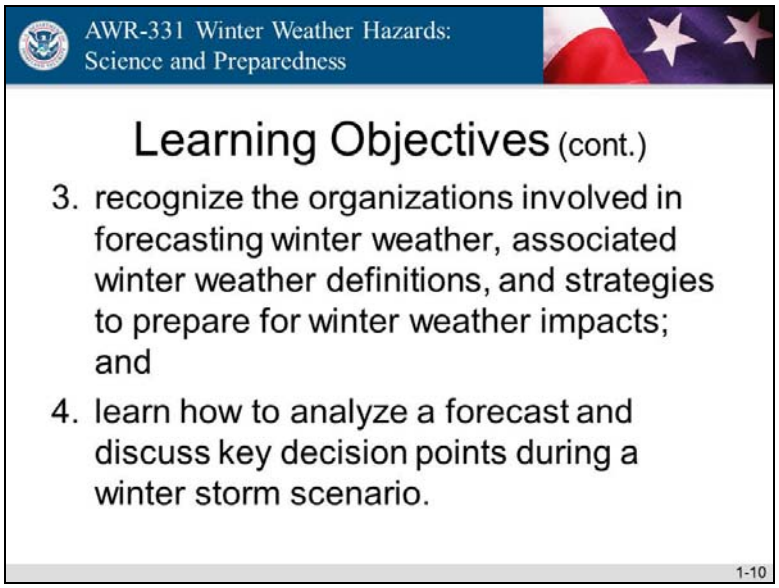
This course does not require any previous subject matter knowledge, so participants should not be concerned about having a background in the topics noted above. All of the knowledge required to answer intra-module and end-of-course assessment questions can be found in the course materials presented in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

Participant Notes:



Slide 1-9. Learning Objectives



Slide 1-10. Learning Objectives (continued)

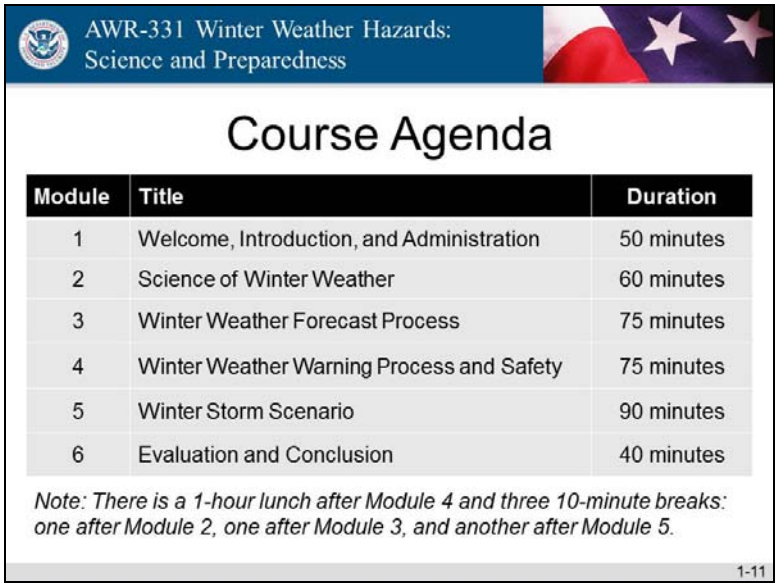
Upon successful completion of this course, participants will be able to:

1. describe the current state of winter weather science;
2. describe the winter weather forecast process, appreciate its complexities, and participate in a forecasting exercise;
3. recognize the organizations involved in forecasting winter weather, associated winter weather definitions, and strategies to prepare for winter weather impacts; and

Participant Notes:

4. learn how to analyze a forecast and discuss key decision points during a winter storm scenario.

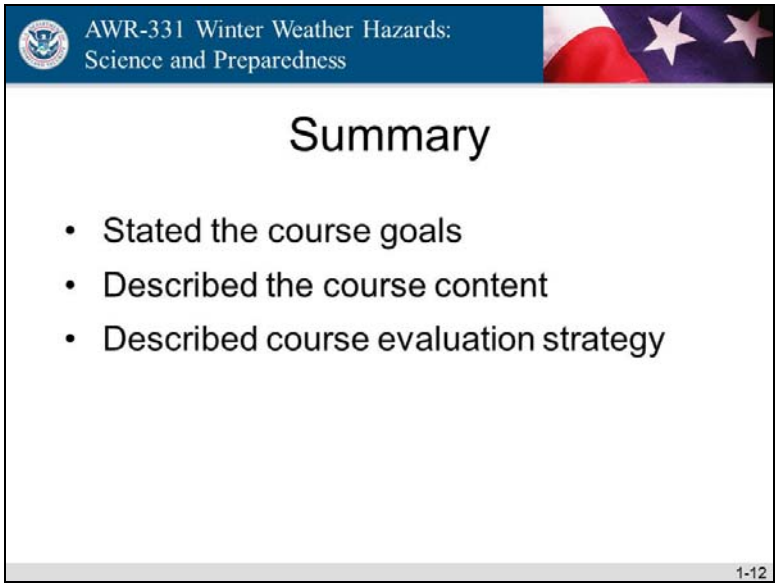
Participant Notes:



Slide 1-11. 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 1-12. 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 winter weather hazard.

AWR-331 Winter Weather Hazards: Science and Preparedness

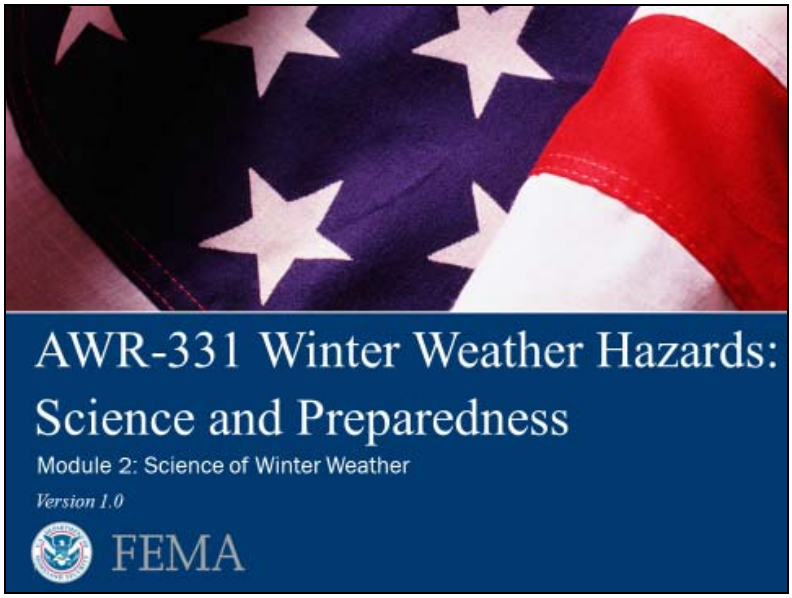
Module 2: Science of Winter Weather

Version 1.0

FEMA

This page is intentionally left blank.

Module 2: Science of Winter Weather – Administration Page



Slide 2-1. Science of Winter Weather

Duration

60 minutes

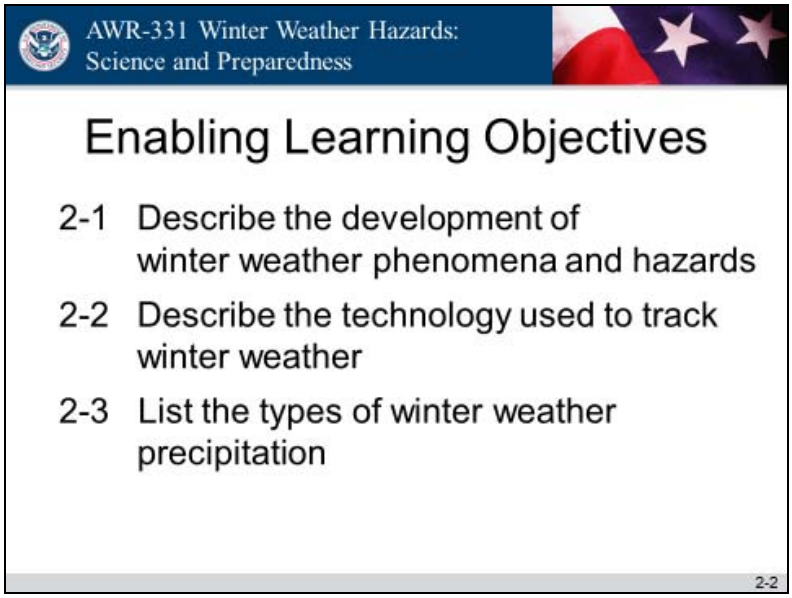
Scope Statement

In this module, the instructors will review definitions, explain concepts, and provide other details pertaining to the science of winter weather. This will include an overview of how winter storms form, how they are tracked, and the types of precipitation that they produce.

Terminal Learning Objective (TLO)

Participants will understand the current state of winter weather 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 development of winter weather phenomena and hazards;
2-2 Describe the technology used to track winter weather; and
2-3 List the types of winter weather precipitation.

Resources

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

Instructor-to-Participant Ratio

2:40

Reference List

CoCoRaHS, 2011. "In depth Snow Measuring." Accessed 2014. http://www.cocorahs.org/media/docs/Measuring%20Snow-National-Training%201.1.pdf

COMET, 2001. "Winter Microphysics Topics." Accessed 2014. http://www.meted.ucar.edu/norlat/snow/micro_ice/1.1.crystal_growth.htm

COMET, 2005. "Topics in Precipitation Type Forecasting" Accessed 2014. http://www.meted.ucar.edu/norlat/snow/preciptype/

COMET, 2014. "Weather Radar Fundamentals." Accessed 2012. http://www.meted.ucar.edu/radar/basic_wxradar/navmenu.php?tab=1&page=8.1.0&type=text

FEMA, 2014. "Winter Storms & Extreme Cold." Accessed 2014. http://www.ready.gov/winter-weather

Junker, Wes. "Winter Weather Forecasting." Accessed 2014. http://www.wpc.ncep.noaa.gov/research/snow2a/snow2a.pdf

NOAA, 2005. "WSR-88D Radar FAQ's." Accessed 2014. http://www.srh.noaa.gov/radar/radinfo/radinfo.html

NOAA, 2009. "Frequently asked questions about the NWS Radiosonde Observations Program." Accessed 2014. http://www.ua.nws.noaa.gov/Faq.htm

NOAA, 2009. "Radiosonde Observations." Accessed 2014. http://www.ua.nws.noaa.gov/factsheet.htm

NOAA, 2010. "Norwegian Cyclone Model." Accessed 2014. http://www.srh.noaa.gov/jetstream/synoptic/cyclone.htm

Skow, 2013. "NWS WSR-88D Radar Fundamentals." Accessed 2014. http://www.meteor.iastate.edu/classes/mt432/lectures/ISURadarTalk_NWS_2013.pdf

Practical Exercise Statement

Not applicable

Assessment Strategy

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

Winter Weather Hazards: Science and Preparedness

Icon Map

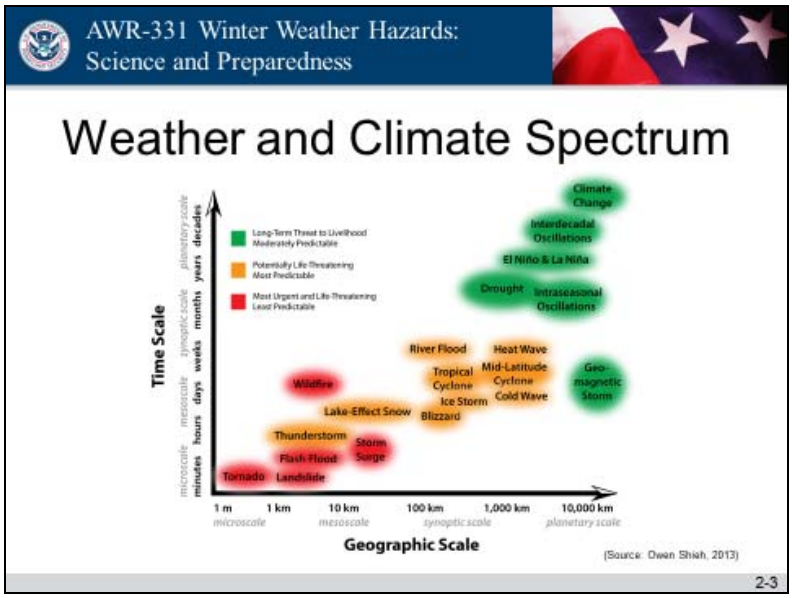
Knowledge Check: Used when it is time to assess participant understanding.

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

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

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

Participant Notes:



Slide 2-3. Weather and Climate Spectrum

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

Highlights of the above graphic are outlined below:

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

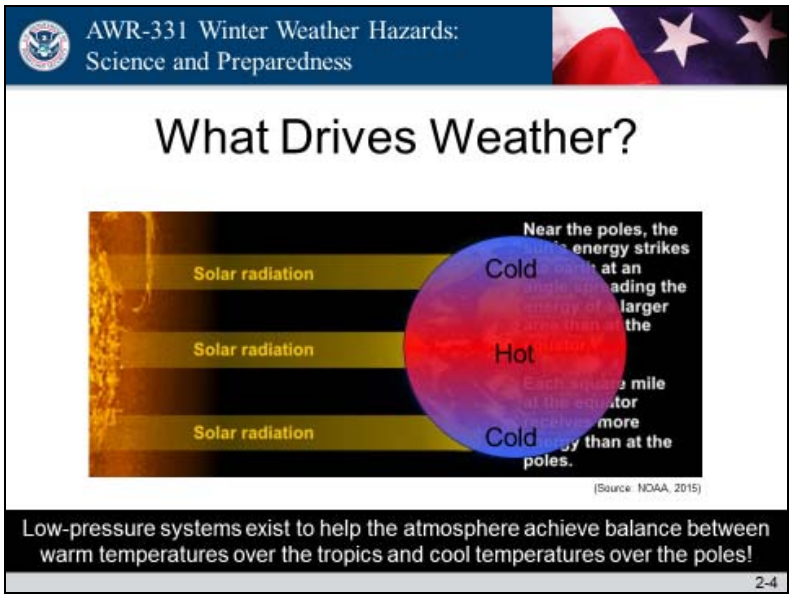
Participant Notes:

- The only non-atmospheric phenomena in this figure are wildfires, landslides, and geomagnetic storms. They were included because they can be closely associated with other weather/climate phenomena. More information on these are provided below:
  - Lightning from thunderstorms often spark wildfires.
  - Flash floods can cause landslides.
  - The source of geomagnetic storms is completely extraterrestrial in nature, but can affect telecommunications systems and electric grids on the planetary scale, all of which would impact the ability to observe and predict hazardous weather phenomena.

The science of meteorology has undergone tremendous improvements in forecast accuracy in recent years. However, challenges still remain in the larger scale phenomena such as climate change, where numerous factors play a role over longer periods of time and are difficult to quantify. Similarly, phenomena at small scales are difficult to understand and resolve in numerical prediction models.

Participant Note: The yellow, or "Potentially Life-Threatening, Most Predictable," phenomena are easiest for meteorologists to forecast because current numerical weather models and observation systems are built to detect events within that time and geographic scale range.

Participant Notes:



Slide 2-4. What Drives Weather?

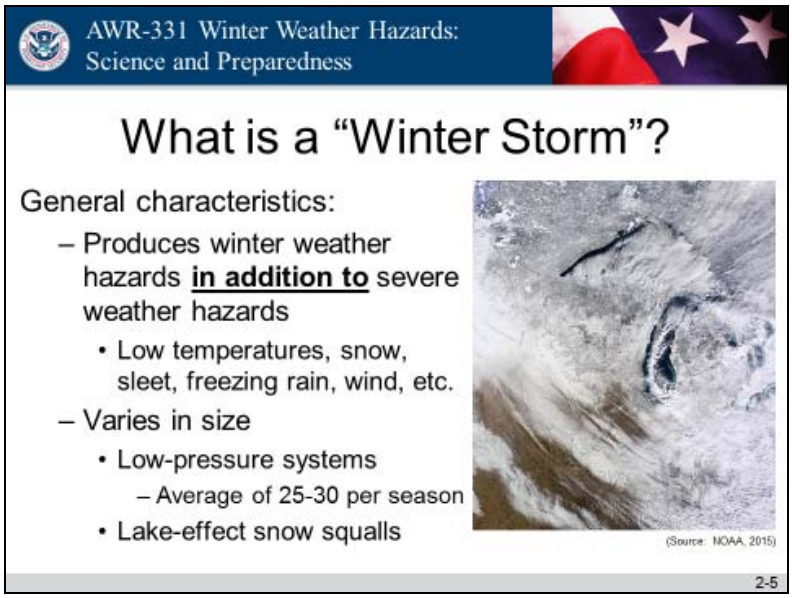
All weather is local, but the source of all weather is solar. The sun provides the earth with incredible amounts of energy that allow both human and meteorological life to flourish.

The sun emits energy through solar radiation that is received by the earth in different amounts at different locations. The equator, which always directly faces the sun no matter the season, receives more direct solar radiation than the earth's poles, which tilt with the seasons. For this reason, the equator is warmer than earth's poles.

The large difference, or gradient, in temperatures between the equator and the poles drives weather. Earth's atmosphere is in a constant battle to reach one uniform temperature and that battle is fought with thunderstorms, tropical cyclones, and winter storms.

The goal of weather is simple: move warm air poleward, move cold air equatorward, and reach one uniform temperature.

Participant Notes:



Slide 2-5. What is a "Winter Storm"?

"Winter storms" have no set definition, but, instead, the term refers to an atmospheric disturbance that boasts any of the following characteristics:

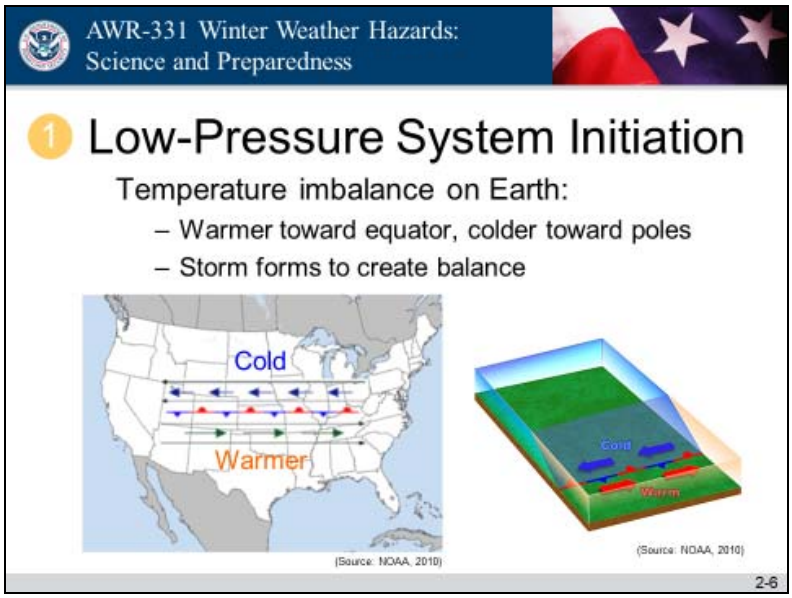
- Produces significant precipitation during the winter;
- Produces any frozen precipitation (snow, sleet, or freezing rain); and/or
- Creates blizzard conditions.

The largest atmospheric disturbance commonly called a "winter storm" is a large low-pressure system known as a *mid-latitude cyclone*. Approximately 25 to 30 of these cyclones, which are named due to the characteristically cyclonic rotation of winds around the storm, will affect the United States between November and March. Throughout this course, mid-latitude cyclones will often be referred to as "low-pressure systems."

Much smaller storms, like lake-effect snow squalls, do not have the same structure or size as a mid-latitude cyclone but still have "winter storm" characteristics.

Participant Note: The Polar Vortex, as described by NOAA/NWS Central Region Headquarters, "is a semi-permanent (meaning usually present) upper level circulation that typically resides near the north and south poles." It is not a type of mid-latitude cyclone but is still often associated with the transport of dangerously low temperatures from northern latitudes southward.

Participant Notes:



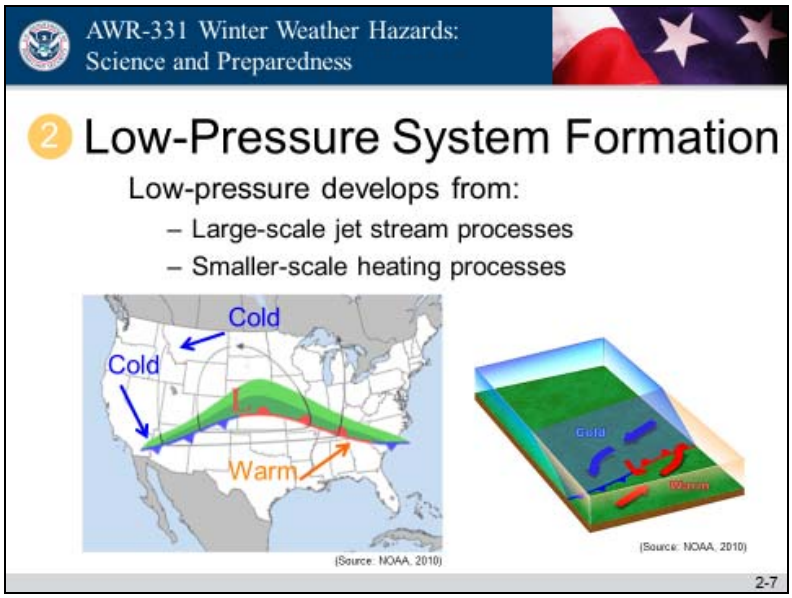
Slide 2-6. (1) Low-Pressure System Initiation

Earth's equator receives more direct solar radiation than Earth's north and south poles, creating quite the temperature difference between the three regions. Keeping our gaze fixed onto the northern hemisphere, cold air is almost always found north of regions of warm air.

During calm and stable atmospheric conditions, cold and warm air masses can border each other at stationary fronts. At a *stationary front*, there is no movement of either the warm or cold air mass; both remain stationary.

In the above image, a cold, dense air mass is north of a warm, less dense air mass. Neither air mass is advancing into or retreating away from the other.

Participant Notes:



Slide 2-7. (2) Low-Pressure System Formation

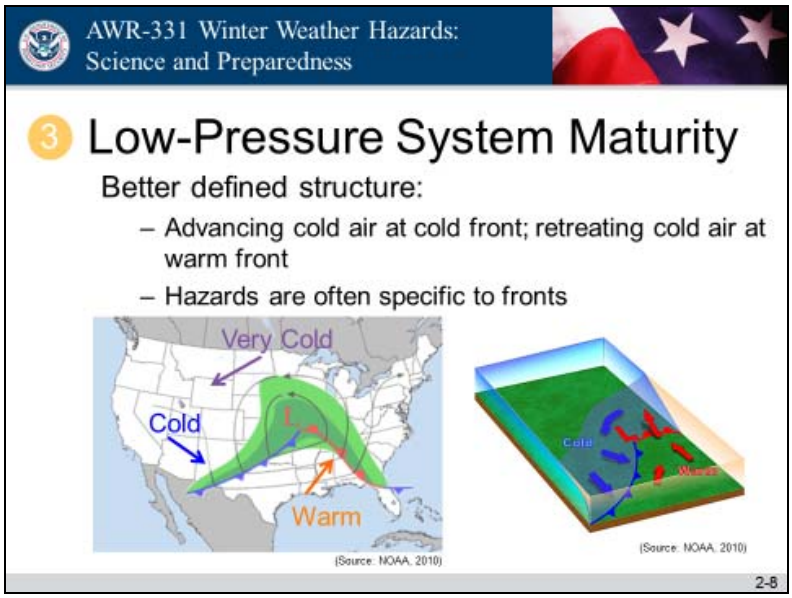
Earth's atmosphere, which is sometimes disturbed and often perturbed, can spark these air masses into motion. This motion arises from a variety of means including:

- Topography,
- The jet steam, and
- Uneven surface heating.

Once disturbed by one of the above means, our previously stable region of bordering air masses has begun to move. Cold air advances into the warm air mass at a cold front and warm air advances into the cold air mass at a warm front.

The center of this disturbance, called a center of circulation, begins to realize a drop in air pressure. Meteorologists refer to these low-pressure systems as mid-latitude cyclones if they originate in the mid-latitudes and do not have tropical characteristics.

Participant Notes:



Slide 2-8. (3) Low-Pressure System Maturity

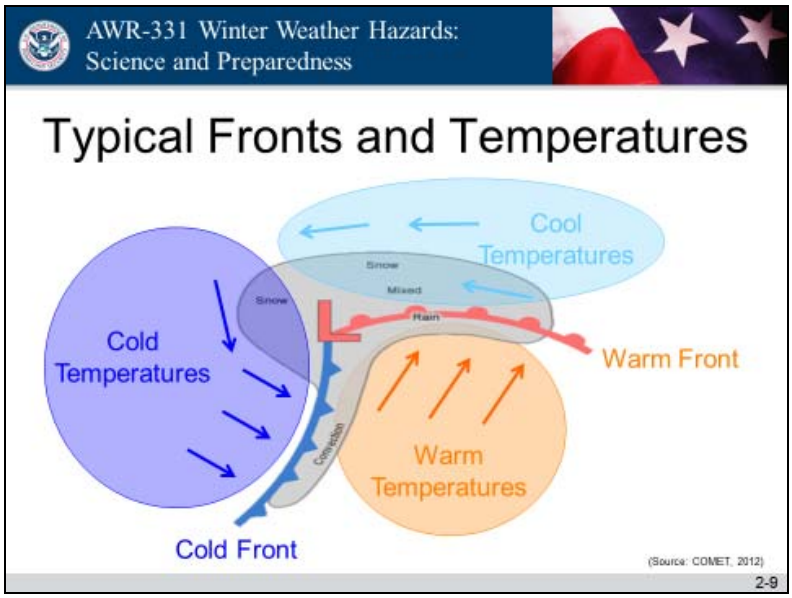
As the low-pressure system strengthens:

1. The temperature gradient (difference between cold and warm air masses) increases;
2. Winds rotating counterclockwise increase in speed as the temperature gradient grows;
3. The pressure inside of the center of circulation begins to dramatically drop;
4. Warm, moist air is drawn poleward (north) by the cyclone's circulation; and
5. *Convection* occurs at the cold front as cold, dense air lifts warm, less dense air vertically.

When the cold front "catches up" and overtakes the warm front, an occluded front is then designated. An *occluded front* notes the area where the cold air mass has overtaken the warm air mass.

Participant Note: During this stage, a low-pressure system may become a "bomb" if the correct atmospheric dynamics are in play. For a low-pressure system to become a "bomb" or, as is commonly heard, for "bombogenesis" to occur, the cyclone's central pressure must decrease by at least one millibar an hour for 24 hours.

Participant Notes:



Slide 2-9. Typical Fronts and Temperatures

This is the standard model of fronts and temperatures around a cyclone. Note that a front is the leading edge of the air behind it.

- A *cold front* is the leading edge of the cold air mass or "cold sector."
- A *warm front* is the leading edge of the warm air mass or "warm sector."
- An *occluded front* is the region where cold air has overtaken or occluded the warm air mass.

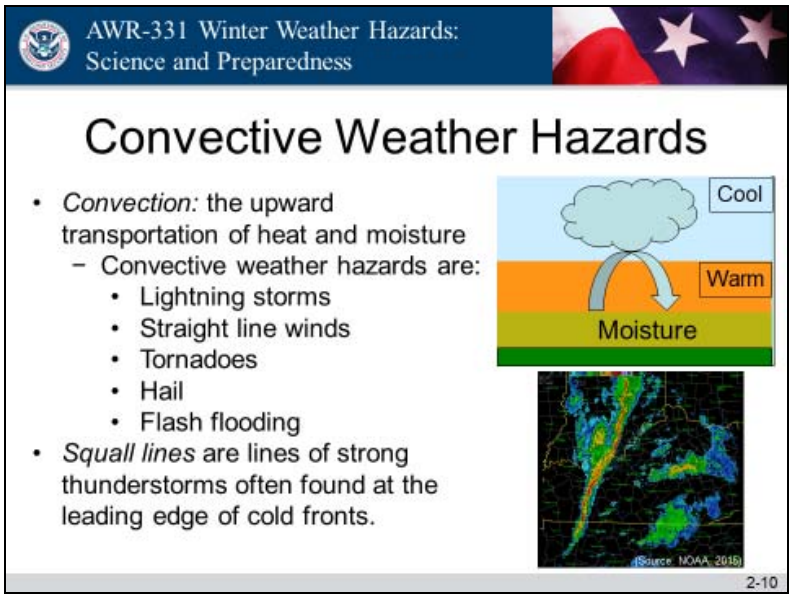
Participant Note: At a warm front, warm air advances and ascends over cold air. This results in rain close to the front and frozen precipitation father away from the front where there is little warm air penetration.

Knowledge Check: What will occur if there is a small change in storm path that deviates from the forecast?

Knowledge Check: Where do the following hazards occur?

- Thunderstorms?
- Blizzard conditions?
- Flash flooding?
- Freezing rain?

Participant Notes:



Slide 2-10. Convective Weather Hazards

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.

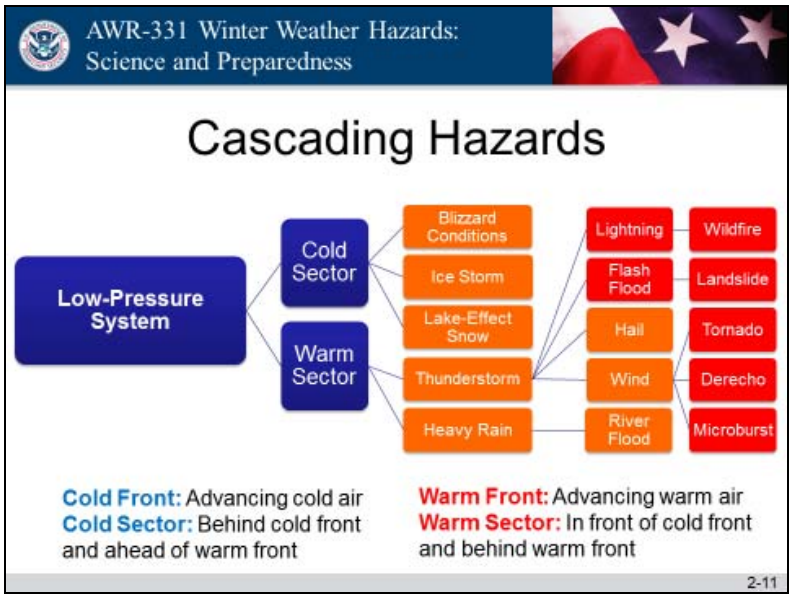
This process is analogous to boiling a pot of water. The stove heats the pot of water from below, causing water to become unstable and boil, with water rising in plumes.

As air ascends in an updraft, air from the surrounding environment rushes to fill in the "gap" that was left by the ascending air. In this way, the atmosphere reloads itself.

Convective weather often creates what are commonly known as *severe weather* hazards. These hazards include lightning, damaging winds, tornadoes, hail, and flash flooding.

The squall line shown above was formed by a cold front that extended from Indiana to Kentucky on January 29, 2008; many tornadoes and >100 mph wind gust reports were submitted to National Weather Service Weather Forecast Offices.

Participant Notes:



Slide 2-11. Cascading Hazards

Local weather hazards result from larger scale weather patterns. In the case of low-pressure systems, the hazards can be divided into where they occur according to their typical location in regard to the cold front.

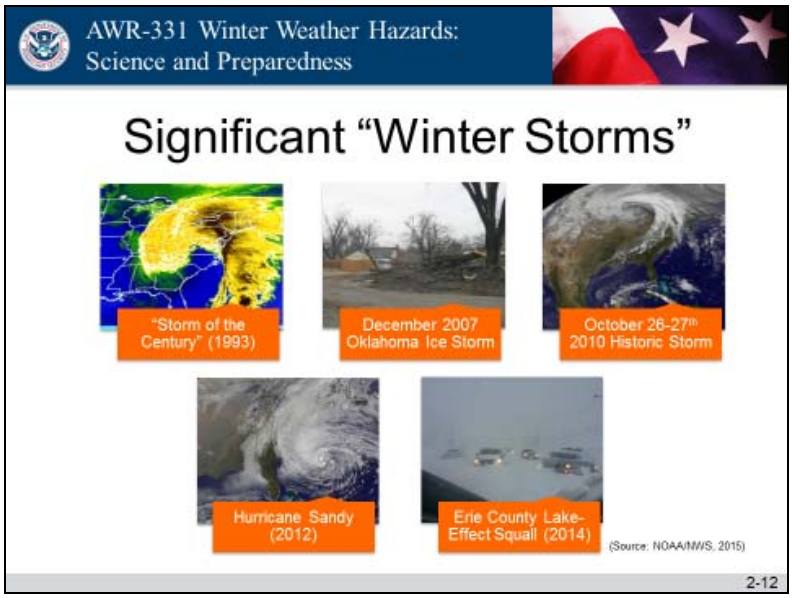
The cold front is the leading edge of cold air. Ahead of it, conditions are warm, moist, and unstable. This region is called the warm sector. Convective hazards such as thunderstorms and heavy rain are more likely here.

Behind the cold front and ahead of the warm front (retreating edge of cold air) is a region where more stable conditions persist with colder air. This region, called the cold sector, contains hazards that are cold in nature such as blizzard conditions, ice storms, lake-effect snow, and steady rain.

Participant Note: Organized lines of thunderstorms, called *squall lines*, are found at the leading edge of the cold front where cold, dense air provides a strong lift mechanism for strong thunderstorms. Warm fronts can also provide powerful lift for strong thunderstorms to form nearby.

Knowledge Check: How do the hazards associated with the warm sector change during the winter?

Participant Notes:



Slide 2-12. Significant "Winter Storms"

Past significant winter storms:

"The Storm of the Century" (1993): Also called "The Superstorm of 1993," this low-pressure system is remembered for producing significant snowfall accumulations from Alabama to Maine, coastal flooding in Florida, and its notably low central pressure. (http://www.erh.noaa.gov/ilm/archive/Superstorm93/)

Participant Note: The term "significant" is used to depict storms with an unusually strong impact on a population. The definition of a significant "winter storm" will vary by region.

December 2007 Oklahoma Ice Storm: An intense freezing rain event impacted Oklahoma from December 8-11, 2007. Over two inches of ice accumulated on trees and utility lines, leaving over 600,000 without power. (http://www.srh.noaa.gov/tsa/?n=weather-event_dec10icestorm)

The October 26-27, 2010, Historic Storm: This low-pressure system was noted for its dramatically low central pressure of 28.21mmHg, measured in Bigfork, MN. The storm produced nearly 400 severe weather cases. (http://cms.met.psu.edu/sref/severe/2010/25Oct2010.pdf)

Participant Notes:

Hurricane Sandy (2012): One of the costliest hurricanes in recent history, Hurricane Sandy transitioned into a post-tropical storm prior to landfall in New Jersey. Sandy produced nearly three feet of snow in West Virginia and western North Carolina. (http://soundwaves.usgs.gov/2012/12/images/Hurr20121028SANDY_GOES-lg.jpg)

Erie County Lake-Effect Snow Storm (2014): An anomalously strong band of lake-effect snow dumped over 48 inches of snow from November 19-21, 2014 on Erie County, New York. (http://www.weather.gov/buf/lake1415_stormc.html)

Participant Notes:

Slide 2-13. Satellite Animation of Strong Winter Storm

Above is an animation of a low-pressure system, known as a mid-latitude cyclone, which moved across the United States in mid-March, 2014. This storm produced heavy snowfall in regions of the Midwest and Ohio Valley as well as blizzard conditions in western New York. Strong winds associated with the system's cold front also caused property damage in Virginia and South Carolina.

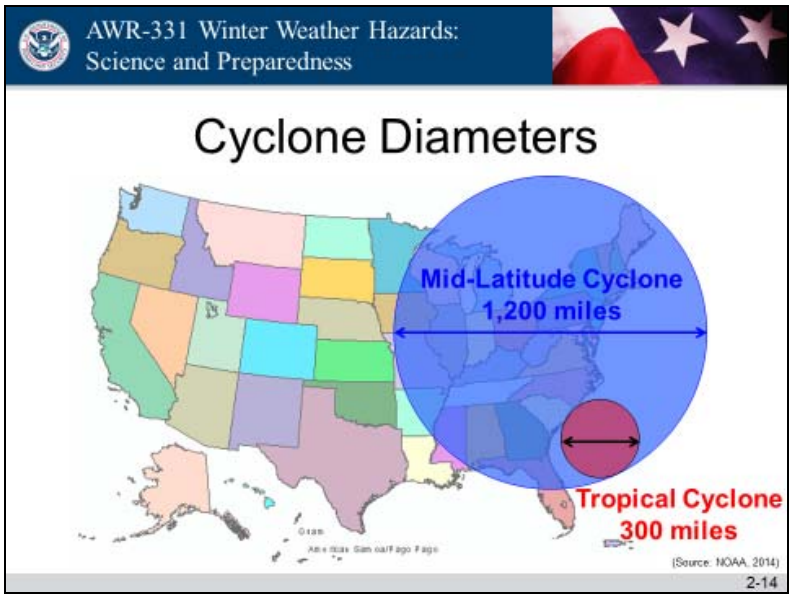
Knowledge Check: Find the following four features of this historic storm:

1. Center of low pressure
2. Cold front
3. Warm front
4. Occluded front

Participant Note: A *cut-off low-pressure system* is a weak system that is separated from the main west-to-east flow of the weather. This storm may not resemble the image on this slide as it lacks defined cold and warm fronts.

Key Point: Low-pressure systems are very large and contain a wide spectrum of hazards. Convective, or severe, weather hazards are common in the warm sector.

Participant Notes:



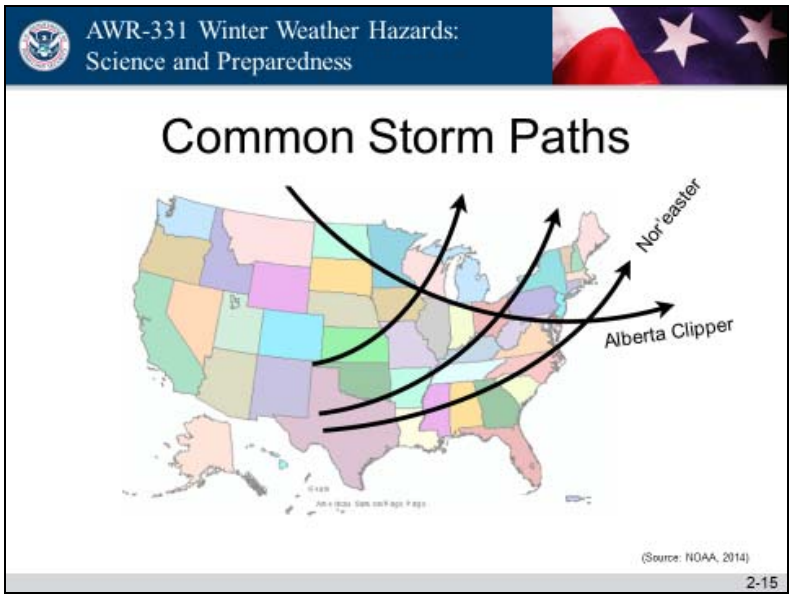
Slide 2-14. Cyclone Diameters

Winter storms are large systems that can cover nearly half of the United States at their greatest extent. Although they are very large, the severity of a winter storm is measured across the broad range of hazards that it causes. These meteorological hazards include:

- Frozen precipitation;
- Damaging winds;
- Tornadoes;
- Severe thunderstorms;
- Flash flooding; and
- Avalanches.

Knowledge Check: How much larger is a winter storm than a tornado? How are they similar?

Participant Notes:



Slide 2-15. Common Storm Paths

Winter storms usually move from west-to-east across the United States because they are driven by, among other smaller processes, the jet stream.

This map shows a few common tracks, following the center of low-pressure systems during the winter. However, much like snowflakes that can be similar but not identical, winter storms may exhibit similar behavior to one another in terms of location and strength but move along slightly different paths.

Nor'easters are named for their strong northeast wind that is observed in New England during their passage. This northeast wind is observed due to the storm's position in relation to New England and the storm's cyclonic circulation of winds around the center of low pressure. Nor'easters also strongly impact the Mid-Atlantic coast and the Chesapeake Bay area.

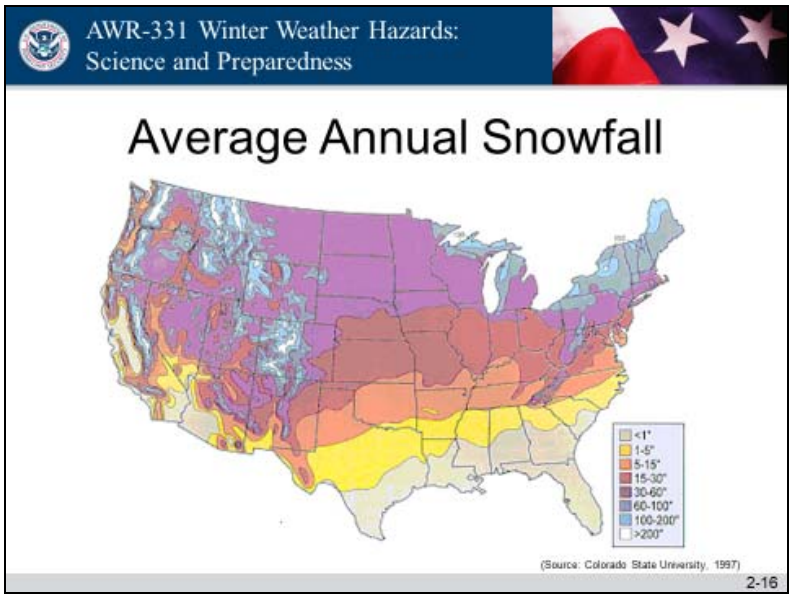
Alberta Clippers, named after a fast sea vessel known as a "clipper," form in the Canadian province of Alberta, just to the east of the Canadian Rocky Mountains and travel southeast into the northeastern United States. These storms usually bring cold air to the eastern half of the United States, but only light to moderate snowfall due to their fast speed.

Participant Notes:

Further west, the influence of the coastal mountains and the Rocky Mountains severely degrades the structure of winter storms so that it becomes difficult to follow a single low-pressure center from the Pacific through the mountains. Nonetheless, the area receives significant precipitation from winter storms as they move inland from the Pacific Ocean.

Key Point: While winter storm characteristics are colloquially described by their paths and origins, each storm is different and the path is no guarantee of a repeated forecast or impact.

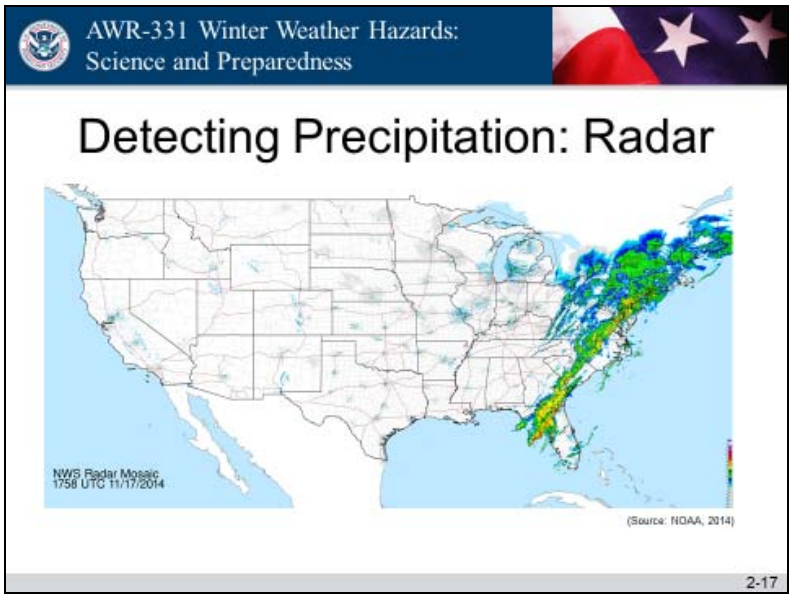
Participant Notes:



Slide 2-16. Average Annual Snowfall

While the snowfall during each winter season can vary quite a bit, the average snowfall map points out that the highest totals occur over the highest elevations across the west United States and the Appalachian Mountains in the eastern United States. High snowfall totals occur downwind of the Great Lakes as a product of lake-effect snowstorms. We will discuss lake-effect snowstorms in more detail in Module 3.

Participant Notes:



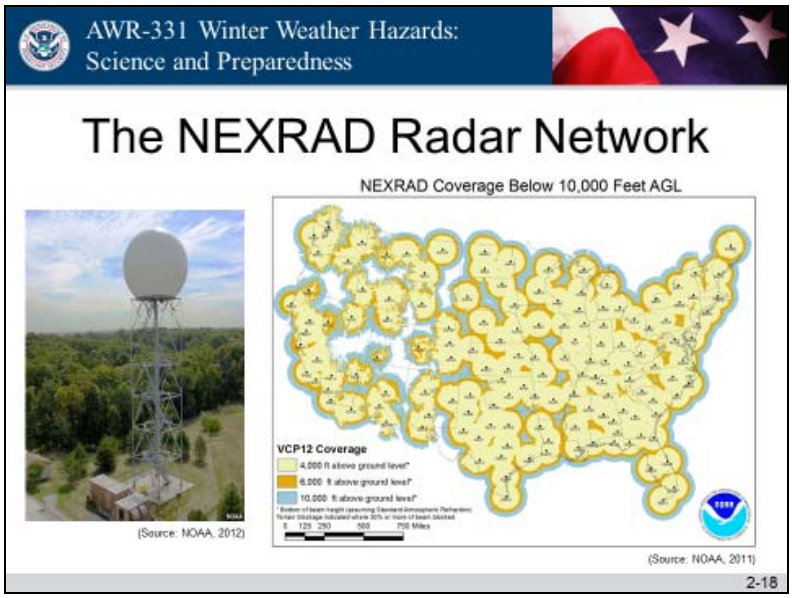
Slide 2-17. Detecting Precipitation: Radar

This is an example loop of Doppler radar reflectivity from a winter storm on November 18, 2014. This image is a compilation of all WSR-88D radar images in the contiguous United States.

The colors present on the East Coast represent a specific value of reflectivity, or the amount of pulse energy returned to the radar by precipitation or objects.

This topic will be discussed further in the following slides.

Participant Notes:

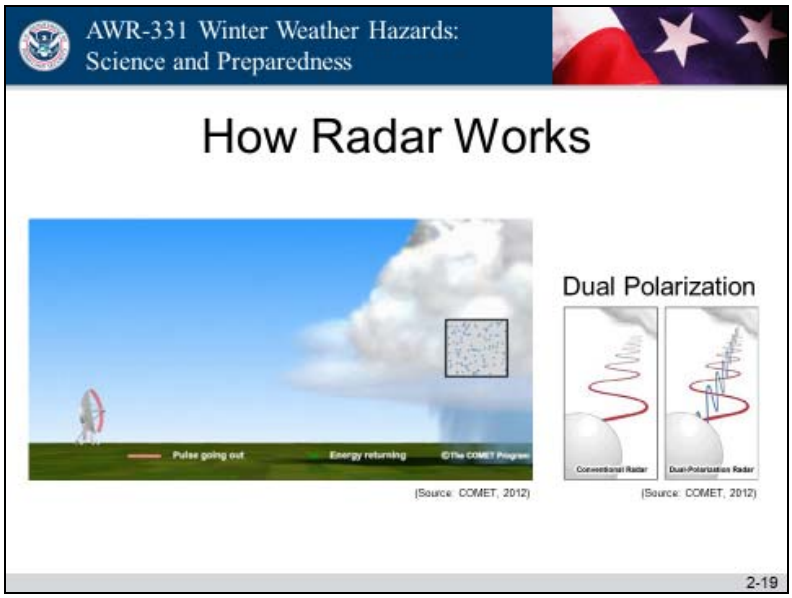


Slide 2-18. The NEXRAD Radar Network

The NEXt generation RADar network was established in the early to mid-1990s. There are now 160 government-operated radars across the United States and its territories. These radars are called WSR-88Ds. The acronym WSR-88D stands for Weather Surveillance Radar, created in 1998, with Doppler capability.

The location of each radar site was chosen to maximize coverage over populated areas and avoid beam blockage from mountains where possible.

Participant Notes:



Slide 2-19. How Radar Works

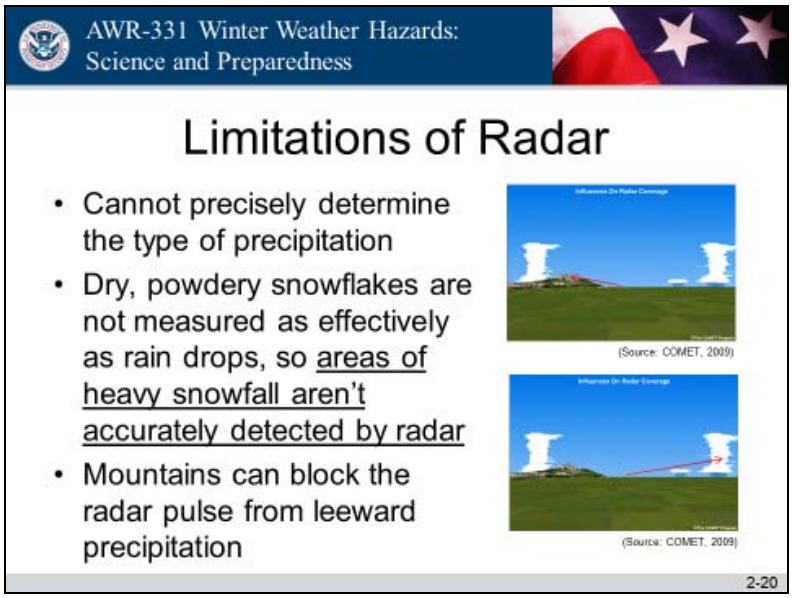
Radar detects what is falling from the cloud and what could hit the ground. Radar rotates to provide a scan of 360 degrees around the radar's location, out to a distance of about 250 miles.

Participant Note: Interestingly, the radar is only transmitting for about seven seconds during each hour. The remaining 59 minutes and 53 seconds are spent "listening" for returned signals.

As of 2013, all NWS radars have been upgraded to "dual polarization." The dual-pol upgrade includes new software and a hardware attachment to the radar dish that sends and receives both horizontal and vertical pulses of energy, providing a much more informative two-dimensional picture. Conventional Doppler radars only send out a horizontal pulse of energy that gives forecasters a one-dimensional picture of whatever is in the air, precipitation or non-precipitation. It can see precipitation, but cannot tell the difference between rain, snow, or hail. Dual-pol radar helps forecasters clearly identify rain, hail, snow, or ice pellets, and other flying objects, improving forecasts for all types of weather.

It should be noted that radar applications that offer "street-level" resolution present the same radar data as all other applications but place that data over a scalable map. Radar advertised by this method is no more accurate or reliable than radar found on NWS WFO webpages.

Participant Notes:



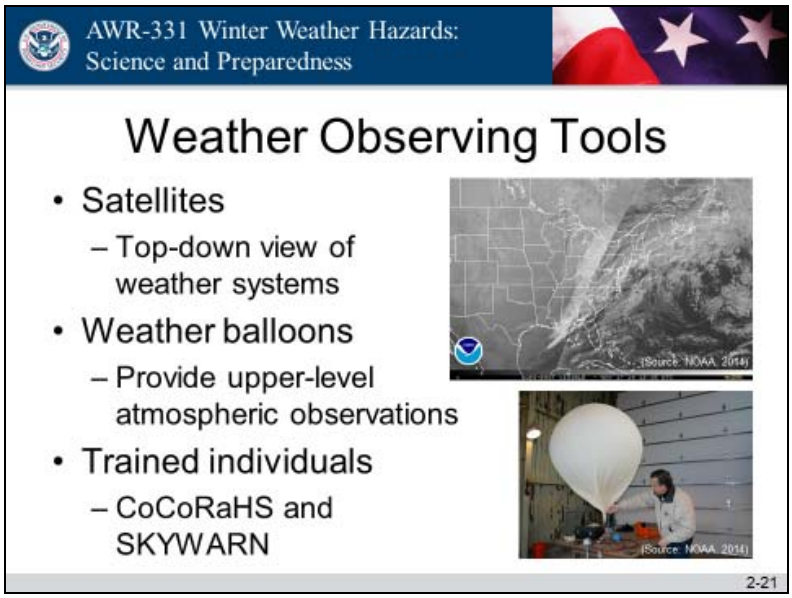
Slide 2-20. Limitations of Radar

Radar works well at observing precipitation in areas with little topography. However, in regions of extreme topography, such as mountain ranges and valleys, it is much less accurate as topography interferes with the radar pulse.

Another limitation of radar is that areas of intense, dry, powdery snow may be displayed on radar as "light green" while an area of intense rain is usually displayed as yellow or red. This disparity is due to the fact that small snow crystals with low water content do not reflect as much energy back to the radar as large raindrops.

Participant Note: If the radar image does not explicitly show the precipitation type, users can estimate the type of precipitation using the following concept. Images that show gradual changes in coloring with fuzzy edges to the precipitation colors often show snow, while liquid rain is usually denoted as having sharper changes from intense areas (yellow) to light areas (light green or blue).

Participant Notes:



Slide 2-21. Weather Observing Tools

Satellites:

There are two main types of satellites: geostationary and polar orbiting.

Satellite imagery is incredibly valuable as a data source that feeds numerical weather models. Satellites provide data from areas of the Earth where there are no weather instruments in place to relay observations for meteorologists.

Satellite images, like any other observational tool, do have their limitations. Images often have to be considered alongside other satellite and ground-based observations to provide perspective and confirmation of suspected atmospheric conditions. This method requires a significant amount of meteorological education and training to perfect.

Weather Balloons:

Weather balloons are launched to allow meteorologists to understand atmospheric conditions between the surface and the upper troposphere. The otherwise unattainable observations allow forecasters to make crucial decisions as well as improve the calculations of numerical weather models.

Participant Notes:

Participant Note: Because the radiosonde transmits data back to Earth in real time, it is unnecessary to recover the instrument package, but about 20% are found by Good Samaritans on the ground and are returned to their local National Weather Service office. These instrument packages can be refurbished and reused.

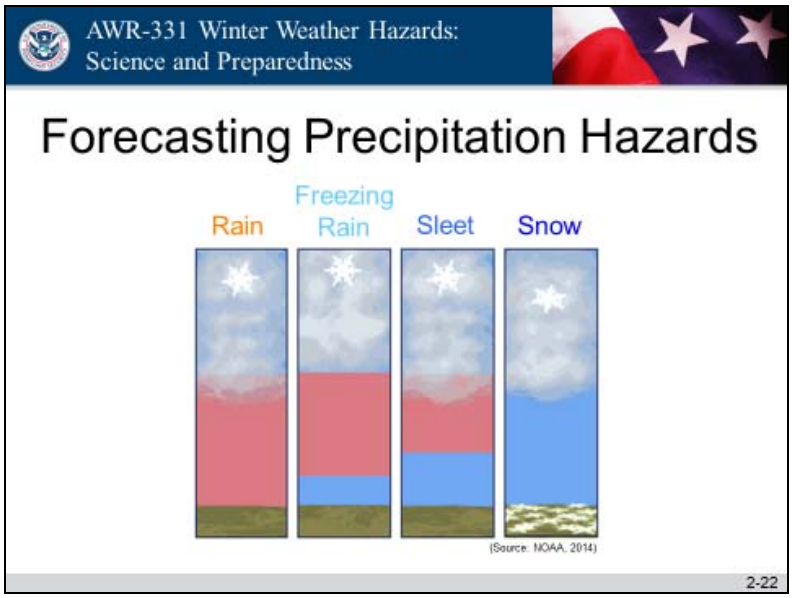
Trained Individuals:

Despite this technology for observing snowfall, the most reliable method to observe snow depth is a snowboard, or white square of wood, and a standard ruler. CoCoRaHS is a group of volunteers across the United States that measure and report snow, rain, and hail. This network of people helps to fill in the gaps in coverage that exist between official weather stations. These observations are critical for FEMA Public Assistance declarations.

Another network of local volunteers is called SKYWARN and focuses on identifying, describing, and reporting observations of local storms. This network is helpful to National Weather Service forecasters as it provides real-time information about weather conditions in local areas. Some National Weather Service Weather Forecast Offices offer SKYWARN training courses focused on winter weather hazards, but most are focused on convective weather hazards.

Participant Note: To find out more about these programs, visit http://www.cocorahs.org/ or http://skywarn.org/.

Participant Notes:



Slide 2-22. Forecasting Precipitation Hazards

The four main types of winter weather precipitation are rain, freezing rain, sleet, and snow.

Layers of warm and cold air between the cloud and the ground create these precipitation types. Specifically, the depth of each warm and cold layer has a strong influence on the type of winter precipitation that falls.

Sleet occurs during a winter storm and is formed as snowflakes fall, melt into raindrops, and then freeze into ice pellets before hitting the ground. Hail, on the other hand, forms under a different process and is associated with strong thunderstorms.

Freezing rain forms as rain falls to meet a thin layer of air below freezing at the surface. The rain does not have enough time to freeze while falling so it remains liquid until making contact with the surface and subsequently freezing. The temperature of the surface is markedly important to whether or not the rain will freeze on the surface.

The type of precipitation is determined by the presence and thickness of the warm air layer, where temperatures are warmer than 32°F.

If this warm air layer extends all the way to the ground from the cloud base, precipitation will fall as rain.

Participant Notes:

If the warm air layer is thick, but the air near the ground is below freezing, precipitation will start as snow, melt into raindrops in the warm layer, hit the ground as rain, and then freeze on contact with any surface. This is called freezing rain.

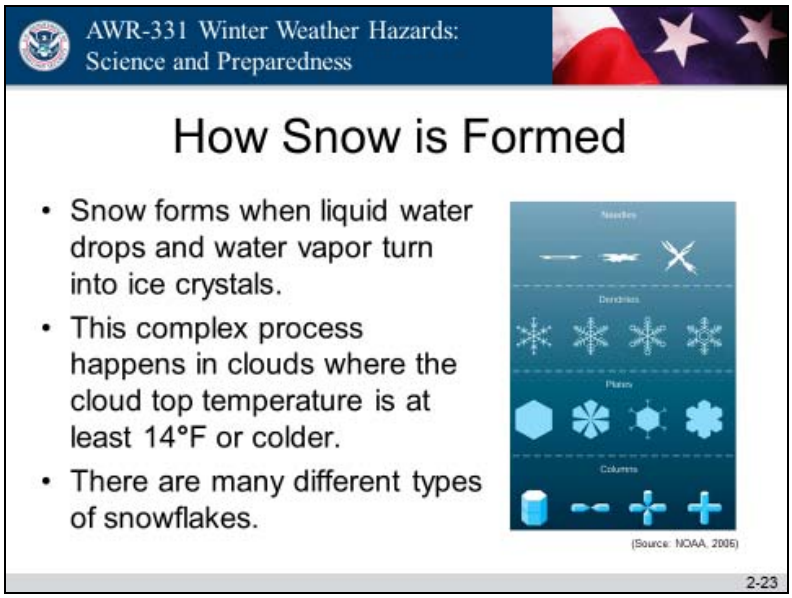
If the warm air layer is thin, then precipitation will start as snow, melt into raindrops in the warm layer, but then spend enough time in colder air below the warm layer to freeze into an ice pellet before hitting the ground. This is called sleet. Sleet differs from hail in that it does not form by the process of convection.

Forecasting the depth and temperature of this warm air layer is difficult. Small changes between the forecast and actual depth of the layer can result in large changes to the amount and type of precipitation that hits the ground.

Knowledge Check: If there is no air layer warmer than 32°F between the cloud and the ground, what type of precipitation will fall?

Example: Freezing rain creates extremely dangerous travel conditions when it forms on roadways (especially when paired with other types of precipitation). Forecasting freezing rain on roadways is a complicated process that includes knowing the temperature of the roadway. This information is often available through private weather services.

Participant Notes:



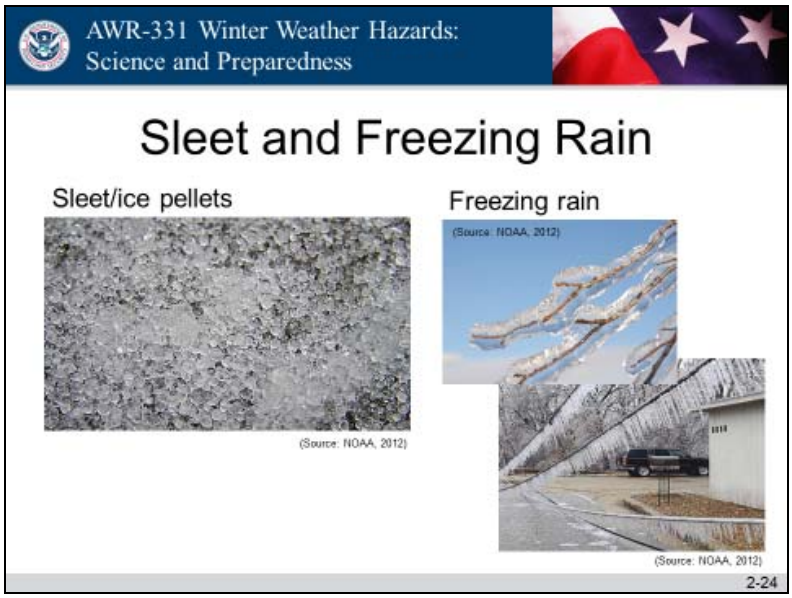
Slide 2-23. How Snow is Formed

Snow formation is complex and known to the meteorology community as the *Bergeron-Findeisen Process*. This process begins with a cloud of water vapor where the temperature is at least 14°F or colder or ideally lower than 0°F. At this temperature, water droplets will begin to solidify into ice crystals. Microscopic particles of bacteria, clay, salt from evaporated seawater, and ash can serve as nuclei for water drops and water vapor to use as the center of a newly formed ice crystal.

Once an ice crystal forms, it grows by pulling moisture from water drops and water vapor molecules around it.

Storms with a high amount of water vapor are often associated with warm temperatures as they pick up this water vapor from relatively warm oceans and bodies of water. These storms will often produce heavier and wetter snow with high moisture content. Conversely, storms with colder temperatures can produce lighter, drier, and fluffier snow. The type of snowflake depends on both the amount of moisture in the air as well as the temperature.

Participant Notes:



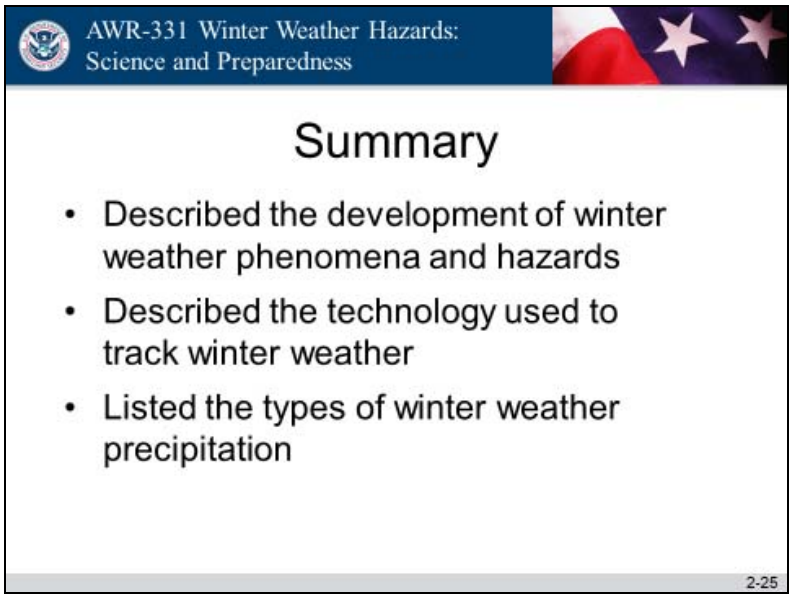
Slide 2-24. Sleet and Freezing Rain

Sleet is a small, hard ball of ice, usually about the same size or smaller than the size of a pea. When sleet hits the ground, it bounces. It often mixes with snow that fell before the sleet began and simply adds to the accumulation on the ground.

Freezing rain can be more hazardous. Rain falls to the ground and immediately freezes to the surface that it touches, including roads, cars, branches, and power lines. This accumulation of ice adds tremendous weight and can often overwhelm and break branches and utility poles. It can glaze roadways and sidewalks with clear ice that becomes slippery at best or impassable at worst.

Participant Note: Sleet and hail are both ice pellets, but hail is formed in the updrafts of thunderstorms, and sleet is formed by specific temperature profiles between the cloud and the surface.

Participant Notes:



Slide 2-25. Summary

This module reviewed definitions, explained concepts, and provided other details pertaining to the science of winter weather. This included an overview of how winter storms form, how they are tracked, and the types of precipitation that they produce.

Forecasting the type and amount of precipitation is difficult as subtle changes in things like the amount and depth of warm air can lead to big changes in the outcome of the eventual storm. We will talk about forecasting uncertainty in Module 3.

✔ **Knowledge Check:** What types of weather hazards can a low-pressure system produce?

AWR-331 Winter Weather Hazards: Science and Preparedness

Module 3: Winter Weather Forecast Process

Version 1.0

FEMA

This page is intentionally left blank.

Module 3: Winter Weather Forecast Process – Administration Page

Slide 3-1. Winter Weather Forecast Process

Duration

75 minutes

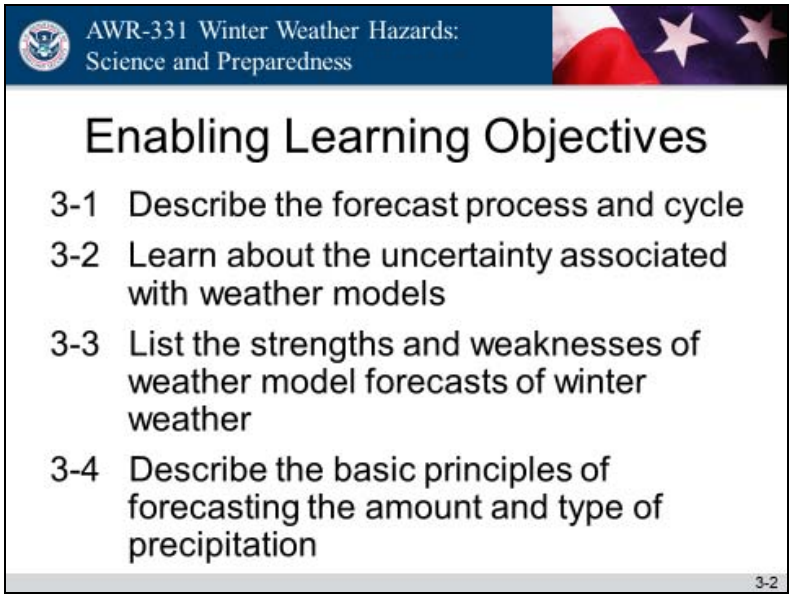
Scope Statement

In this module, the instructors will discuss how weather forecasters use numerical weather models to create a forecast of winter weather. This will include a general background about numerical weather models, the strengths and weaknesses of the models, and how to use the models to forecast the amount and type of precipitation. A group activity will provide participants with the opportunity to experience the challenges associated with forecasting snow, sleet, and freezing rain.

Terminal Learning Objective (TLO)

Participants will be able to understand the winter weather forecast process, appreciate its complexities, and participate in a forecasting exercise.

Enabling Learning Objectives (ELOs)



Slide 3-2. Enabling Learning Objectives

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

3-1 Describe the forecast process and cycle;
3-2 Learn about the uncertainty associated with weather models;
3-3 List the strengths and weaknesses of model forecasts of winter weather; and
3-4 Describe the basic principles of forecasting the amount and type of precipitation.

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)
- Group Handouts
- One of each of the following items per participant:
    - Participant Guide (PG) available for download from http://ndptc.hawaii.edu/

Instructor-to-Participant Ratio

2:40

Reference List

CIPS, 2005. "Snow-to-Liquid Ratio Climatology." Accessed 2014. http://www.eas.slu.edu/CIPS/slr.html

COMET, 2005. "Topics in Lake Effect Snow Forecasting." Accessed 2014. http://www.meted.ucar.edu/norlat/snow/lake_effect/

NOAA, 2007. "The History of Numerical Weather Prediction." Accessed 2014. http://celebrating200years.noaa.gov/foundations/numerical_wx_pred/welcome.html

NOAA, 2008. "Warm Water and Cold Air." Accessed 2014. http://www.noaa.gov/features/02_monitoring/lakesnow.html

NOAA, 2010. "Precipitation." Accessed 2014. http://www.srh.noaa.gov/jetstream/synoptic/precip.htm

NOAA, 2014. "Rapid Refresh." Accessed 2014. http://rapidrefresh.noaa.gov/

Weather Forecasting On-Line, 2010. "Freezing Rain and Ice Pellets." Accessed 2014. http://www.wxonline.info/topics/zrain_ip.html

Practical Exercise Statement

This activity provides an opportunity for participants to develop a stronger understanding of weather forecasting through a group activity. Participants will consider horizontal and vertical temperature profiles of the atmosphere and forecast hazards and precipitation types accordingly. The objective of the activity is to use the knowledge and understanding gained from previous modules to better understand weather forecasts and the complexity of forecasting precipitation types.

Assessment Strategy

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

Winter Weather Hazards: Science and Preparedness

Icon Map

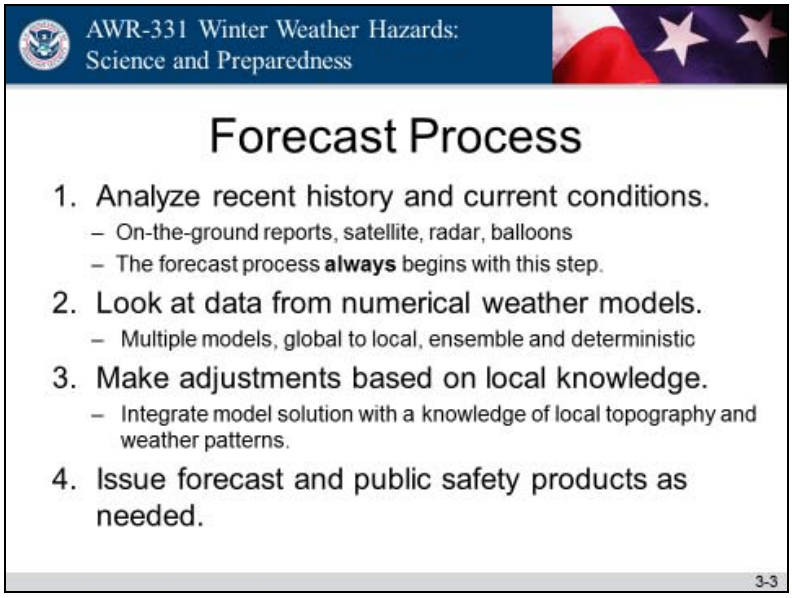
Knowledge Check: Used when it is time to assess participant understanding.

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

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

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

Participant Notes:



Slide 3-3. Forecast Process

The forecast process starts with analyzing current weather conditions using a mixture of:

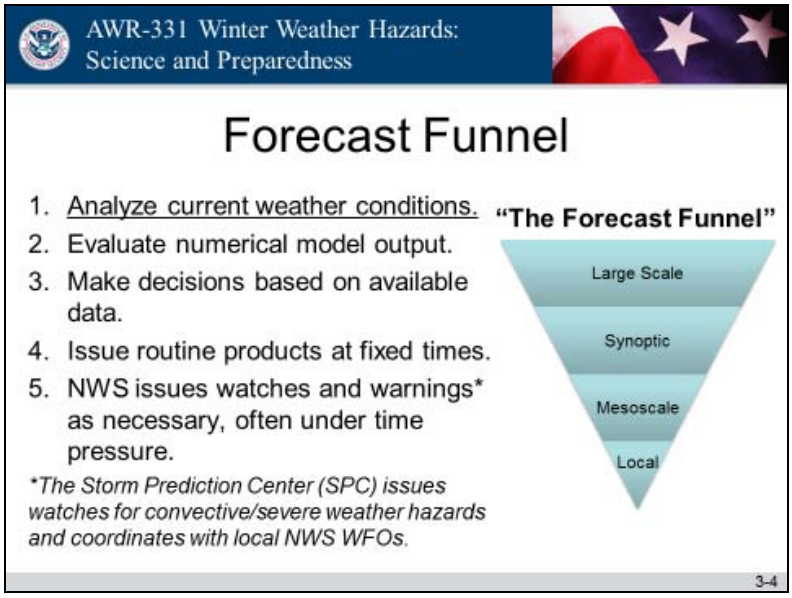
- Radar data;
- Satellite data;
- Ground observation;
- Weather balloons; and
- Manual weather map analysis.

Meteorologists then use numerical weather model forecasts to analyze projections of general atmospheric flow. Focusing first on large-scale phenomena, meteorologists can then relate regional dynamics to local impacts. More details about numerical weather models will be covered in the following slides.

Using their understanding of local terrain effects, meteorologists adjust the numerical weather model forecast to more effectively map local impacts. Many models that cover the entire globe cannot accurately predict the effects of local terrain.

All of this information is then incorporated into a weather forecast and, if necessary, alerts are issued for current and future weather conditions.

Participant Notes:



Slide 3-4. Forecast Funnel

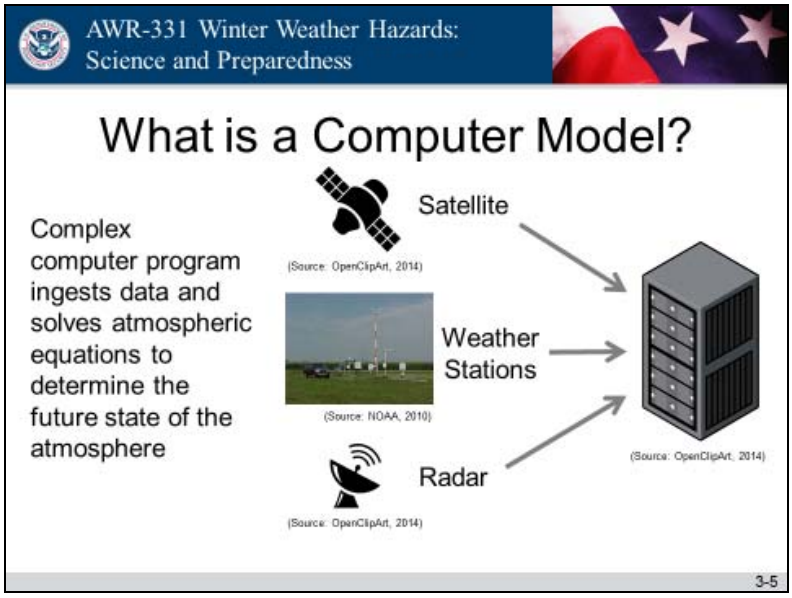
The concept of the forecast funnel is similar to building a business plan or planning for a large event. The "big picture" must first be analyzed before the details and local impacts can be known. For meteorologists, this translates into first analyzing global weather on the scale of thousands of miles.

This global scale is brought down to a national, or synoptic, scale. Synoptic, as explained on earlier slides, is a description of events on the scale of hundreds to thousands of miles and hours to days. At this scale, weather observation systems are blended together to allow meteorologists to understand the interconnected nature of the current conditions.

The effects of a winter storm are variable across the storm and so a meteorologist must focus on the local, or mesoscale, phenomena. Mesoscale describes weather phenomena that are on the scale of tens to hundreds of miles that exist from minutes to hours.

While understanding the larger context of the weather pattern is important, all weather is local.

Participant Notes:



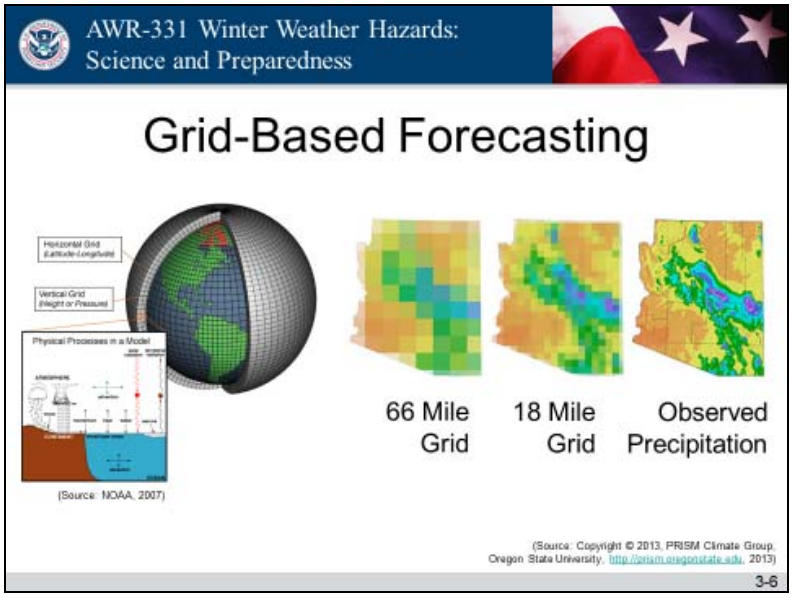
Slide 3-5. What is a Computer Model?

Numerical weather prediction models, simply referred to as "computer models," are supercomputers that use advanced chemical, physical, and atmospheric equations to turn weather observations into weather forecasts.

The first model was produced in April of 1950 using an ENIAC computer that filled a 30-foot by 50-foot room. This first forecast of 24-hour weather conditions took more than 24 hours to be produced. While the forecast itself was not useful, it did prove that computer-based weather prediction was feasible.

Computer modeling of the atmosphere became more efficient as computer power increased and allowed the models to forecast both with more detail and with less time.

Participant Notes:



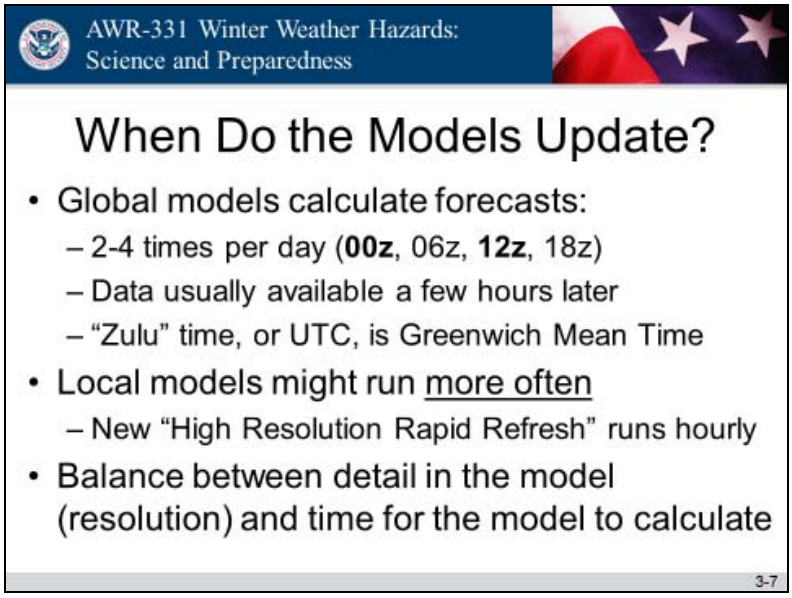
Slide 3-6. Grid-Based Forecasting

A numerical weather model breaks up the surface of the Earth into a grid, extending well above the surface beyond 50,000 feet.

The model brings in observations from weather radar, satellites, weather balloons, and ground stations to generate a current weather condition code for each grid box. Then the model uses advanced physical, chemical, and atmospheric equations to create a forecast for weather conditions within each grid box.

The size of the grid is important. Larger grid boxes mean that the detail of the model is much coarser, but the model will run more quickly. Conversely, a higher resolution model with smaller grid boxes will produce a more detailed forecast, but the model will also take longer to run.

Participant Notes:



Slide 3-7. When Do the Models Update?

An important concept when discussing numerical weather modeling is the time of issuance. Weather modeling is a global endeavor and so the meteorological community uses the global time standard of Greenwich Mean Time, named after the city of its namesake in England. This time is also referred to as "GMT," "Zulu," "Z," or "UTC."

Most global models ingest data twice daily at 00z and 12z. This means that the models pull in the most current observations at this time. When all of the current observations are assimilated into the model to provide the most accurate snapshot of what the atmosphere looks like at that time, the model then begins to "run" by processing the equations and generating a forecast.

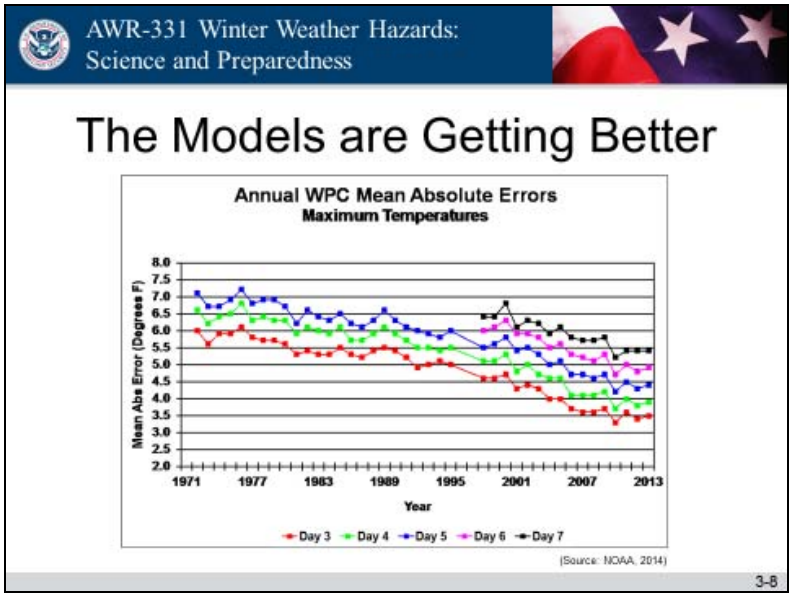
Participant Note: Some models are produced more frequently than twice a day, like the American GFS (Global Forecasting System) model, which runs at 00z, 06z, 12z, and 18z. Some high-resolution models that look at a smaller area (for example, the United States instead of the globe) run each hour, like the RAP (Rapid Refresh) and the HRRR (High Resolution Rapid Refresh).

A good rule of thumb is that a high quality, accurate model will take longer to update. However, sometimes model quality must be sacrificed for the sake of public safety.

Participant Notes:

Key Point: Note that many models update in six-hour intervals but some update hourly.

Participant Notes:



Slide 3-8. The Models are Getting Better

As of 2013, a four-day forecast was as accurate as the three-day forecast was just a decade before. In other words, the forecast has improved at the rate of about one day of lead-time over 10 years.

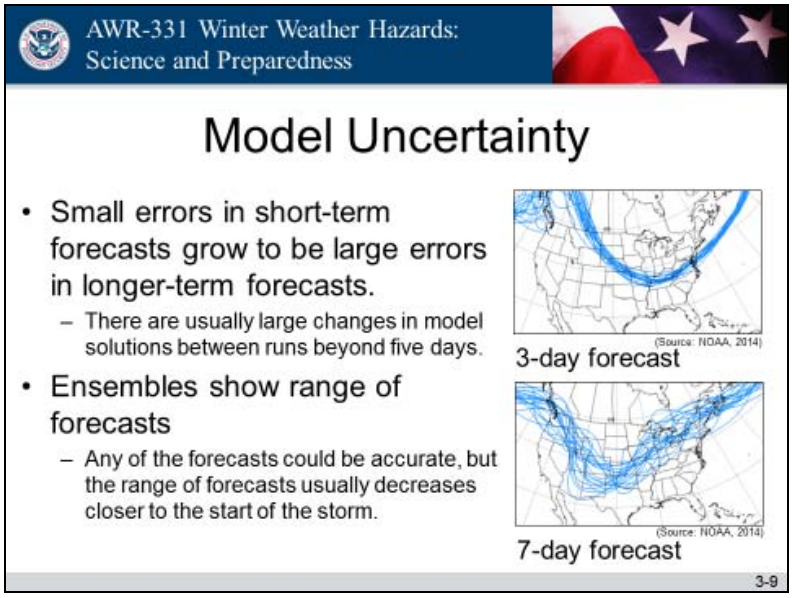
As another example, in 2013 a seven-day forecast is as accurate as the four-day forecast was 20 years before, a rate of improvement slightly faster at about one and one-half days of lead-time in 10 years.

The models undoubtedly have their weaknesses and are far from perfect, but this is a remarkable achievement that only started one generation ago in the 1950s.

Key Point: The errors of weather models continue to decrease.

Participant Note: A forecast range is the distance into the future that the forecast is issued. This is typically 36 hours, three days, five days, seven days, and 10 days.

Participant Notes:



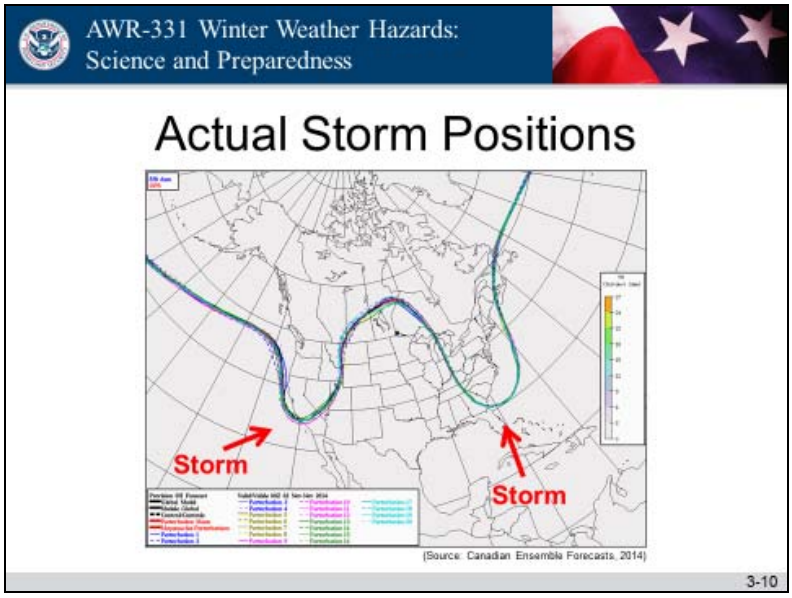
Slide 3-9. Model Uncertainty

Numerical weather prediction using models does not produce a perfect forecast. To better assist meteorologists during the forecast processes, ensemble numerical weather models were developed.

Many versions of a forecast model (sometimes 20 to 50) can be run simultaneously, with each version changed just slightly from the one before. These changes usually occur within the initial weather conditions fed into the model. The idea is that when the initial conditions are changed, each model version within the ensemble will produce a different forecast, especially at longer distances into the future.

If all of the versions within the ensemble show a similar forecast, then there is higher confidence in that forecast and lower uncertainty. However, at longer forecast times, there is often a large difference between the versions within the ensemble and this difference is used to quantify the uncertainty within a forecast.

Participant Notes:



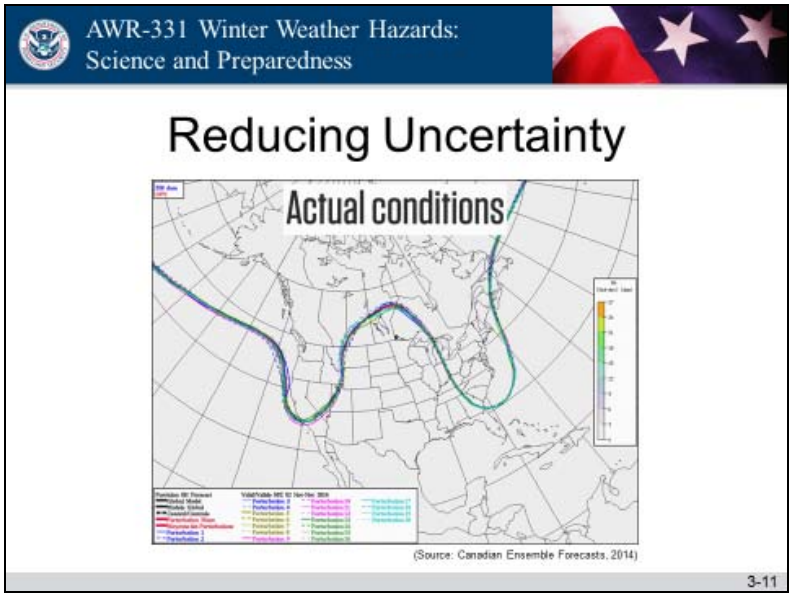
Slide 3-10. Actual Storm Positions

The dips in the lines show troughs or areas of colder air sinking south and, in this case, snowfall over both the Rocky Mountains and the Appalachian Mountains. Troughs generally represent areas of anticipated inclement weather conditions. The larger the "dip" observed in the lines, the stronger the trough and subsequent storm.

If you look carefully, you can see multiple lines, and each line represents one of twenty versions of an ensemble of forecasts from the Canadian GEM model. Since this image is the initialization of the model, each version within the ensemble roughly shows the same atmospheric flow. However, 16 days earlier, the forecast made for this time looked quite different.

✔ **Knowledge Check:** Will each ensemble member agree with the others, or will they show wildly different solutions for a 16-day forecast?

Participant Notes:



Slide 3-11. Reducing Uncertainty

The animation shows the forecast from 384 hours (16 days) to present time. Each individual line shows the forecast of one version of one model.

Each line, or ensemble member, above was created by changing the observations that the model ingests to produce a forecast. By slightly adjusting the initial data, we capture the uncertainty of the data that goes into the model. This uncertainty exists because there are large distances between locations where we measure pressure, temperature, moisture, and wind.

The red line is the average of all the model versions (also called "ensemble members"). The background colors show the agreement between the model versions. In areas of brighter color, there is a large difference between the ensemble member forecasts, and this points to high uncertainty in the forecast.

At 10 days out, there was some hint that there could be a trough over the west and over New England, but there was also considerable spread, or uncertainty, in each of these areas. Day 9 looked similar.

At Day 8, most ensemble members pointed toward two troughs, one on the east coast and one over the west, but there was still considerable spread. In fact, none of the ensemble members showed the possibility of each storm being as strong as they eventually were (stronger storms have troughs that push further south). Day 7 and Day 6 looked similar.

Participant Notes:

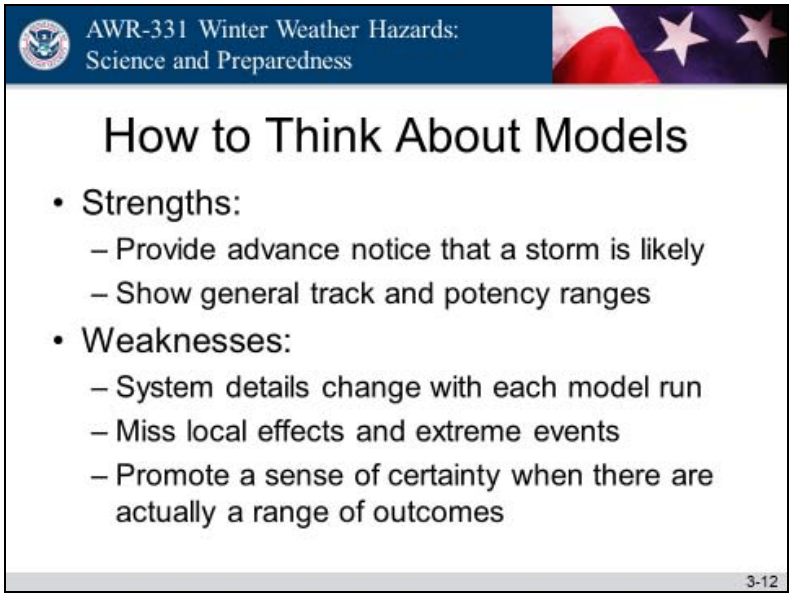
The trend from Day 6 to Day 5 to Day 4 was to strengthen each trough and shift it back to the west. Finally, by Day 4 most ensemble members showed the correct position of the troughs.

Note that even though ensembles are helpful in showing the uncertainty with forecasts, they do not show all possible outcomes. It may be unwise to simply follow the average of all members or the trend from day-to-day, as in this case, Day 7 showed one member on the east coast with the correct strength of storm, but this disappeared from the map on the next day.

Knowledge Check: What lead-time would you feel comfortable issuing a forecast for a winter storm with significant impacts?

Key Point: Numerical weather model solutions beyond five days usually exhibit large changes between each model run.

Participant Notes:



Slide 3-12. How to Think About Models

Numerical weather models have gained a tremendous amount of accuracy over the past six decades; however, their best use beyond approximately five days is to serve as a general signal that a storm is possible in a certain time frame and to show the general strength of the system. They produce different forecasts with each new run and no run should be considered as absolute certainty or fact.

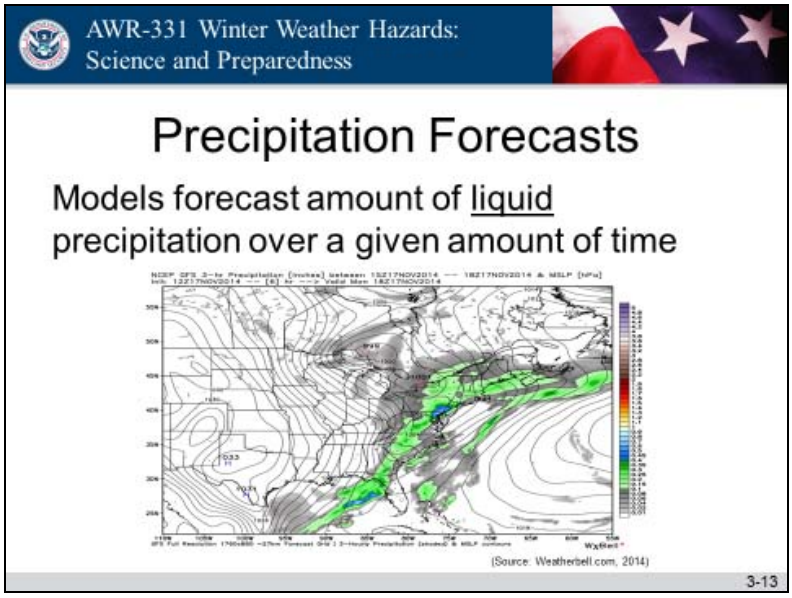
e.g.

Example: On January 25, 2015, New York City was nearly struck by what would have been a winter storm of historic strength. The city set travel bans, shut down public transportation, and effectively forced a citywide "snow day" in advance of the storm that was broadcast as "historic" by media outlets nationwide.

What happened? Meteorologists across the nation struggled to interpret numerical weather models that forecast a wide range of storm tracks. The Global Forecast System (GFS), or "American model," projected a track that moved away from New York City; the European Center for Mid-range Weather Forecasting (ECMWF), or "European model," projected a track to heavily impact the city. Many meteorologists used past experience with the ECMWF's success with Hurricane Sandy and weighed their forecast toward this outcome.

As it became more apparent that the storm track would mimic the GFS path, New York City was already prepared for the worst.

Participant Notes:



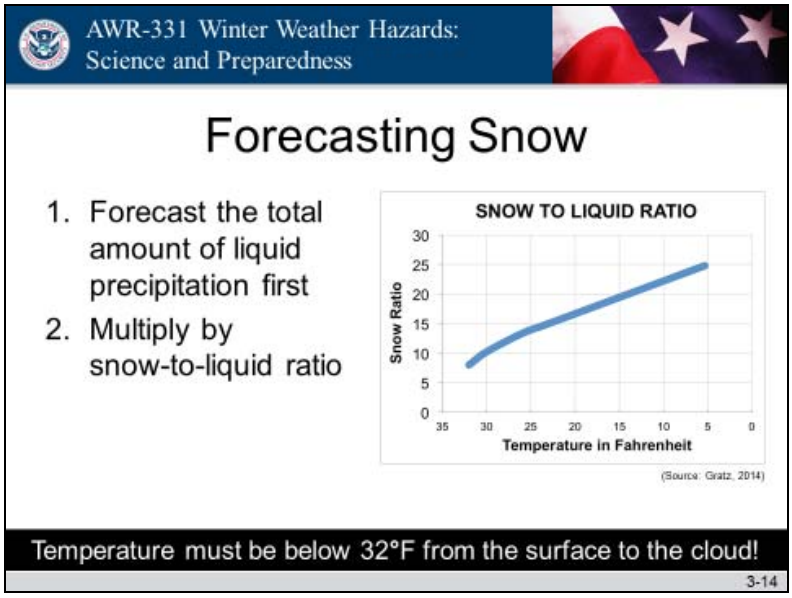
Slide 3-13. Precipitation Forecasts

The numerical weather models produce forecasts for many weather variables including, but not limited to, temperature, moisture, wind, pressure, and precipitation.

Numerical weather model-produced precipitation forecasts provide a forecast for the amount of liquid precipitation that will fall during a certain time period (e.g., six hours or 12 hours).

To anticipate the correct type of winter weather hazard, a forecaster must first determine the most likely precipitation type based on the vertical temperature profile (discussed in future slides in this module), and then convert liquid precipitation into the amount of snow, sleet, or freezing rain.

Participant Notes:



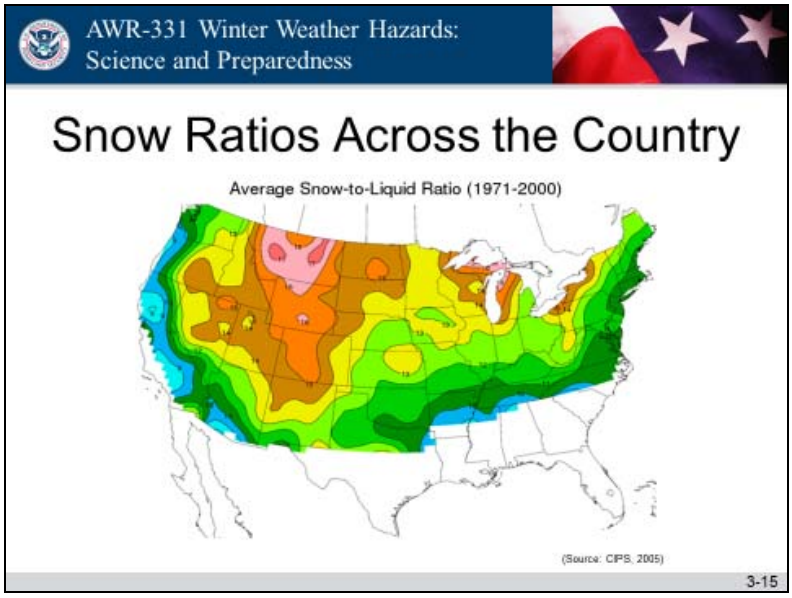
Slide 3-14. Forecasting Snow

Forecasting the snow-to-liquid ratio is difficult because it is based on the forecast temperature as well as on the forecast wind speed. These factors can change the shape of snowflakes and allow them to stack higher or pack together more tightly.

In general, a lower temperature translates to a higher snow-to-liquid ratio. In other words, at colder temperatures, the same amount of liquid turns into deeper amounts of snow.

Key Point: Numerical weather models do not forecast snowfall, but instead forecast liquid precipitation totals and snow-to-liquid ratios. Meteorologists must correctly analyze each variable to produce an accurate snow forecast.

Participant Notes:

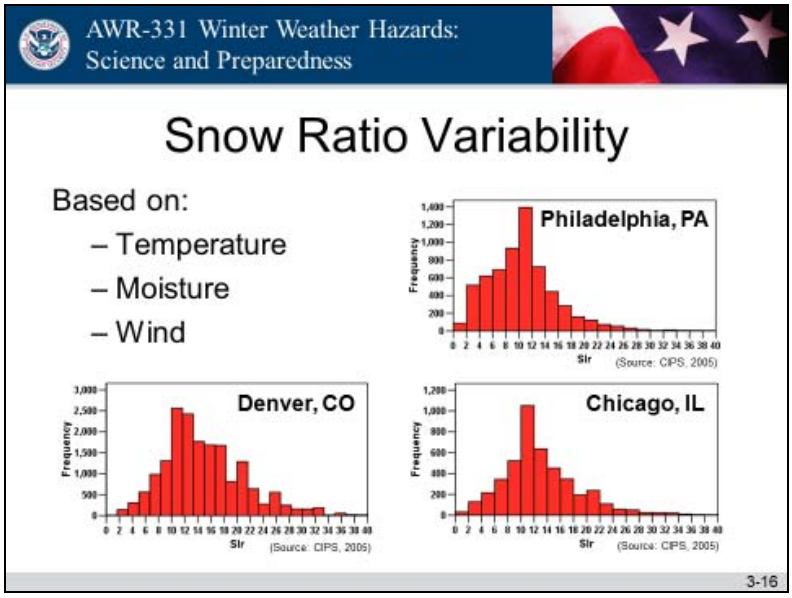


Slide 3-15. Snow Ratios Across the Country

The graphic shows the average snow ratio during November through March. However, there is considerable variability from month to month and from storm to storm.

In general, the highest snow-to-liquid ratios are found over the Rocky Mountains due to colder temperatures at higher elevations. A secondary area of high snow ratios exists in the lee of the Great Lakes where lake-effect snow is common. This high snow ratio is likely due to low air temperatures over warm lake water, both of which are ingredients for lake-effect snow.

Participant Notes:



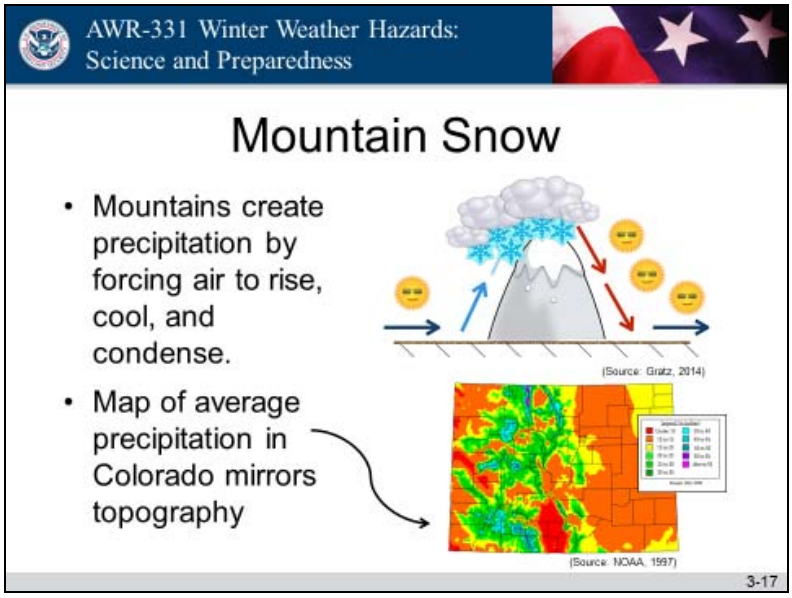
Slide 3-16. Snow Ratio Variability

The histograms above show the observed snow-to-liquid ratio on the y-axis and the snow-to-liquid ratio listed along the x-axis.

While a 10-to-1 ratio is the ratio that is observed most frequently, the ratio varies quite a bit.

- Denver, Colorado, sees more high-ratio events, and their average is 15.1-to-1.
- Chicago, Illinois, is more evenly distributed than Denver, but also averages above the 10-to-1 snow-to-liquid ratio with an actual average of 13.1-to-1.
- Philadelphia, Pennsylvania, due to mostly warmer storms as they are closer to the relatively warm Atlantic Ocean, averages 10.6-to-1.

Participant Notes:



Slide 3-17. Mountain Snow

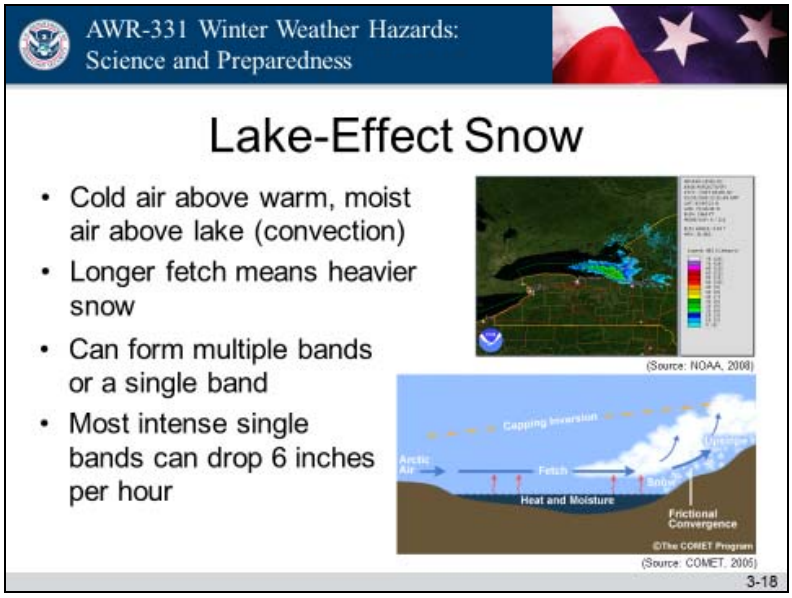
Snow needs two ingredients to form: *moisture* and *lift*.

Lift occurs when wind rises over a mountain (or any tall topography) and the resulting ascent cools the air. As the air cools and rises, water vapor condenses into liquid drops and, once present in air below 32°F, freeze into ice crystals and snowflakes.

The lift created by mountains and other tall topography is often not well handled by numerical weather models because the models do not have the resolution to quantify the extreme changes in topography over small distances (e.g., 3,000 vertical feet gained in one-half mile). Local forecasters will often adjust model output to better capture the additional snow that falls due to the effect of the mountains.

The average precipitation over mountainous terrain will often increase alongside the topography of the region due to the effect of topographic lift.

Participant Notes:



Slide 3-18. Lake-Effect Snow

Intense, narrow bands of snow can form near and downwind of a body of water like a lake or ocean.

The first ingredient for snow – *moisture* – is found just above ocean/lake surface where water molecules have escaped from the surface of the water and mixed with the air. This moisture above and inside of the ocean/lake absorbs and retains energy from the sun much more efficiently than the surrounding land. As a result, lakes are often warmer than surrounding land in the fall and early winter.

The second ingredient for snow – *lift* – is created by the vertical ascent of warm, less dense air upwards through cold, dense air. This process is called *convection*. This is the same process that creates thunderstorms.

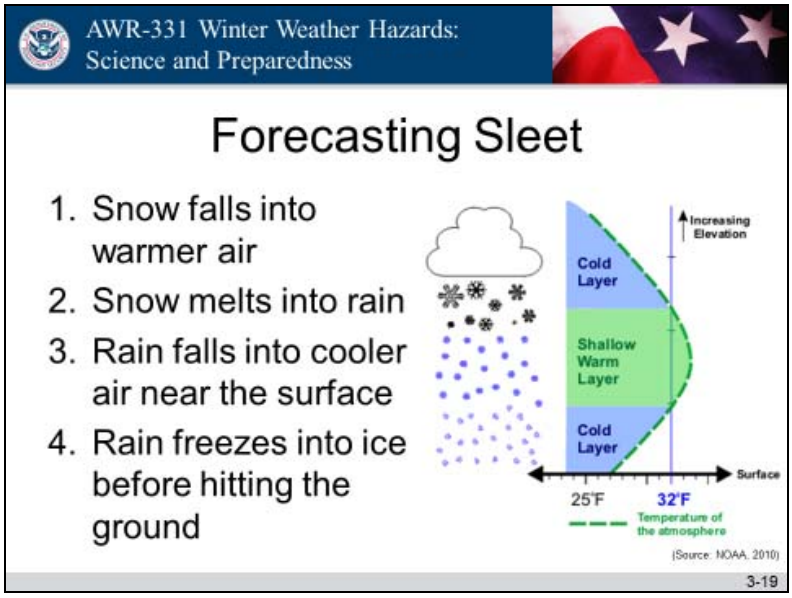
The final ingredients are the speed and direction of the wind. For the most intense single bands to form, the wind should blow over the lake surface for the longest possible distance at about 17-23 mph. If the wind speed is any lower than ~17 mph, then it will be overwhelmed by other forces; if it is higher than ~23 mph, then the band will be torn apart. The distance that the wind travels over the lake is called the *fetch*.

Participant Notes:

Participant Note: As a general rule for the Great Lakes, the temperature of the air at about 5,000 feet (850 mb) should be at least 23°F (13°C) colder than the surface of the lake. For the Great Salt Lake in Utah, this temperature differential between the lake and about 10,000 feet (700 mb) should be at least 29°F (16°C). Although they are much smaller than the Great Lakes and the Great Salt Lake, the New York Finger Lakes also aid in the creation of lake-effect snow squalls.

The same process of lake-effect snow occurs in Japan, except the moisture source is not a lake but rather the ocean to the west of Japan. This creates heavy snowfall rates in the northern and western mountains of Japan as cold air moves across the Sea of Japan from China and Russia.

Participant Notes:

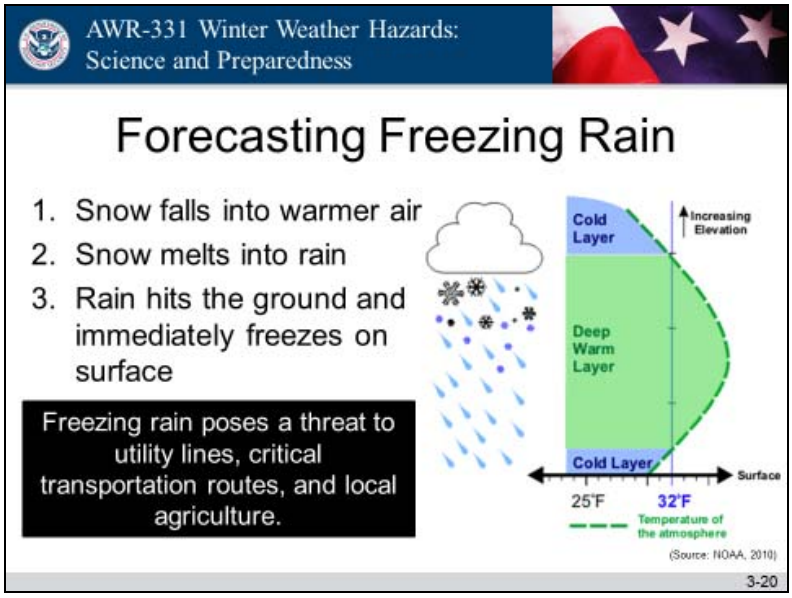


Slide 3-19. Forecasting Sleet

In winter storms, a warmer layer of air that is above the freezing layer can exist in the middle of the atmosphere. This often happens north of the warm front.

As snow falls into this warm layer, some snowflakes melt completely and others only partially melt. When this mixture of liquid drops and ice crystals hit the colder layer below, the liquid drops will have time to freeze before they hit the surface.

Participant Notes:

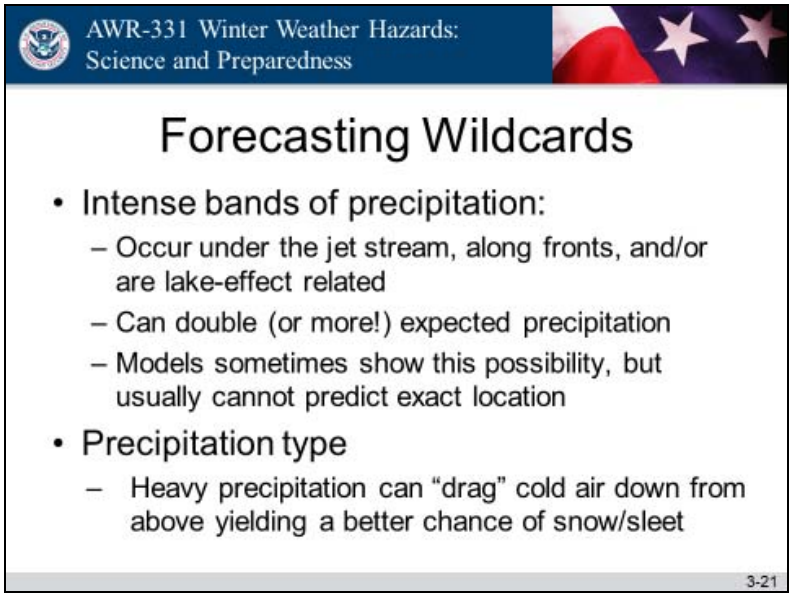


Slide 3-20. Forecasting Freezing Rain

During winter storms, a warmer layer of air that is above the freezing temperature can exist in the middle of the atmosphere. This often happens north of the warm front.

As snow falls into this warm layer, snowflakes melt completely. When the liquid drops fall into the colder layer below, the liquid drops will cool to below freezing but will not have the time or the ingredients to form back into ice. Therefore the water drops that are below freezing hit the surface as liquid. When they hit the surface, they freeze on contact into a glaze of ice.

Participant Notes:



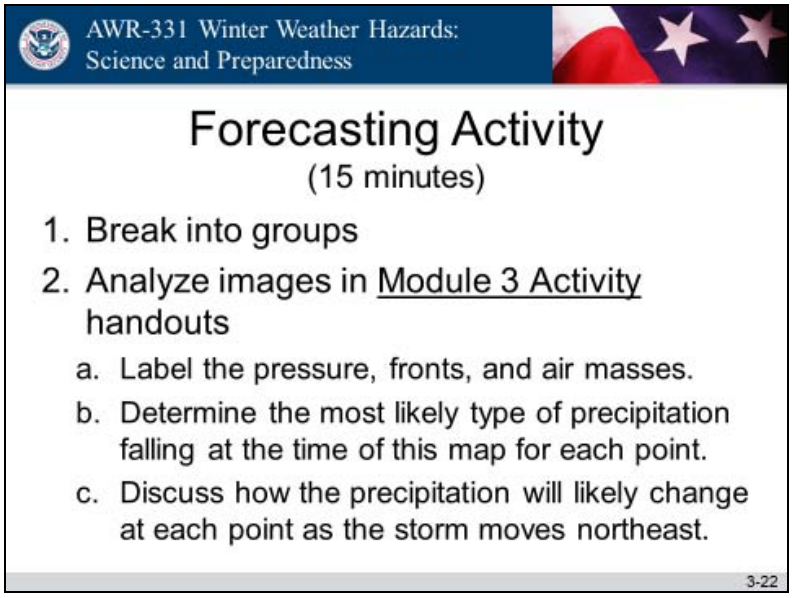
Slide 3-21. Forecasting Wildcards

While the numerical weather models often make accurate forecasts of the general location, amounts, and types of precipitation during a storm, they may not be able to accurately predict the location and intensity of small-scale and intense areas of precipitation. Forecasters may say that these small-scale phenomena are likely, but cannot forecast exactly where they will be located.

Users of the forecast should know that intense areas of precipitation or subtle shifts in the location of frozen versus liquid precipitation can occur and may not be able to be forecast in advance.

Further, as precipitation falls, it can pull down air from above. Since higher-elevation air is usually cooler, this air from above can cool the lower part of the atmosphere and allow snow to fall instead of liquid precipitation. This often happens within heavier areas of precipitation, and can be sporadic, lasting for only as long as the heavy precipitation falls, and then transitioning back to rain when the precipitation is lighter.

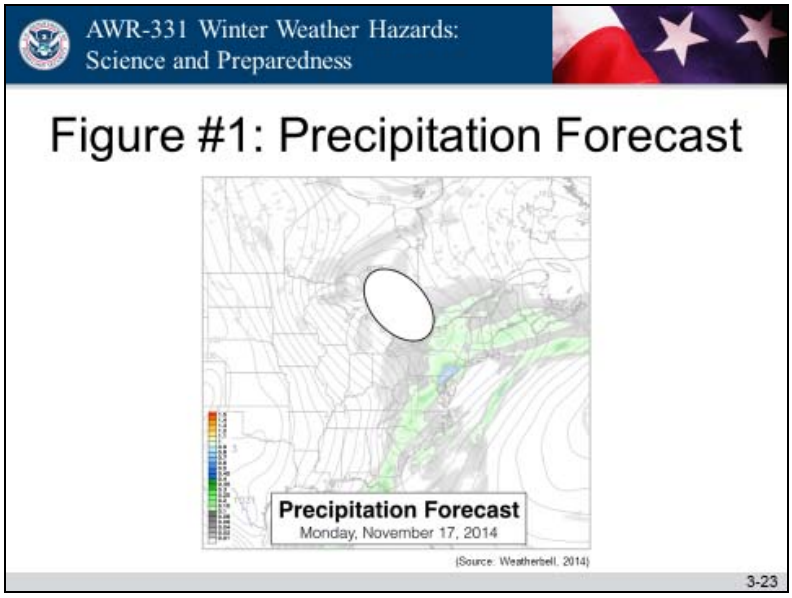
Participant Notes:



Slide 3-22. Forecasting Activity

This exercise allows participants to work together to reinforce the earlier discussion of the typical structure of winter storms. Using temperature profiles for three locations within different regions of the storm, participants determine the most likely precipitation type, and discuss how the precipitation will change as the storm moves.

Participant Notes:

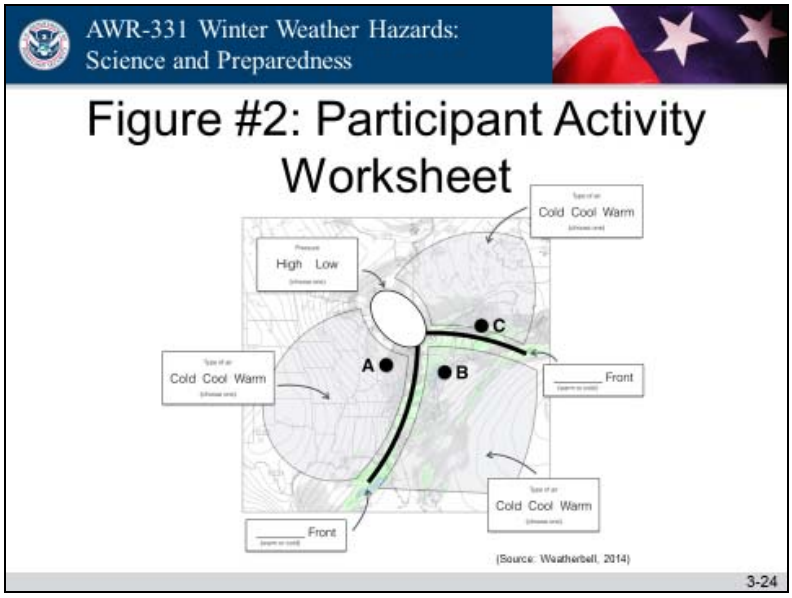


Slide 3-23. Figure #1: Precipitation Forecast

This map is an actual forecast of a winter storm from the U.S.-based Global Forecast System (GFS) weather model for November 17, 2014. The colors show the amount of precipitation that is forecast to fall over a three-hour period. The black lines show the isobars, or lines of constant pressure, associated with the storm.

The next figure will ask you to identify several features that are typical in winter storms, and include the type of pressure, higher or lower, associated with a typical winter storm. The center of the higher or lower pressure is highlighted by the white oval.

Participant Notes:



Slide 3-24. Figure #2: Participant Activity Worksheet

The instructors have highlighted important parts of a typical winter storm, as discussed in Module 2. Participants should choose the best answer for each part of the storm that requires a label. Participants should also note the location of points A, B, and C, as these will be discussed on the next three pages of the handout.

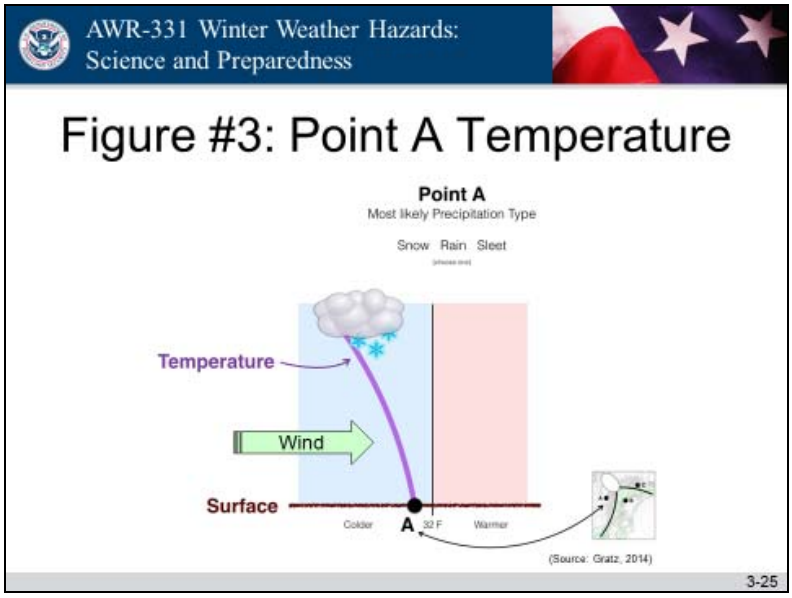
The typical structure of a winter storm has been broken into numerous parts. Participants should identify the following:

- Type of air mass that occupies each of the three sectors
- Type of fronts dividing separate air mass sectors
- The type of pressure (high or low) that drives a winter storm

Participants should:

- Circle the correct type of air mass that occupies each of the three sectors in the appropriate box;
- Fill in the blank space of each front with its correct corresponding name; and
- Circle the correct type of pressure that drives a winter storm.

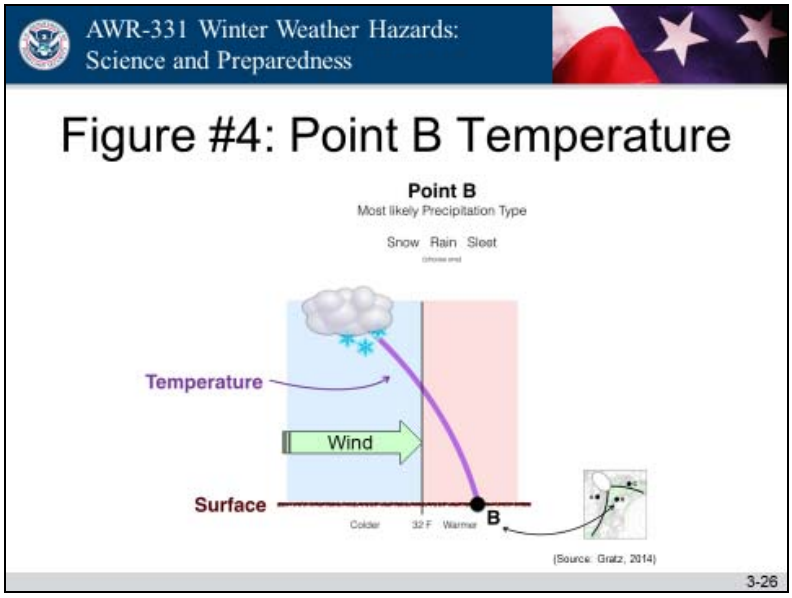
Participant Notes:



Slide 3-25. Figure #3: Point A Temperature

The image shows a vertical temperature profile from the surface to the cloud. The purple line extended from the base of the cloud to the surface denotes the vertical temperature profile. This temperature profile begins in a region below 32°F at cloud base and ends in a region below 32°F at the surface.

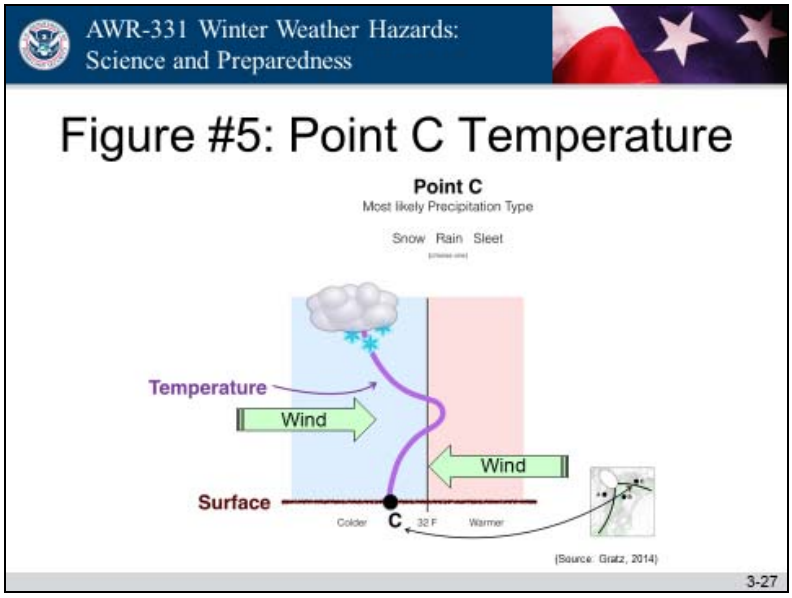
Participant Notes:



Slide 3-26. Figure #4: Point B Temperature

The image shows a vertical temperature profile from the surface to the cloud. The purple line extended from the base of the cloud to the surface denotes the vertical temperature profile. This temperature profile begins in a region below 32°F at cloud base and ends in a region above 32°F at the surface.

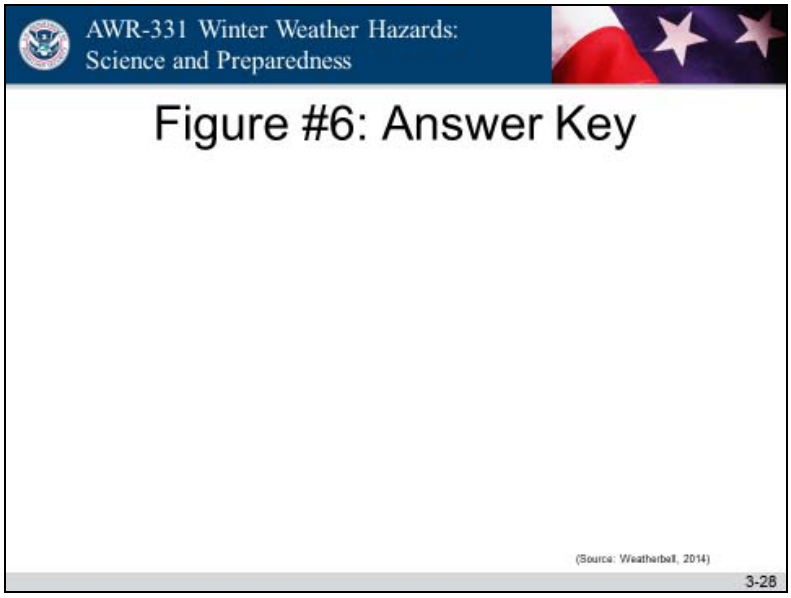
Participant Notes:



Slide 3-27. Figure #5: Point C Temperature

The image shows a vertical temperature profile from the surface to the cloud. The purple line extended from the base of the cloud to the surface denotes the vertical temperature profile. This temperature profile begins in a region below 32°F at cloud base and ends in a region below 32°F at the surface with a small region between the surface and cloud base that is above 32°F.

Participant Notes:

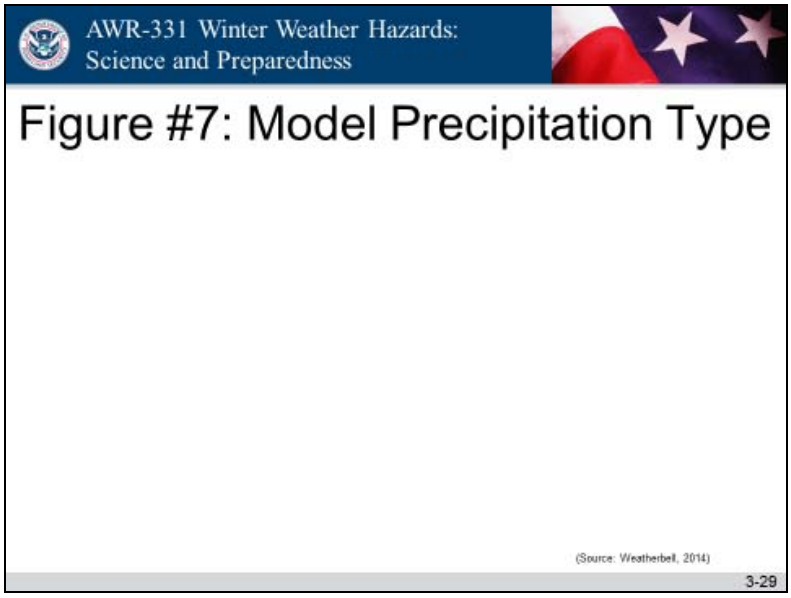


Slide 3-28. Figure #6: Answer Key

Knowledge Check: As the storm moves northeast, how will the precipitation type change?

Knowledge Check: As the cold front moves through western Pennsylvania, what will happen to the wet ground (from rain) as cold air moves in? Also, if the Great Lakes are not frozen (this is an early-winter storm), and cold air moves over the lake in the wake of the storm, what type of "special" hazard might develop?

Participant Notes:

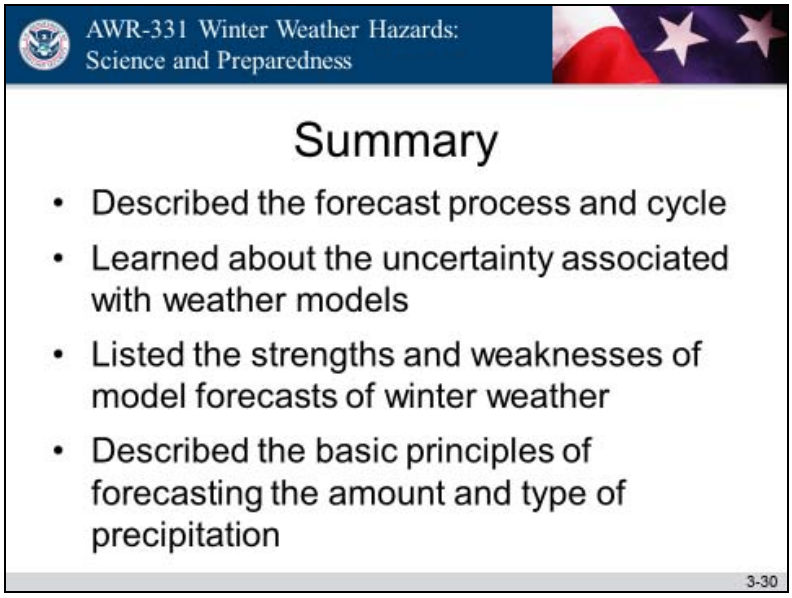


Slide 3-29. Figure #7: Model Precipitation Type

The image shows the GFS numerical weather model precipitation-type forecast for the prior winter storm. The numerical weather model projection reinforces the correct answers on the prior slide.

Key Point: The purpose of this slide is to show that the computer weather model can determine the general types of precipitation.

Participant Notes:



Slide 3-30. Summary

This module discussed how weather forecasters use numerical weather models to create a forecast for winter weather hazards. This included a general background about numerical weather models, the strengths and weaknesses of the models, and how to use the models to forecast the amount and type of precipitation. A group activity provided participants with the opportunity to experience the challenges associated with forecasting snow, sleet, and freezing rain.

✔ **Knowledge Check:** What type of frozen precipitation will fall if there is a large volume of air warmer than 32°F between the surface and the ground? What if that volume of air is much smaller and located closer to the surface?

This page is intentionally left blank.

AWR-331 Winter Weather Hazards: Science and Preparedness

Module 4: Winter Weather Warning Process and Safety

Version 1.0

FEMA

This page is intentionally left blank.

Module 4: Winter Weather Warning Process and Safety – Administration Page

Slide 4-1. Winter Weather Warning Process and Safety

Duration

75 minutes

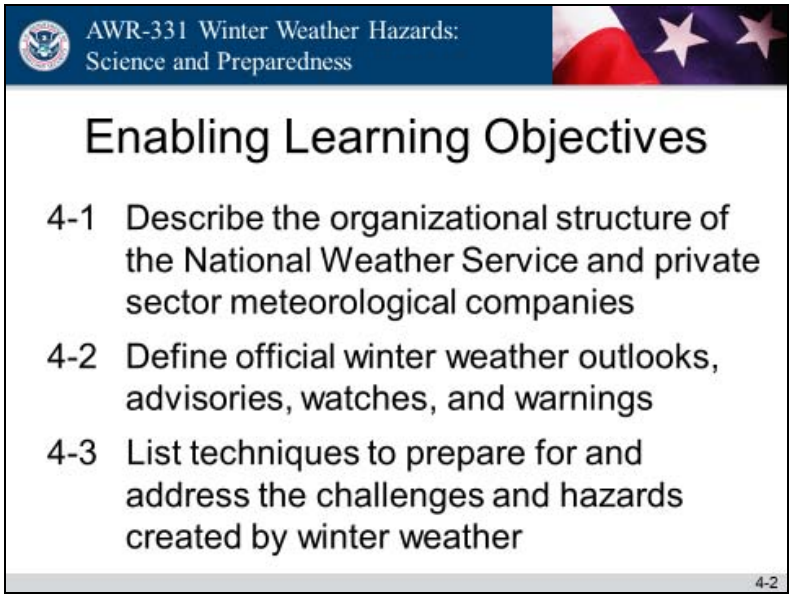
Scope Statement

In this module, the instructors will discuss what information is provided by the National Weather Service and private sector meteorological companies. In addition, the instructors will define winter weather advisories, watches, and warnings. Participants will see examples of the safety hazards associated with winter weather and methods to address each hazard.

Terminal Learning Objective (TLO)

Participants will be able to understand the organizations involved in forecasting winter weather, associated winter weather definitions, and strategies to prepare for winter weather impacts.

Enabling Learning Objectives (ELOs)



Slide 4-2. Enabling Learning Objectives

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

- 4-1 Describe the organizational structure of the National Weather Service and private sector meteorological companies;
- 4-2 Define official winter weather outlooks, advisories, watches, and warnings; and
- 4-3 List techniques to prepare for and address the challenges and hazards created by winter weather.

Resources

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

Instructor-to-Participant Ratio

2:40

Reference List

City of Boston, 2014. "Regulations and Safety Tips for Residential Outdoor Cooking and Heating." Accessed 2014. http://www.cityofboston.gov/fire/safety/bbq_safety.asp

DOC, 2014. "Department of Commerce Organizational Chart." Accessed 2014. http://www.commerce.gov/department-commerce-organizational-chart-pdf

FEMA, 2014. "Winter Storms & Extreme Cold." Accessed 2014. http://www.ready.gov/winter-weather

NOAA, 2008. "Winter Storms: The Deceptive Killers." Accessed 2014. http://www.nws.noaa.gov/os/winter/resources/Winter_Storms2008.pdf

NOAA, 2012. "Weather Forecast Offices." Accessed 2014. http://www.srh.noaa.gov/jetstream/nws/wfos.htm

NOAA, 2014. "Eastern Region Winter Warning and Advisory Criteria." Accessed 2014. http://www.erh.noaa.gov/okx/PB/ERwintercriteria.html

NOAA, 2014. "NOAA Headquarters Organization." Accessed 2014. http://www.pco.noaa.gov/org/orgImages/NOAA_Org_Chart.pdf

NOAA, 2014. "NOAA Organizations." Accessed 2014. http://www.noaa.gov/organizations.html

NOAA, 2014. "National Weather Service Organization." Accessed 2014. http://www.weather.gov/organization

The Weather Channel, 2014. "The Science Behind Naming Winter Storms at The Weather Channel" Accessed 2014. http://www.weather.com/news/science-behind-naming-winter-storms-weather-channel-20140121

Practical Exercise Statement

Not applicable

Assessment Strategy

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

Winter Weather Hazards: Science and Preparedness

Icon Map

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

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

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

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

Participant Notes:

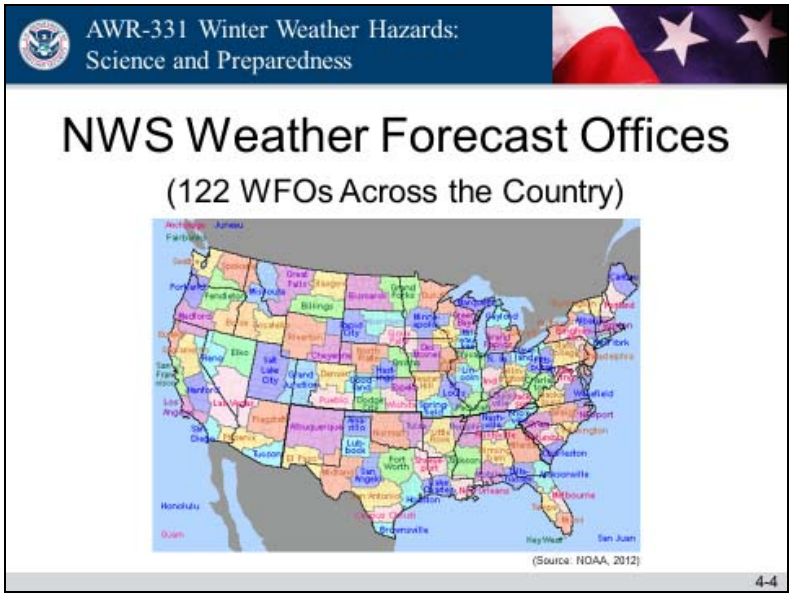
Slide 4-3. Structure of NOAA and NWS

The Department of Commerce is one of fifteen departments under the executive branch of the United States. Within the Department of Commerce is the National Oceanic and Atmospheric Administration (NOAA), and within NOAA is the National Weather Service (NWS).

The National Weather Service consists of many national centers, one of which is called the National Centers for Environmental Prediction (NCEP). These specialized centers are responsible for collecting weather data, running it through advanced super computers, and outputting forecast data.

The National Weather Service also has many local Weather Forecast Offices, or WFOs, split up into six regions around the country: Alaska, Pacific, Western, Southern, Central, and Eastern. WFOs within these regions are where local forecasters issue weather forecasts and alerts about significant weather events.

Participant Notes:



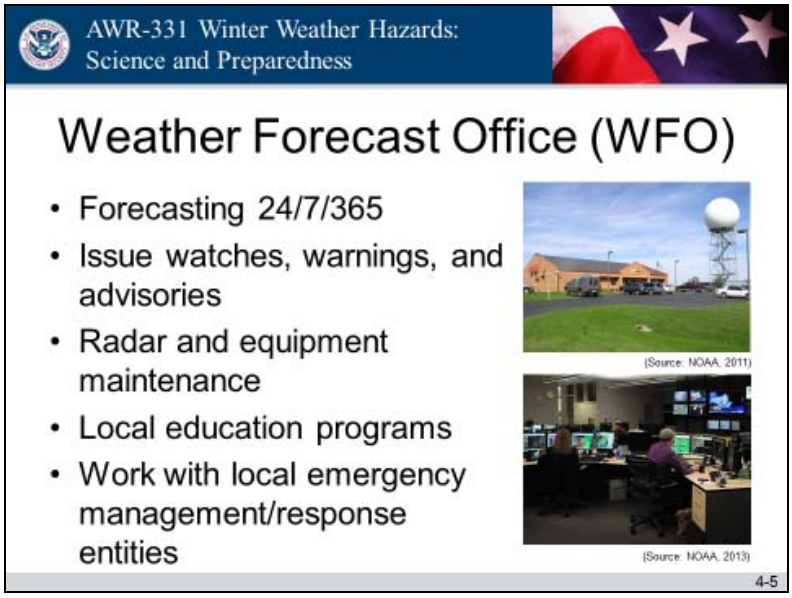
Slide 4-4. NWS Weather Forecast Offices

The NWS has 122 local offices across the United States that are called "Weather Forecast Offices" or WFOs. Each office coordinates with neighboring offices and with the NOAA national centers to help ensure that the reasoning that drives the forecasts is consistent and accurate. Ultimately, these local offices are responsible for the forecasts and public safety alerts.

Participant Note: Why are there so many local offices? The answer is to account for the regional challenges of predicting weather, including oceans, lakes, and mountains.

Knowledge Check: Where is the closest local office to your location? What area does it cover?

Participant Notes:



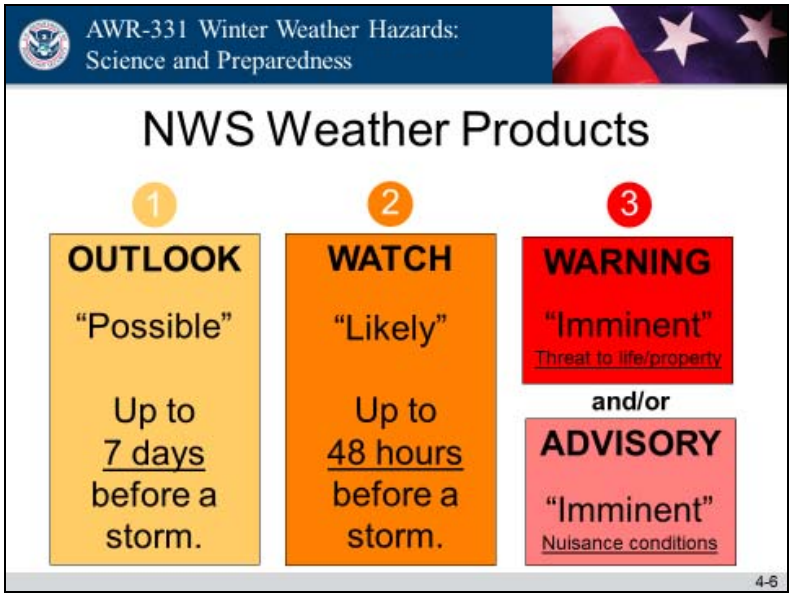
Slide 4-5. Weather Forecast Office (WFO)

NWS WFOs are usually but not always located in buildings near a Doppler weather radar site.

Inside the office, there are workstations with advanced meteorological software to help the forecasters view and interpret large amounts of data and graphics.

Participant Note: Each office is staffed with a MIC (Meteorologist-In-Charge) who is in charge of the office, a WCM (Warning Coordination Meteorologist) who conducts product evaluations and preparedness programs, and multiple Senior Forecasters and General Forecasters who produce the routine forecast and alert products.

Participant Notes:



Slide 4-6. NWS Weather Products

The NWS Glossary provides the following definitions:

"*Outlooks* indicate a hazardous weather or hydrologic event may develop. It's used to provide information to those needing considerable lead time to prepare for the event."

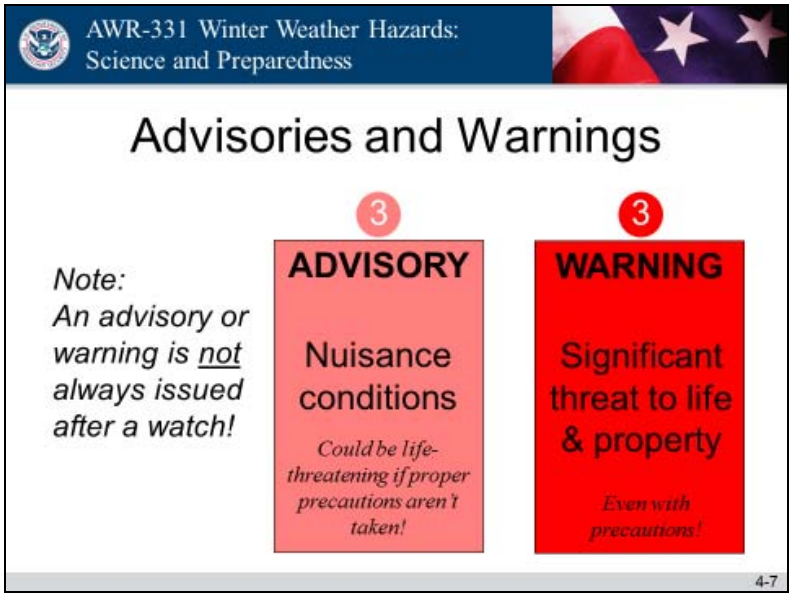
"*Watches* indicate the risk of a hazardous weather or hydrologic event has increased significantly, but its timing, occurrence, and/or location is uncertain. It's used to provide enough lead time for those needing to set plans in motion."

"*Warnings* are 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."

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

Participant's Note: There may be confusion between NWS warnings and advisories. While both products are similar in their immediacy, they differ in severity and/or confidence.

Participant Notes:

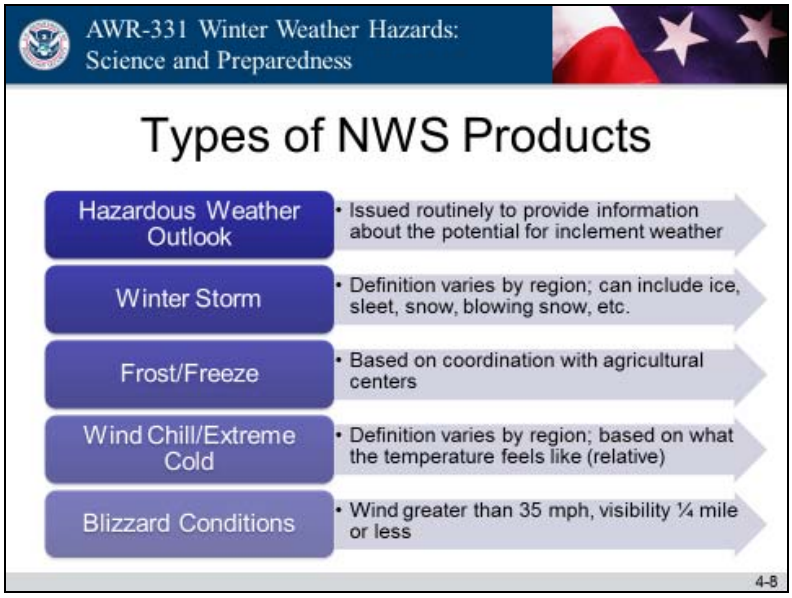


Slide 4-7. Advisories and Warnings

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.

After a watch is issued and when the storm is imminent, the forecasters at the WFO will decide whether to replace the watch with an advisory or a warning based on definitions that the course will discuss in future slides.

Participant Notes:

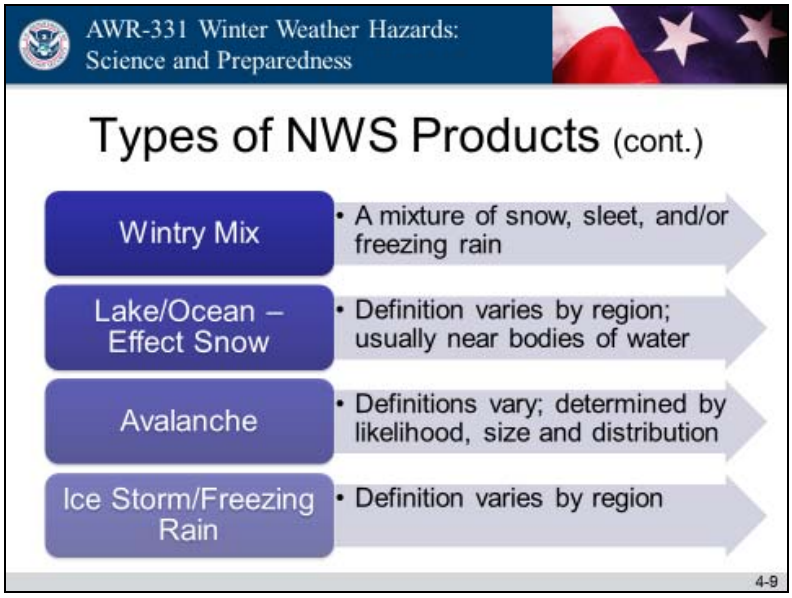


Slide 4-8. Types of NWS Products

Winter weather alerts can be complex because there are different criteria based on the location of the WFO. Areas of the country that are typically warmer and experience less frequent winter weather will see lower-threshold criteria (e.g., lower snow totals will trigger a warning). Areas of the country that often see winter weather, like New England and the Midwest, have higher-threshold criteria for alerts (e.g., higher snow totals).

Blizzard conditions are an exception because the definition does not vary by geographical location. The criteria for blizzard conditions are sustained winds of 35 mph or greater, visibility of 0.25 miles or lower, and for these two factors to be expected for more than 3 hours.

Participant Notes:

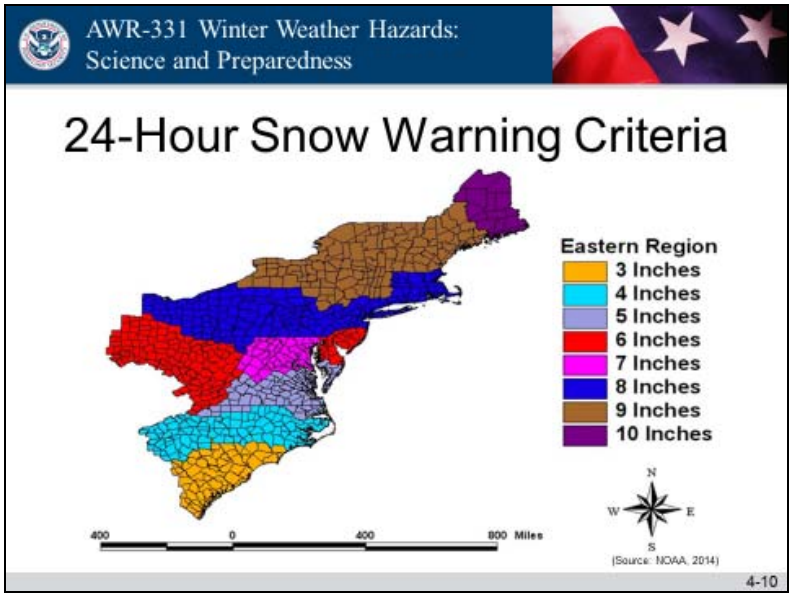


Slide 4-9. Types of NWS Products (continued)

It is important to understand your local area's level of vulnerability for each hazard. Wintry mix (sometimes referred to as "mixed precipitation") and ice storms are prevalent in many areas across the United States; while only certain regions are susceptible to avalanche, lake- or ocean-effect snow, participants should be able to identify challenges relating to each hazard and its associated product(s).

Participant Note: The target audience for and implications of various NWS products vary considerably across geography, jurisdiction, and stakeholder mix. While most products are of interest to a wide audience of decision-makers and the public, some alerts are targeted to a select audience (e.g., frost- and freeze-related warnings are not particularly valuable in most emergency management settings, but are crucial for members of the agricultural/ farming community who similarly rely on hard freeze and killing frost warnings).

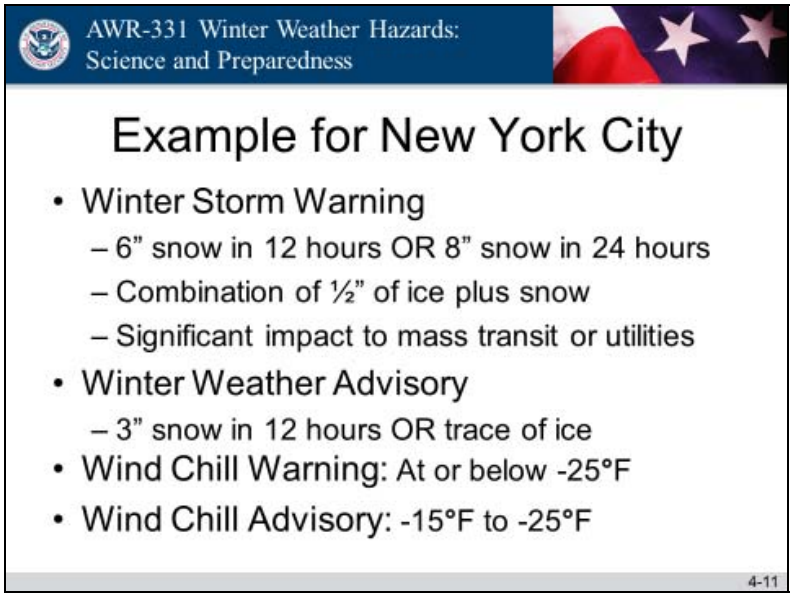
Participant Notes:



Slide 4-10. 24-Hour Snow Warning Criteria

This map shows the amount of snow within a 24-hour period to meet the criteria for a Winter Storm Warning. The criteria for a snow warning is lower for locations in South Carolina, where snow falls less frequently, than it is in New England, where snow is a more regular occurrence.

Participant Notes:



Slide 4-11. Example for New York City

As discussed previously, alert criteria vary by geographical location. Listed on this slide as an example are the criteria for New York City.

The local WFO will issue a winter storm watch up to 48 hours before the storm, signifying that there is a risk of a storm with significant impacts. The WFO will then wait until closer to the event to assess the latest forecast data and determine whether they should follow the winter storm watch with a winter storm warning or a winter weather advisory.

While there are established protocols that the WFO uses to decide whether to issue a warning or advisory, there is an allowance for the forecaster to use their best judgment about whether the storm will cause significant impacts to mass transit or utility operations.

An ice storm warning and a freezing rain advisory both alert the public to the likelihood of ice accumulating on surfaces. Issuing an advisory instead of a warning indicates the event is not expected to pose a risk to life and property (if proper preparedness/protective measures are taken).

Ice accumulation is not as likely to occur in mountainous areas of the western United States and is more likely to occur along the east coast, in the central and southern United States, and over parts of the northwest coast of the United States. These latter locations are unique in that cold air can stay near the surface while warmer air, usually influenced by a wind coming off of a relatively warmer ocean, can push into the middle of the atmosphere.

Participant Notes:

Slide 4-12. "The Weather Enterprise"

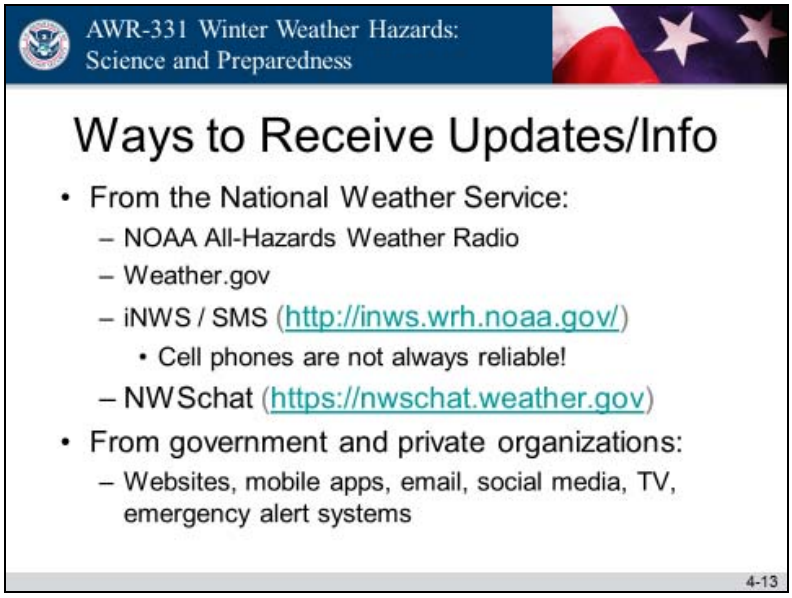
The National Weather Service is the only organization tasked with issuing official weather products (outlooks, watches, warnings, and advisories) for public safety. Stakeholders can receive alerts directly from the NWS in a variety of formats and on a multitude of platforms.

Private organizations and news media stations receive these alerts from the NWS and help distribute them to the general public.

In addition to sharing the NWS alerts, private companies produce customized alerts for their client's specific needs (such as a school district, a city, a company, etc.).

Research organizations, like colleges and government-funded groups, help the NWS and private companies to create more accurate forecasts and alerts, advise on their effectiveness, and study societal applications.

Participant Notes:



Slide 4-13. Ways to Receive Updates/Info

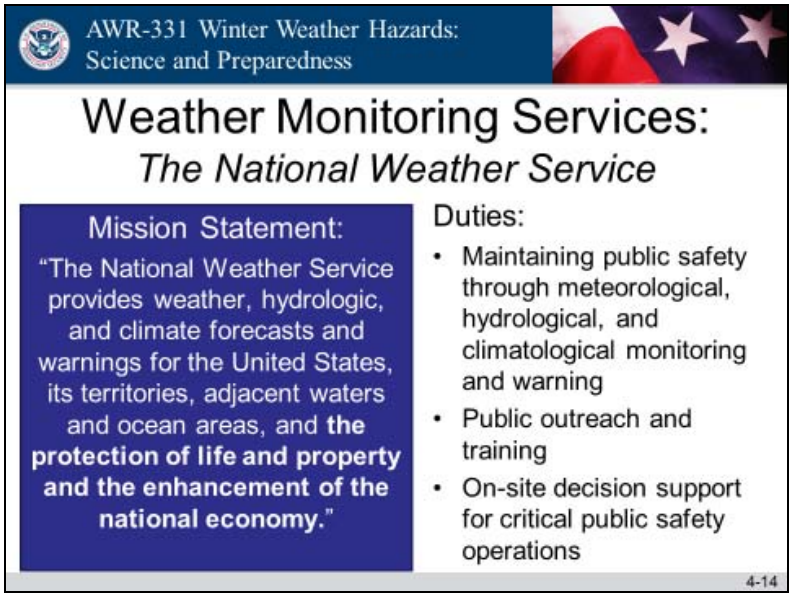
Stakeholders can receive products, updates, and special weather statements directly from the NWS or from private companies. Many people receive alerts via smartphone apps or local television.

NOAA weather radio (NWR) and Interactive NWS (iNWS) are also useful and lesser-known ways to receive alerts.

From the NWS: “Under a January 1975 White House policy statement, NOAA Weather Radio was designated the sole Government-operated radio system to provide direct warning into private homes for both natural disasters and nuclear attack.” NOAA Weather Radio All Hazards (the official name) is known as the “voice of the NWS” and can be accessed through a variety of VHF public service bands by utilizing a specific receiver that can be purchased at a number of retailers. NWR operates outside the standard AM or FM broadcast bands.

The Interactive NWS (iNWS) is a service that allows emergency management professionals and responders to set preferences about which alerts they want, for which locations, and they will then receive text messages with those alerts.

Participant Notes:



Slide 4-14. Weather Monitoring Services: The National Weather Service

The National Weather Service (NWS) should be utilized for public safety and the protection of life and property. NWS forecasters are routinely used by emergency management, first response, and other public safety organizations for decision-support of public safety operations. They are not, however, intended to be responsible for the operations of private organizations or events, such as concerts or university athletic events. While watches, warnings, and advisories may be used by these private organizations, detailed decision-support may not be provided.

Participant Notes:

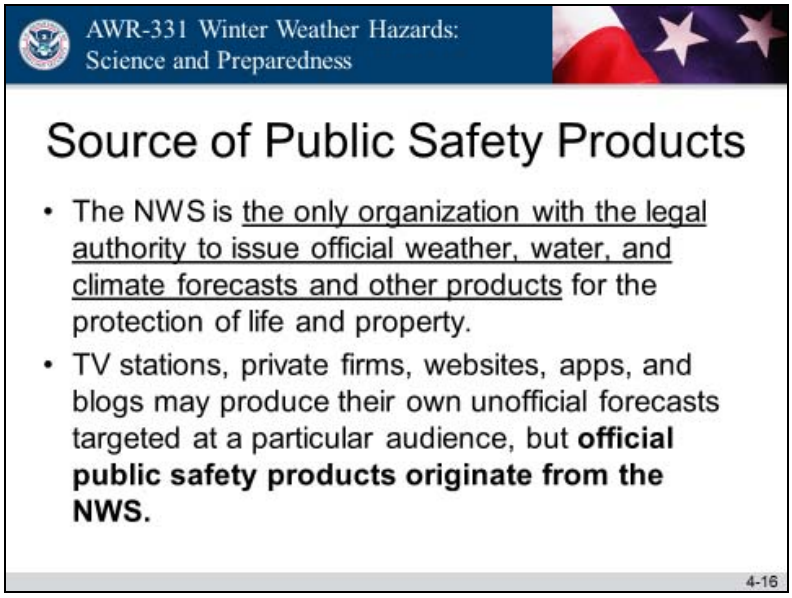
Slide 4-15. Weather Monitoring Services: Private Weather Consulting/Monitoring

Private sector meteorology consulting and monitoring firms are better suited to provide hazardous weather decision-support for events that are beyond the mission statement of the National Weather Service. These services are often utilized by large event venues, touring musicians, organizations with critical outdoor operations, and by those parties wishing to purchase tailored weather forecasts.

This allows a more personal, localized way to communicate threats to the local community.

Participant Note: The cost of private weather monitoring services varies between companies and an accurate estimate will include understanding the type of services needed. Services that include consultation with a meteorologist may be more expensive but are often much more efficient. Such services are offered between $1,000 and $10,000 a year.

Participant Notes:

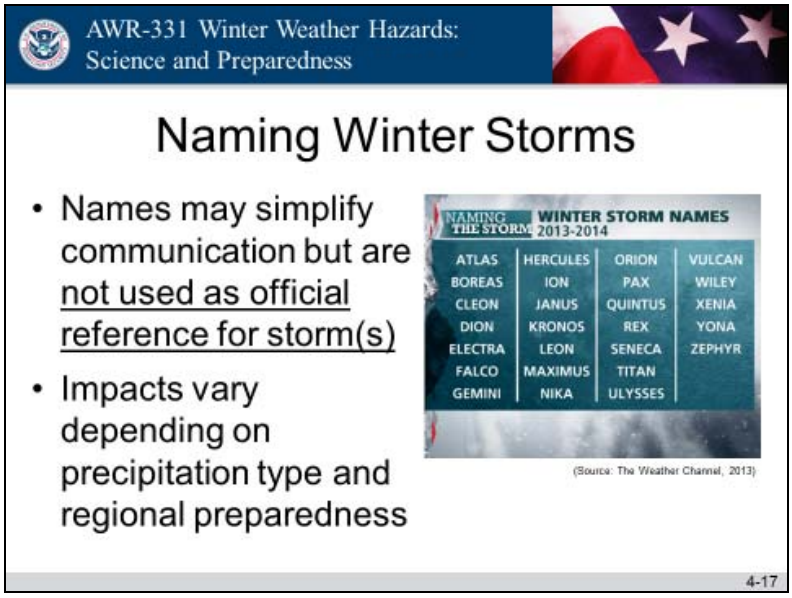


Slide 4-16. Source of Public Safety Products

It is important to re-emphasize that the National Weather Service is the only entity authorized to issue official weather, water, and climate forecasts and advisory products for the purpose of public safety. These products are often rebroadcast through third party or private meteorology applications and services.

Key Point: Be wary of weather advisory products issued for public safety by any organization other than the National Weather Service.

Participant Notes:



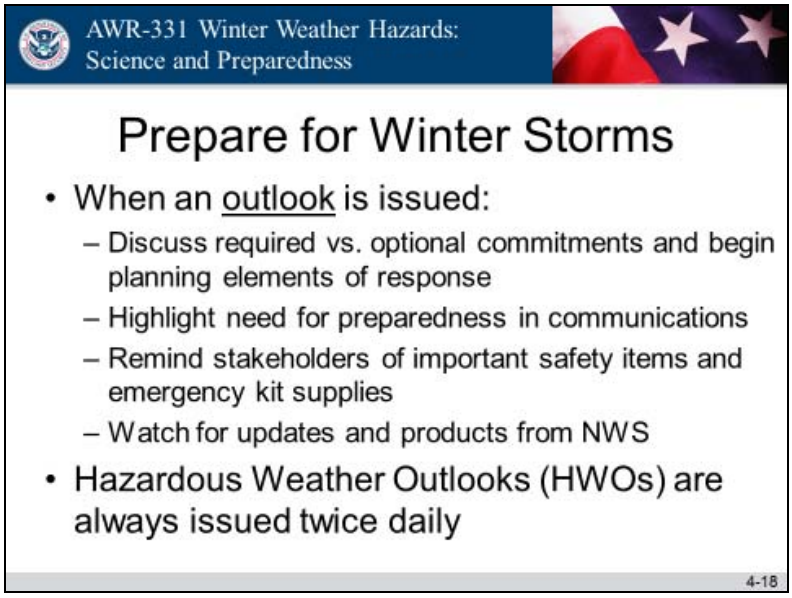
Slide 4-17. Naming Winter Storms

The Weather Channel began naming winter storms during the 2012-2013 winter season. They began doing this due to the success of the weather community naming hurricanes since the 1940s. The threshold for naming a storm varies (e.g., more than two million people or 400,000 square kilometers need to be under a winter storm warning, or eight million people or 600,000 square kilometers need to be under a winter weather advisory).

Once again, remember that only the National Weather Service issues official watches, warnings, and advisories for public safety. The Weather Channel's goal of naming winter storms is to "better communicate the threat" of the storm. As of 2014, the NWS does not participate in the storm-naming process nor does it use storm names in its forecasts and alert products.

✔ **Knowledge Check:** What are the differences between naming a hurricane and naming a winter storm?

Participant Notes:



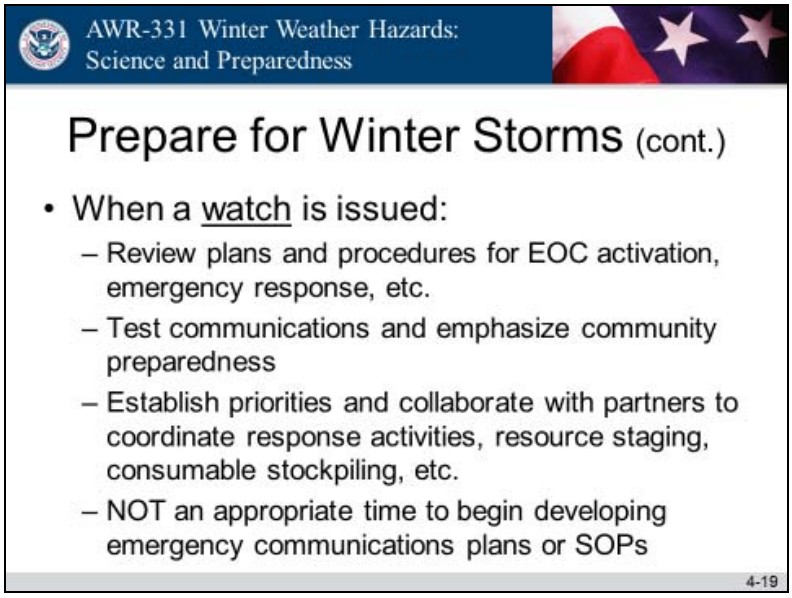
Slide 4-18. Prepare for Winter Storms

Planning for a winter storm should be coordinated well before an impending storm. When an outlook is issued that explains the threat of winter storm(s), community members should review their emergency plans, stock up on supplies (if they have not already), and remain vigilant.

Stakeholders, defined here as emergency managers, first responders, government personnel, and others involved in emergency response planning, should begin coordinating their public information management with partners, stage supplies and equipment per local plans/protocols, and heed the advice of the National Weather Service.

✔ **Knowledge Check:** Does your organization's protocols for winter storms reference what actions to take when certain NWS products are issued? What type of preparations does your organization take when a winter storm outlook is issued?

Participant Notes:



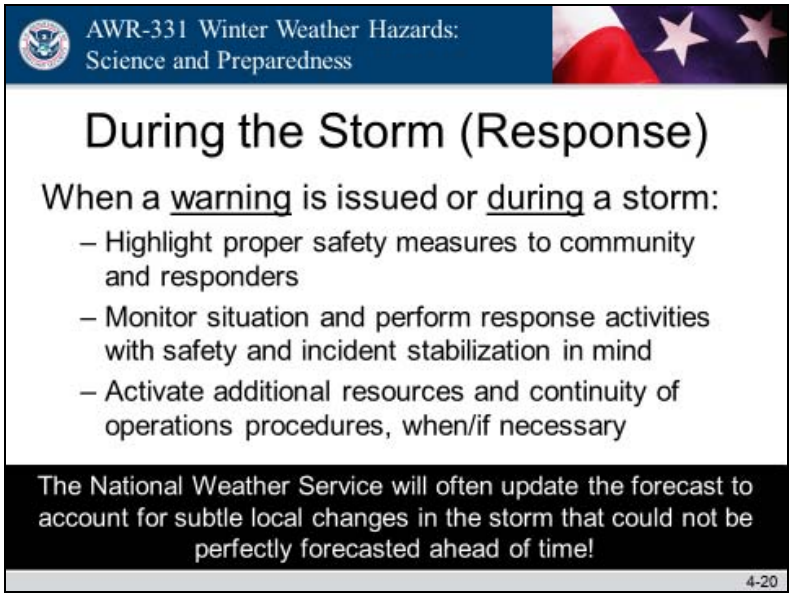
Slide 4-19. Prepare for Winter Storms (continued)

Understanding the progression of weather updates and products, participants should understand the escalation represented by NWS outlooks vs. watches.

When a watch is issued by the local WFO, emergency personnel and others related to potential response activities should begin to get resources in place, establish and communicate priorities, activate appropriate pre-emergency protocols and plans, and begin testing communications.

Actions in this stage should be communicated with transparency to promote coordination with stakeholders and partners. Safety recommendations and preparedness messaging disseminated to members of the public should be consistent with NWS guidance.

Participant Notes:



Slide 4-20. During the Storm (Response)

By the time the NWS issues a winter weather warning (blizzard conditions, snow, ice, etc.), resources, personnel, and plans should ideally already be in place. Focus should be placed on maintaining situational awareness, promoting a common operating picture, and monitoring events as they unfold.

As the storm evolves, initial priority will be given to road and infrastructure maintenance, road clearance, and other duties coordinated by departments of transportation/public works, highway authorities, and law enforcement. Response activities should be coordinated with these actions, and emergency personnel should perform rescues when it is deemed safe to do so by the incident commander, emergency manager, or incident safety officer.

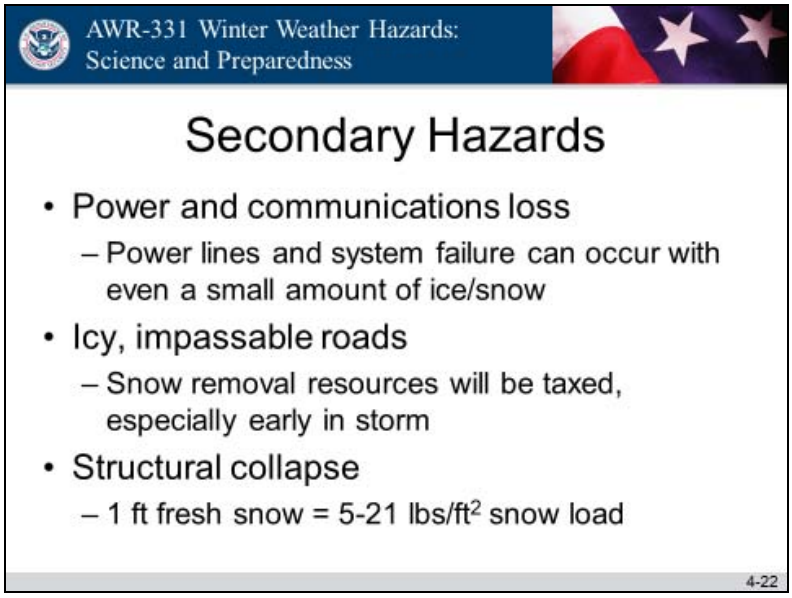
Participant Notes:

Slide 4-21. Winter Storm Event Timeline

This graphic outlines a simple progression of events that could unfold during a winter storm event. It is important to note that not all of these hazards will occur with every winter storm.

The main idea being conveyed in this slide is that winter weather events can cascade into a multitude of incidents (some more serious than the initial precipitation/hazard); winter weather events are dynamic and require forward-thinking emergency management practices from a host of organizations.

Participant Notes:



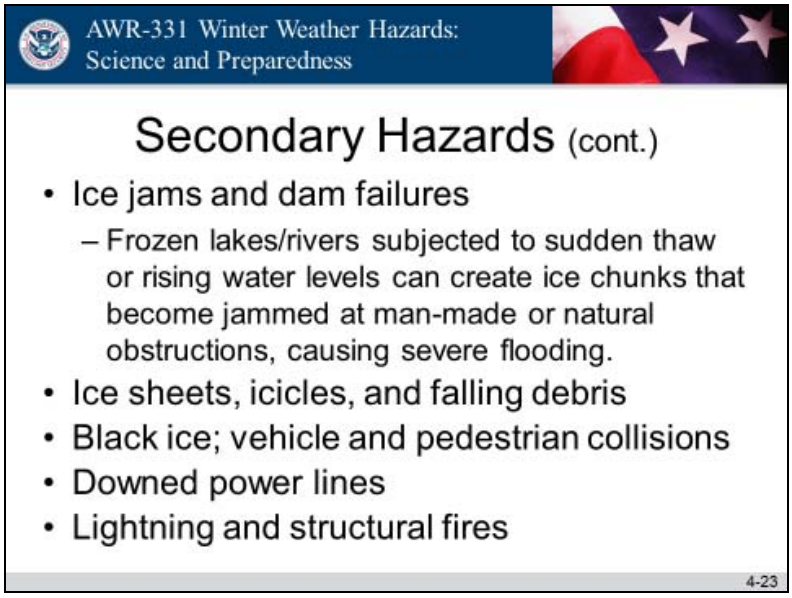
Slide 4-22. Secondary Hazards

The hazards outlined in slides 4-22 and 4-23 can be experienced by any jurisdiction faced with a winter weather incident. Though these hazards may be easily understood by participants, emergency response personnel should understand that winter weather scenarios compound over time and feature a multitude of "cascading" incidents (secondary hazards that could complicate, slow down, or halt response activities).

Many of the hazards outlined here can be mitigated to reduce consequences with appropriate preparatory measures and public education.

✔ **Knowledge Check:** Did you know that one foot of dry snow weighs 5+ lbs or that one foot of wet snow can weigh as much as 21 lbs? What structural damage might you expect in your area following a significant snowfall?

Participant Notes:



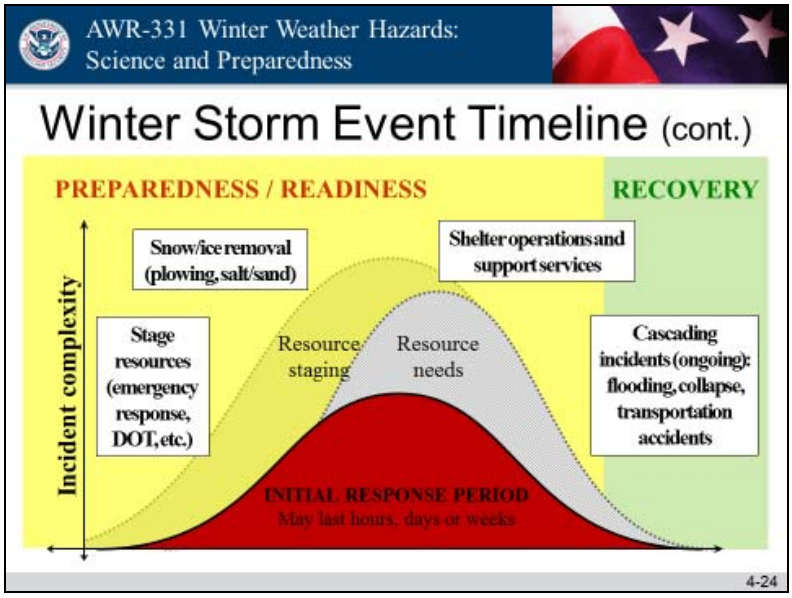
Slide 4-23. Secondary Hazards (continued)

New England has experienced recent winter storms (e.g., the November 2014 “Winter Storm Knife” in Erie County, New York) that have aided ice jams. These hazards threaten bridges and other man-made obstructions.

These secondary and tertiary hazards pose a significant threat to first responders as they may occur well after the initial storm passes through the community. Hazards outlined in slides 4-22 and 4-23 should be well understood by responders, emergency managers, and the public to ensure safety.

Participant Note: *Black ice* is a term used to describe a nearly invisible layer of ice that has formed onto a black road surface, like asphalt. The ice is not black, but instead almost completely transparent.

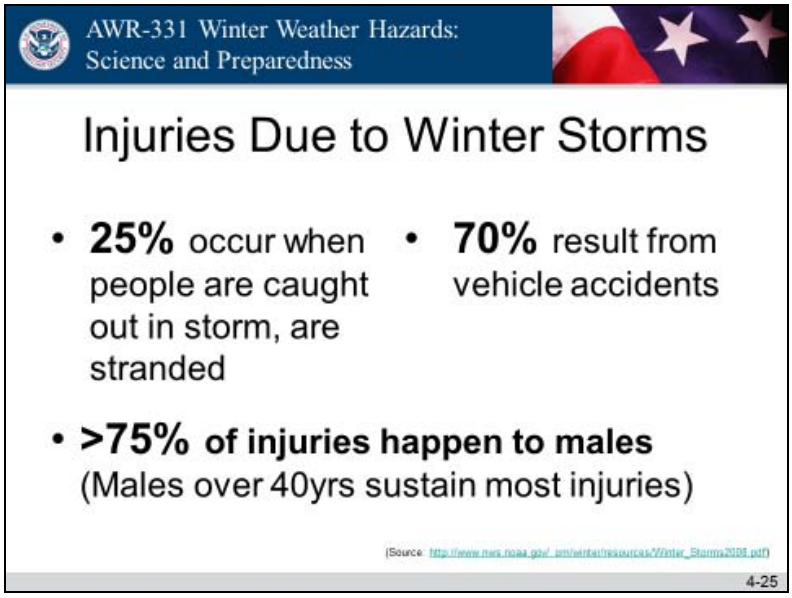
Participant Notes:



Slide 4-24. Winter Storm Event Timeline (continued)

This slide highlights the same graphic as slide 4-21, with the addition of potential resource- and response-oriented concerns for the transportation, first response, and emergency management communities.

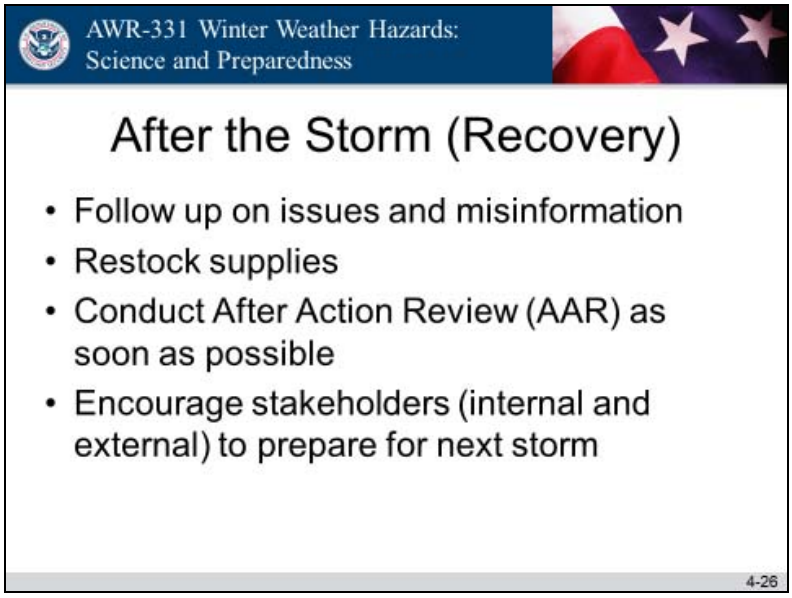
Participant Notes:



Slide 4-25. Injuries Due to Winter Storms

It is important to note that the vast majority of injuries and deaths relating to winter storms is preventable if appropriate safety measures are taken. Emergency communicators and public information officers operating in a winter storm scenario can reference these statistics in their messaging and urge caution from public and emergency responders alike.

Participant Notes:

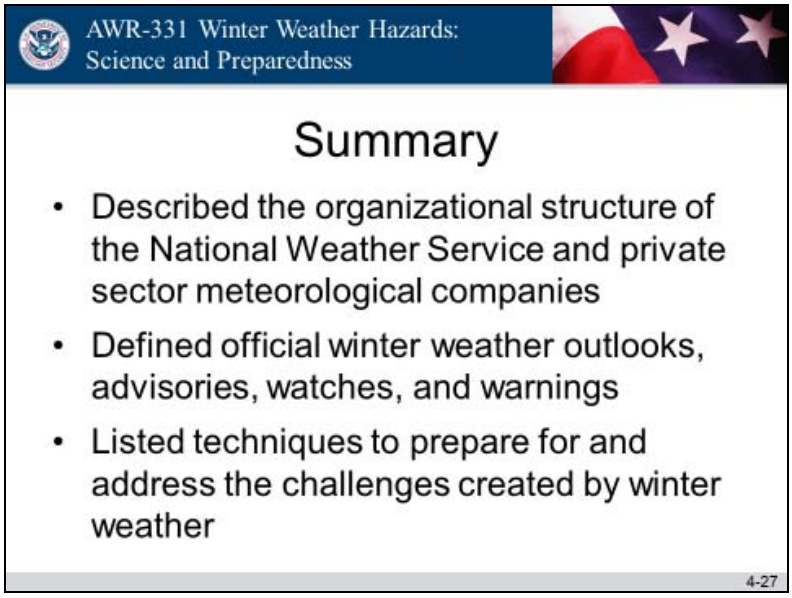


Slide 4-26. After the Storm (Recovery)

Though this is not the most glamorous part of a winter storm event, it is arguably the most critical. Activities and recovery measures taken following even a minor winter storm can either help the community, its economy, and its people recover from and adapt to conditions, or hurt their future preparedness.

Emergency personnel should not underestimate the value of a strong, coordinated After Action Review (AAR) in debriefing and educating responders and the general public for future winter weather incidents/hazards. These meetings and associated documentation should be published and shared (as appropriate) with partner agencies, other jurisdictions, etc.

Participant Notes:



Slide 4-27. Summary

This module described the structure of the National Weather Service and the private sector meteorological companies, defined official winter weather outlooks, advisories, watches, and warnings, and their variations by geography, and listed ways in which individuals can prepare for the hazards associated with winter weather.

This page is intentionally left blank.

AWR-331 Winter Weather Hazards: Science and Preparedness

Module 5: Winter Storm Scenario

Version 1.0

FEMA

This page is intentionally left blank.

Module 5: Winter Storm Scenario – Administration Page

Slide 5-1. Winter Storm Scenario

Duration

90 minutes

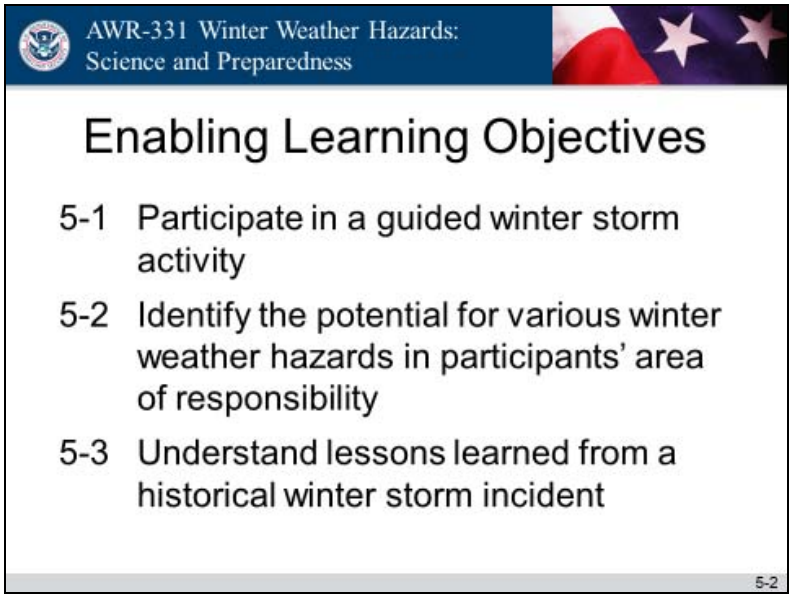
Scope Statement

In this module, participants will integrate all of the knowledge obtained in this course through a group activity consisting of a winter storm scenario. Participants will be expected to analyze the forecast, make preparedness decisions at the right time, and deal with a band of heavy snow.

Terminal Learning Objective (TLO)

Participants will be able to analyze a forecast and discuss key decision points during a winter storm scenario.

Enabling Learning Objectives (ELOs)



Slide 5-2. Enabling Learning Objectives

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

5-1 Participate in a guided winter storm activity;

5-2 Identify the potential for various winter weather hazards in participants' area of responsibility; and

5-3 Understand lessons learned from a historical winter storm incident.

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)
- Group Handouts
- One of each of the following items per participant:
    - Participant Guide (PG) available for download from http://ndptc.hawaii.edu/

Instructor-to-Participant Ratio

2:40

Reference List

Environment Canada, 2014. "Canadian Ice Service." Accessed 2014. http://www.ec.gc.ca/glaces-ice/default.asp?lang=En&n=D32C361E-1

Iowa Environmental Mesonet, 2014. "IEM NWS Text Product Finder." Accessed 2014. https://mesonet.agron.iastate.edu/wx/afos/

MRCC, 2009. "Ice Storms." Accessed 2014. http://mrcc.isws.illinois.edu/living_wx/icestorms/

NOAA, 2001. "Winter Storms: The Deceptive Killers." Accessed 2014. http://www.crh.noaa.gov/images/ilx/pdf/winterstorms.pdf

NOAA, 2014. "Winter Storm Survival Kit for Travelers." Accessed 2014. http://www.crh.noaa.gov/images/ilx/pdf/Winterstorm_Survival_Kit.pdf

NOAA, 2014. "Winter Weather Preparedness." Accessed 2014. http://www.nws.noaa.gov/os/winter/

State of Illinois, 2014. "Winter Weather Preparedness Guide." Accessed 2014. http://www.crh.noaa.gov/images/ilx/pdf/Winter%20Weather%20prep%20guide.pdf

Practical Exercise Statement

This exercise provides an opportunity for participants to work together in groups to role-play in a winter storm situation. Participants will consider the different decisions and courses of action that should be made prior to and during a winter storm. The objective of the activity is to use the knowledge and understanding gained from this course to understand when to make key preparedness decisions and to feel the surprise when encountering a situation that was not forecast correctly.

Assessment Strategy

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

Winter Weather Hazards: Science and Preparedness

Icon Map

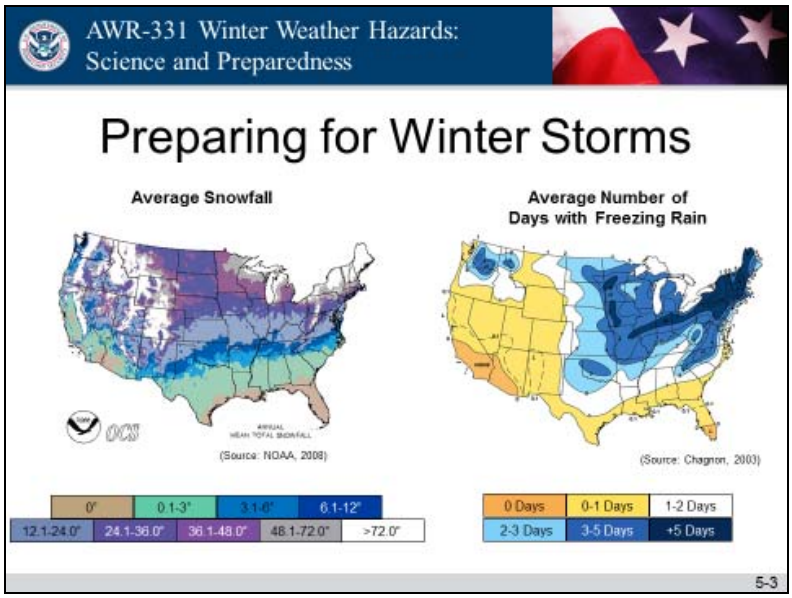
Knowledge Check: Used when it is time to assess participant understanding.

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

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

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

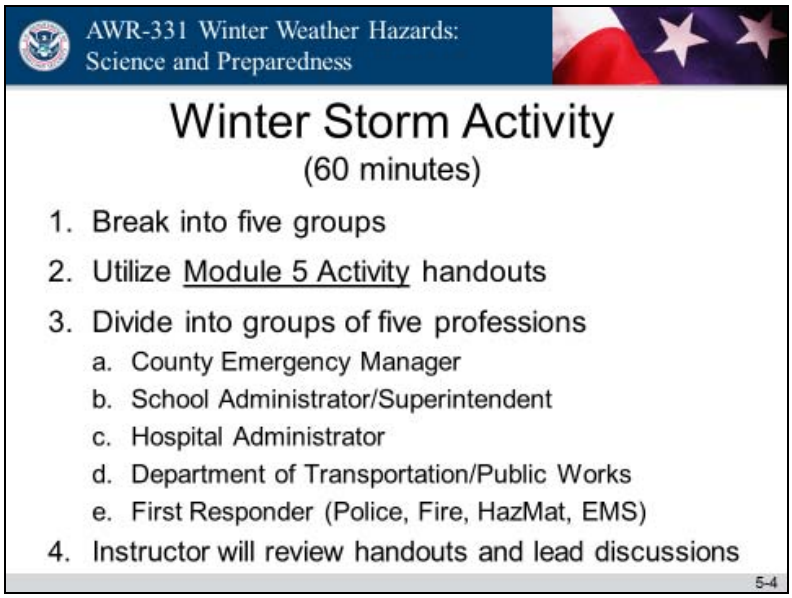
Participant Notes:



Slide 5-3. Preparing for Winter Storms

The first step in preparing for winter storms is to understand the likely threats a user's community will face. These maps show the average snowfall during the winter, and the average number of days with freezing rain, which is a separate hazard from snow since freezing rain can severely damage trees and cause widespread and long-lasting power outages.

Participant Notes:

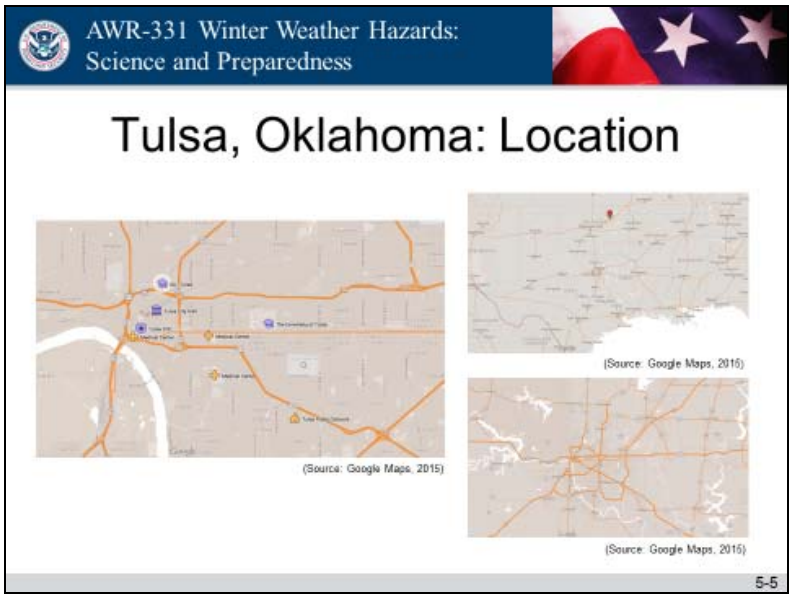


Slide 5-4. Winter Storm Activity

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 winter weather situation.

The total time for this exercise is estimated at 60 minutes.

Participant Notes:



Slide 5-5. Tulsa, Oklahoma: Location

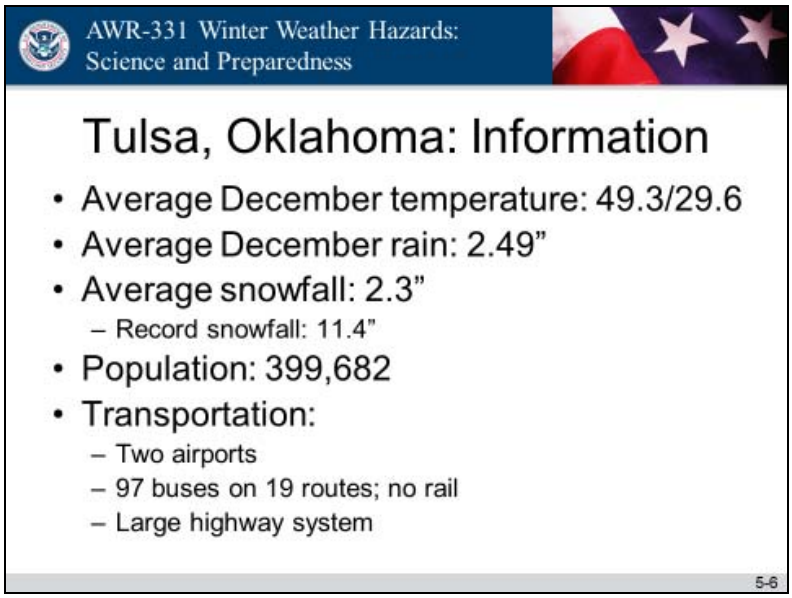
The above three images are "Google Maps" images showing the location of Tulsa, Oklahoma. Tulsa, which will be the location of focus in the following activity, is located in northeastern Oklahoma.

The largest of the three images outlines the following points of interest:

- The University of Oklahoma at Tulsa Campus
- Tulsa City Hall
- The University of Tulsa Campus
- The Tulsa Emergency Operations Center
- Three Medical Centers
- The Tulsa Public Schools Office

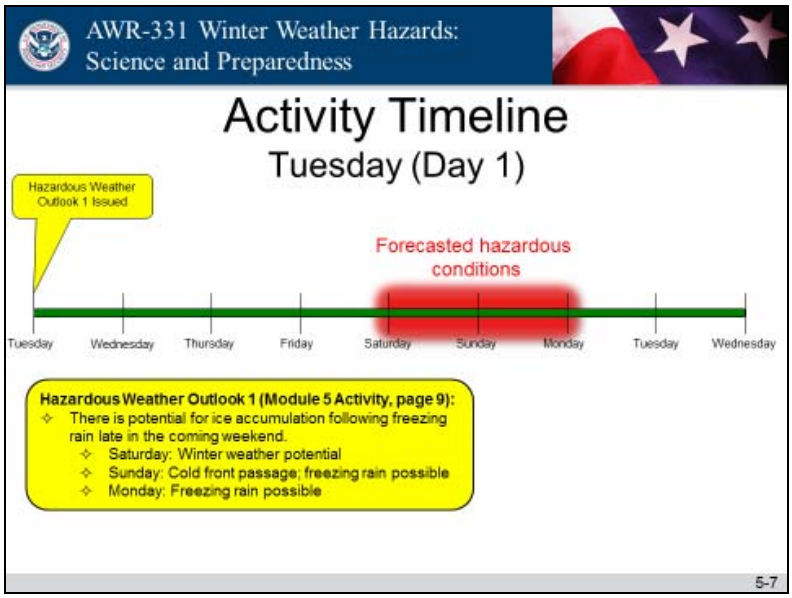
There is a local NWS office located in the city of Tulsa; this WFO covers much of eastern Oklahoma and a portion of northwestern Arkansas.

Participant Notes:



Slide 5-6. Tulsa, Oklahoma: Information

Participant Notes:



Slide 5-7. Activity Timeline, Tuesday (Day 1)

At 05:09 AM on Tuesday (Day 1), the National Weather Service issued the following Hazardous Weather Outlook:

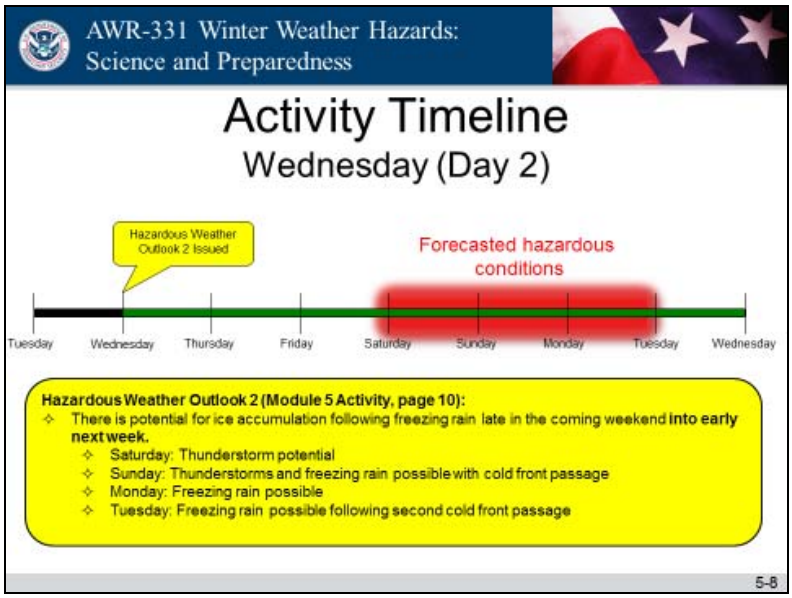
"DAYS TWO THROUGH SEVEN...WEDNESDAY THROUGH MONDAY.
WEDNESDAY...NO HAZARDS.
THURSDAY...NO HAZARDS.
FRIDAY...NO HAZARDS.
SATURDAY...WINTER WEATHER POTENTIAL.
SUNDAY...WINTER WEATHER POTENTIAL.
MONDAY...WINTER WEATHER POTENTIAL.

EXTENDED DISCUSSION...
A COLD FRONT WILL MOVE ACROSS THE AREA WEDNESDAY... HOWEVER LIMITED MOISTURE AHEAD OF THE FRONT WILL PRECLUDE ANY RAIN. SHORTWAVE ENERGY PASSING TO THE NORTH ON THURSDAY WILL OFFER LOW CHANCES FOR RAIN MAINLY ACROSS NORTHEAST OKLAHOMA. THE UPPER PATTERN BECOMES MORE ACTIVE AS IT TRANSITIONS TO THE SOUTHWEST BY THE WEEKEND. A SHALLOW...BUT STRONG COLD FRONT WILL MOVE THROUGH ON SUNDAY. BEHIND THE BOUNDARY...A WINTRY PRECIPITATION EVENT IN THE FORM OF FREEZING RAIN WILL BE POSSIBLE ACROSS NORTHEAST OKLAHOMA SUNDAY AND INTO MONDAY.

Participant Notes:

EMERGENCY MANAGEMENT PLANNING STATEMENT...
INTERESTED PARTIES SHOULD MONITOR THE LATEST FORECASTS AND DISCUSSIONS CONCERNING THE POTENTIAL FOR FREEZING RAIN ACROSS NORTHEAST OKLAHOMA LATE IN THE WEEKEND AND EARLY NEXT WEEK."

Participant Notes:



Slide 5-8. Activity Timeline, Wednesday (Day 2)

At 11:46 PM on Wednesday (Day 2), the National Weather Service issued the following Hazardous Weather Outlook:

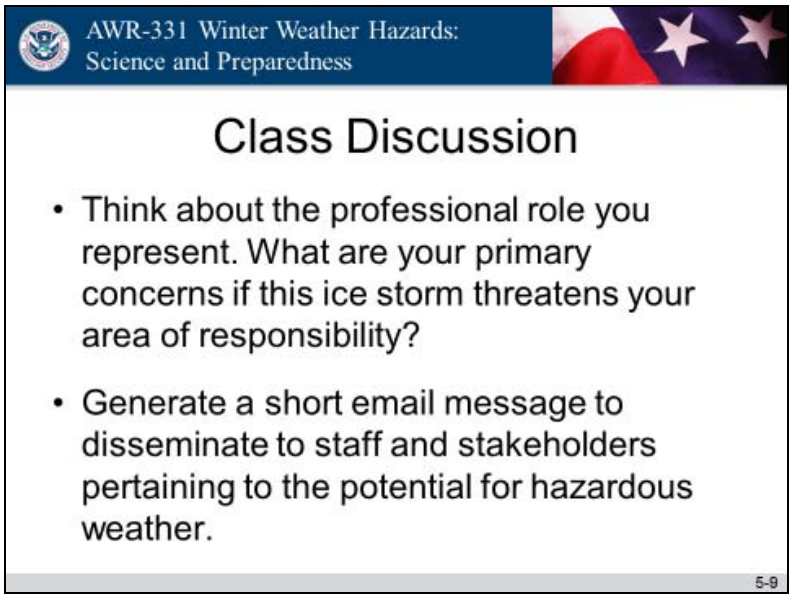
"DAYS TWO THROUGH SEVEN...THURSDAY THROUGH TUESDAY.
THURSDAY...NO HAZARDS.
FRIDAY...NO HAZARDS.
SATURDAY...THUNDERSTORM POTENTIAL.
SUNDAY...THUNDERSTORM POTENTIAL...WINTER WEATHER POTENTIAL.
MONDAY...WINTER WEATHER POTENTIAL.
TUESDAY...WINTER WEATHER POTENTIAL.

EXTENDED DISCUSSION...
A COLD AIRMASS WILL SPREAD ACROSS THE AREA LATE IN THE WEEKEND...RESULTING IN SHARPLY COLDER TEMPERATURES LATE SUNDAY AND EARLY NEXT WEEK. SHOWERS AND THUNDERSTORMS WILL BE POSSIBLE ALONG THE FRONT ACROSS NORTHWEST ARKANSAS AND SOUTHEAST OKLAHOMA SATURDAY NIGHT INTO SUNDAY MORNING. MOIST SOUTHWESTERLY FLOW ALOFT WILL BRING SEVERAL WAVES OF PRECIPITATION TO THE REGION...WHICH MAY FALL PRIMARILY AS FREEZING RAIN OR SLEET ACROSS MUCH OF NORTHEAST OKLAHOMA AND NORTHWEST ARKANSAS LATE SUNDAY INTO MONDAY. THE RAIN AND FREEZING RAIN THREAT WILL CONTINUE TUESDAY AS YET ANOTHER WAVE EJECTS OUT OF THE SOUTHWESTERN STATES."

Participant Notes:

EMERGENCY MANAGEMENT PLANNING STATEMENT...
INTERESTED PARTIES SHOULD MONITOR THE LATEST FORECASTS AND DISCUSSIONS CONCERNING THIS POTENTIAL WINTER WEATHER EVENT THIS WEEKEND INTO THE EARLY PART OF THE WORK WEEK."

Participant Notes:

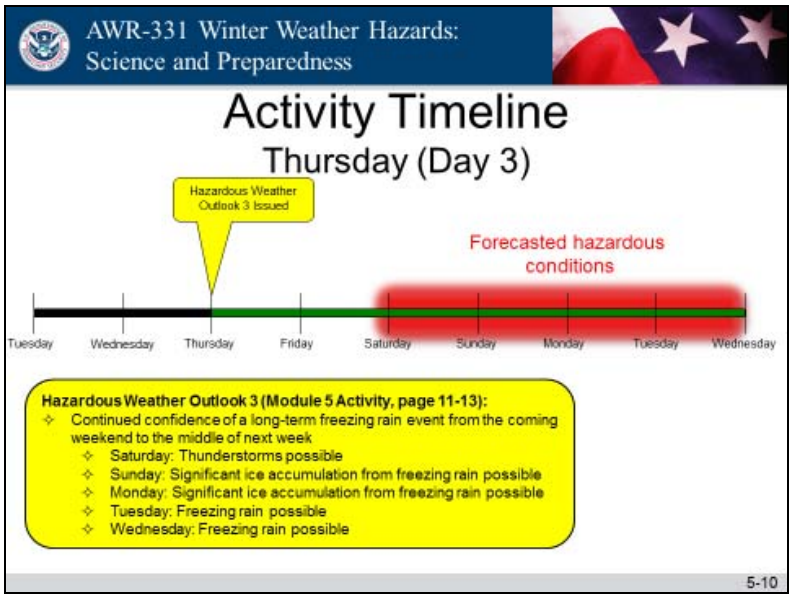


Slide 5-9. Class Discussion

Think about the professional role you represent. What are your primary concerns if this winter storm threatens your area of responsibility?

What types of risk communications and messaging will you focus on to help your stakeholders prepare for this potential storm?

Participant Notes:



Slide 5-10. Activity Timeline, Thursday (Day 3)

At 05:08 AM on Thursday (Day 3), the National Weather Service issued the following Hazardous Weather Outlook:

"DAYS TWO THROUGH SEVEN...FRIDAY THROUGH WEDNESDAY.
FRIDAY...NO HAZARDS.
SATURDAY...WINTER WEATHER POTENTIAL.
SUNDAY...WINTER WEATHER POTENTIAL.
MONDAY...WINTER WEATHER POTENTIAL.
TUESDAY...WINTER WEATHER POTENTIAL.
WEDNESDAY...WINTER WEATHER POTENTIAL.

EXTENDED DISCUSSION...
LOW CHANCES FOR RAIN WILL CONTINUE FOR THE NEXT SEVERAL DAYS AS WARM ADVECTION ENSUES AND MOISTURE INCREASES. A COLD FRONT WILL APPROACH THE AREA FRIDAY...AND WILL LIKELY STALL ACROSS NORTHEAST OKLAHOMA LATE FRIDAY AND SATURDAY. A STRONGER SHOT OF COLD AIR WILL EFFECTIVELY PUSH THIS BOUNDARY THROUGH SOUTHEAST OKLAHOMA BY LATE SUNDAY. A MUCH COLDER...BUT SHALLOW AIRMASS WILL BE IN PLACE ACROSS NORTHEAST OKLAHOMA BY SUNDAY. A STRONG UPPER SYSTEM WILL APPROACH THE WEST COAST LATE IN THE WEEKEND WITH MOIST SOUTHWESTERLY FLOW ALOFT MAINTAINED AHEAD OF THE APPROACHING LOW. A LARGE AREA OF PRECIPITATION IS EXPECTED TO DEVELOP ACROSS THE REGION NORTH OF THE FRONT SATURDAY NIGHT AND SUNDAY. THE THERMAL PROFILE

Participant Notes:

STILL SUGGESTS THAT MUCH OF NORTHEAST OKLAHOMA WILL SEE PERIODS OF FREEZING RAIN AS EARLY AS SATURDAY NIGHT. THE SHALLOW COLD AIR WILL BE SLOW TO MODERATE AND PIECES OF UPPER ENERGY EJECT FROM THE UPPER LOW...WHICH WILL RESULT IN CONTINUED CHANCES FOR FREEZING RAIN THROUGH WEDNESDAY ACROSS NORTHEAST OKLAHOMA.

EMERGENCY MANAGEMENT PLANNING STATEMENT...

EMERGENCY MANAGEMENT GROUPS AND OTHER INTERESTED PARTIES SHOULD MONITOR THE LATEST FORECASTS AND DISCUSSIONS CONCERNING WINTER WEATHER POTENTIAL FOR THE EARLY TO MIDDLE PART OF NEXT WEEK."

At 01:10 PM on Thursday (Day 3), the National Weather Service issued the following Hazardous Weather Outlook:

"...SIGNIFICANT ICING EVENT POSSIBLE ACROSS PARTS OF THE REGION

BEGINNING BY SATURDAY NIGHT...

THIS OUTLOOK IS FOR NORTHWEST AND WEST CENTRAL ARKANSAS AS WELL AS

MUCH OF EASTERN OKLAHOMA.

DAY ONE...THIS AFTERNOON AND TONIGHT.

WINTER WEATHER.

ICE ACCUMULATION.

RISK...LIMITED.

AREA...FAR NORTHEAST OKLAHOMA...MAINLY NEAR THE KANSAS BORDER. ONSET...AFTER MIDNIGHT.

DISCUSSION...

A WARM AIR ADVECTION PATTERN SHOULD RESULT IN DEVELOPING PRECIPITATION ACROSS THE REGION DURING THE OVERNIGHT HOURS. TEMPERATURES AT THE SURFACE COULD BRIEFLY DIP TO NEAR FREEZING...RESULTING IN SOME LIGHT FREEZING RAIN LATE TONIGHT NEAR THE KANSAS BORDER.

SPOTTER AND EMERGENCY MANAGEMENT ACTION STATEMENT...

SPOTTER ACTIVATION NOT EXPECTED.

DAYS TWO THROUGH SEVEN...FRIDAY THROUGH WEDNESDAY.

FRIDAY...WINTER WEATHER POTENTIAL.

SATURDAY...THUNDERSTORM POTENTIAL...WINTER WEATHER POTENTIAL.

Participant Notes:

SUNDAY...WINTER WEATHER POTENTIAL.
MONDAY...WINTER WEATHER POTENTIAL.
TUESDAY...WINTER WEATHER POTENTIAL.
WEDNESDAY...WINTER WEATHER POTENTIAL.

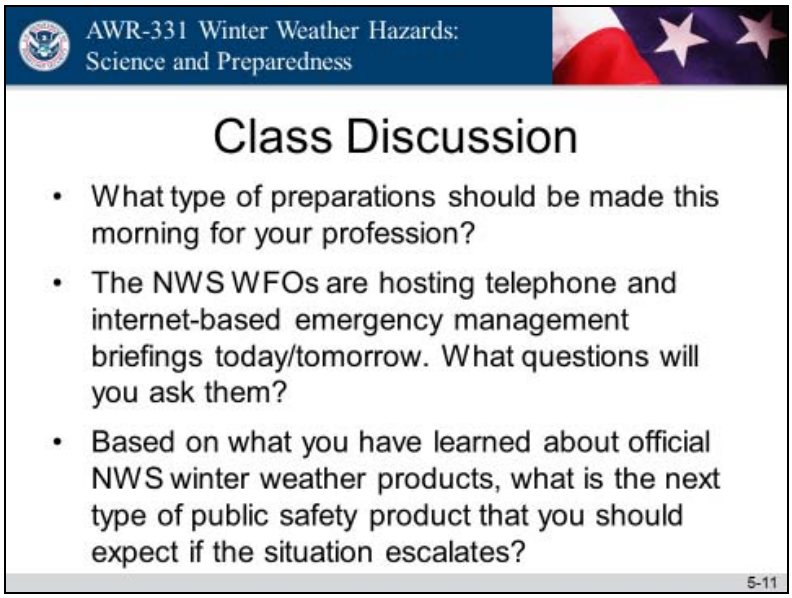
EXTENDED DISCUSSION...
A SIGNIFICANT WINTER WEATHER EVENT IS SHAPING UP FOR PARTS OF EASTERN OKLAHOMA AND NORTHWEST ARKANSAS OVER THE WEEKEND.

THE SHALLOW COOL AIRMASS CURRENTLY ACROSS THE AREA WILL LIFT SLOWLY NORTH ON SATURDAY...RESULTING IN A LARGE TEMPERATURE SPREAD ACROSS EASTERN OKLAHOMA AND NORTHWEST ARKANSAS. A REINFORCING SHOT OF COLDER AIR WILL EVENTUALLY PUSH THE BOUNDARY BACK SOUTH INTO SOUTHEAST OKLAHOMA OVERNIGHT SATURDAY. THERE APPEARS TO BE ENOUGH MOISTURE AND INSTABILITY TO SUPPORT A FEW THUNDERSTORMS NEAR THE FRONT IN SOUTHEAST OKLAHOMA...BUT SEVERE WEATHER IS NOT EXPECTED.

THE COLD SHALLOW AIRMASS IS EXPECTED TO SETTLE ACROSS MUCH OF REGION BY SUNDAY...WITH TEMPERATURES STRUGGLING TO REACH THE FREEZING MARK ACROSS PORTIONS OF NORTHEAST OKLAHOMA AND FAR NORTHWEST ARKANSAS. MOIST LOW-LEVEL WARM AIR ADVECTION SHOULD OVERRIDE THIS COOL AIRMASS...SETTING THE STAGE FOR SIGNIFICANT ICING OVER NORTHEAST OKLAHOMA BEGINNING LATE SATURDAY NIGHT INTO SUNDAY. IMPULSES OF ENERGY EJECTING FROM THE SOUTHWESTERN U.S. UPPER SYSTEM COULD RESULT IN SEVERAL ROUNDS OF WINTRY PRECIPITATION THROUGH THE EARLY PART OF NEXT WEEK. AT THIS TIME...AREAS ALONG AND NORTH OF INTERSTATE 44 APPEAR TO HAVE THE BEST CHANCES FOR SIGNIFICANT ICING.

EMERGENCY MANAGEMENT PLANNING STATEMENT...
THERE STILL REMAINS MUCH UNCERTAINTY AS TO THE TIMING AND PLACEMENT OF WINTRY PRECIPITATION...SO INTERESTED PARTIES SHOULD CONTINUE TO MONITOR THE LATEST FORECASTS AND DISCUSSIONS CONCERNING THIS POTENTIAL WINTER WEATHER EVENT."

Participant Notes:



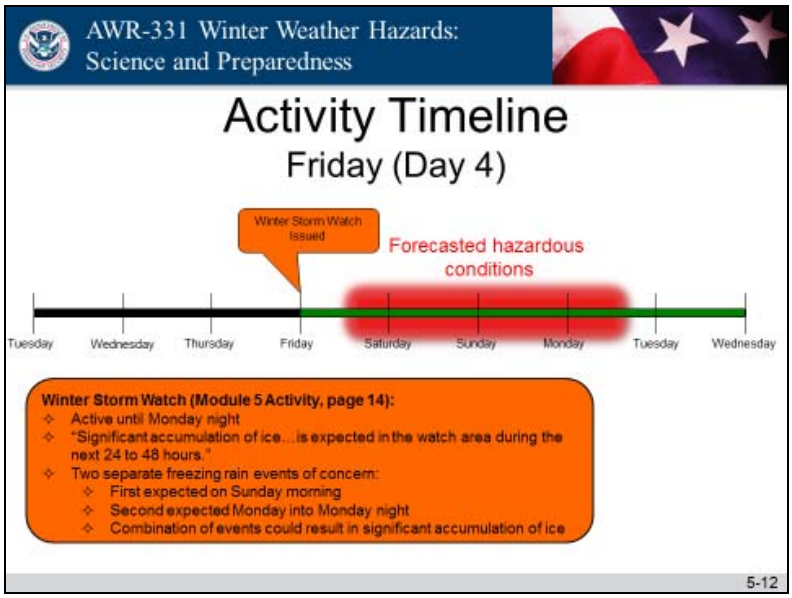
Slide 5-11. Class Discussion

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

The NWS WFOs are hosting telephone and Internet-based emergency management briefings today/tomorrow. What questions will you ask them?

Based on what you have learned about official NWS winter weather products, what is the next type of public safety product that you should expect if the situation escalates?

Participant Notes:



Slide 5-12. Activity Timeline, Friday (Day 4)

At 02:19 PM on Friday (Day 4), the National Weather Service issued the following Winter Storm Watch:

"...WINTER STORM WATCH IN EFFECT FROM SUNDAY MORNING THROUGH LATE MONDAY NIGHT...

THE NATIONAL WEATHER SERVICE IN TULSA HAS ISSUED A WINTER STORM WATCH...WHICH IS IN EFFECT FROM SUNDAY MORNING THROUGH LATE MONDAY NIGHT FOR THE FOLLOWING COUNTIES...

IN OKLAHOMA...
OSAGE...WASHINGTON...NOWATA...CRAIG...OTTAWA...PAWNEE...
TULSA...ROGERS...CREEK.

A SECONDARY SURGE OF COLD AIR IS EXPECTED TO PUSH INTO NORTHEAST OKLAHOMA SATURDAY NIGHT INTO SUNDAY. PRECIPITATION SHOULD EXPAND IN COVERAGE FROM THE SOUTHWEST SATURDAY NIGHT...WITH A MIX OF LIGHT FREEZING RAIN AND RAIN EXPECTED TO DEVELOP BY SUNDAY MORNING MAINLY NEAR THE KANSAS BORDER. COLDER AIR WILL CONTINUE TO FILTER SOUTH ON SUNDAY...WITH THE FREEZING LINE POSSIBLY REACHING THE INTERSTATE 44 CORRIDOR BY LATE SUNDAY.

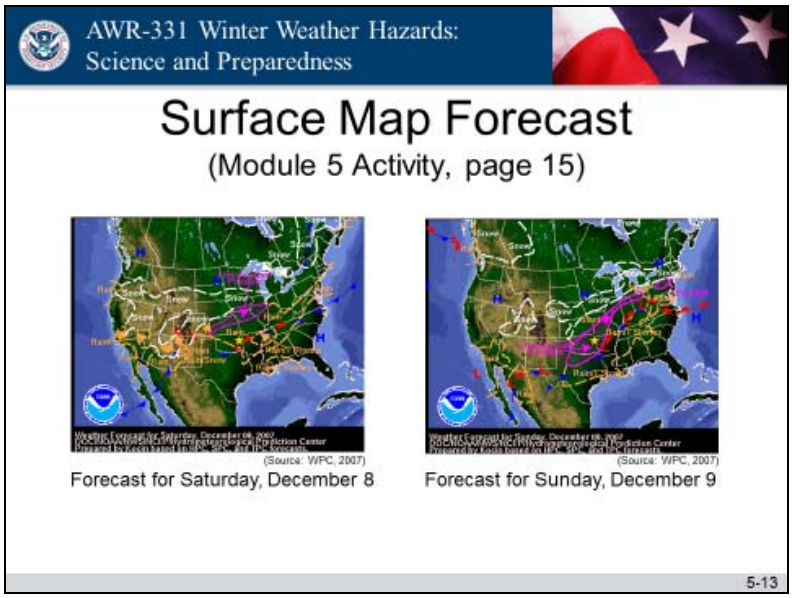
Participant Notes:

A SECONDARY WAVE OF PRECIPITATION IS EXPECTED BY MONDAY INTO MONDAY NIGHT. THIS COULD RESULT IN SIGNIFICANT ICING...WITH ICE ACCUMULATIONS OF A QUARTER TO ONE HALF INCH POSSIBLE ACROSS AREAS IN THE WATCH.

THERE REMAINS MUCH UNCERTAINTY AT THIS TIME AS TO WHERE THE TRANSITION BETWEEN RAIN AND FREEZING RAIN WILL DEVELOP ACROSS NORTHEAST OKLAHOMA. THE WINTER STORM WATCH MAY BE ADJUSTED AS ADDITIONAL DATA BECOMES AVAILABLE.

A WINTER STORM WATCH MEANS HEAVY SNOW OR A SIGNIFICANT ACCUMULATION OF ICE OR SLEET IS EXPECTED IN THE WATCH AREA DURING THE NEXT 24 TO 48 HOURS. RESIDENTS IN THE WATCH AREA SHOULD PREPARE NOW FOR WINTER STORM CONDITIONS. MAKE SURE YOUR CAR IS WINTERIZED AND IN GOOD WORKING ORDER. ALSO MAKE SURE YOU HAVE AN ADEQUATE SUPPLY OF FOOD...WATER AND THE NECESSARY MEDICATION TO LAST THROUGH THE DURATION OF THE WINTER STORM."

Participant Notes:



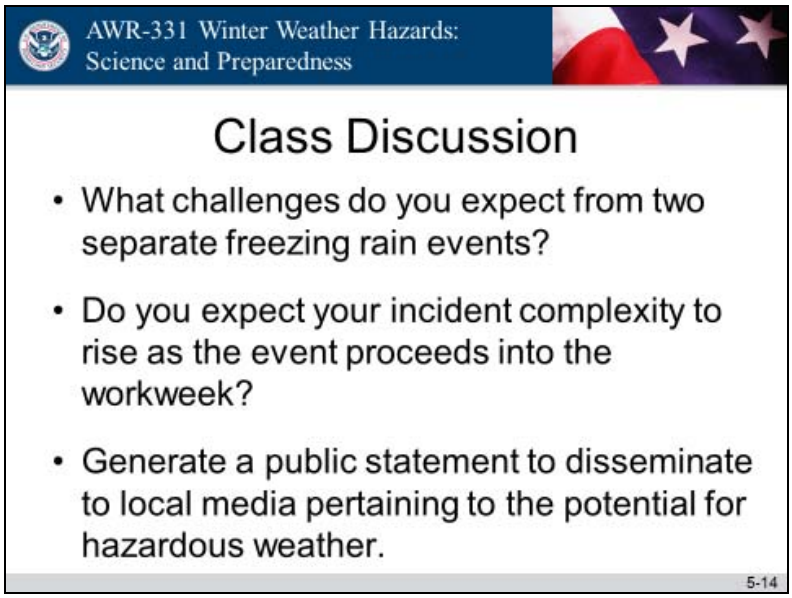
Slide 5-13. Surface Map Forecast

The above two images are surface map forecasts for Saturday, December 8 (left), and Sunday, December 9 (right). Plotted on these maps are synoptic weather systems and anticipated hazards across North America. Tulsa, Oklahoma, is denoted with a small yellow star.

On Saturday, December 8, the warm front of a low-pressure system will be directly south of Tulsa, Oklahoma. Freezing rain is outlined in pink as a hazard well to the north of Tulsa.

On Sunday, December 9, the cold front of the same low-pressure system will have passed to the east of Tulsa. Most of Oklahoma is outlined in pink as being at risk for freezing rain at this time.

Participant Notes:



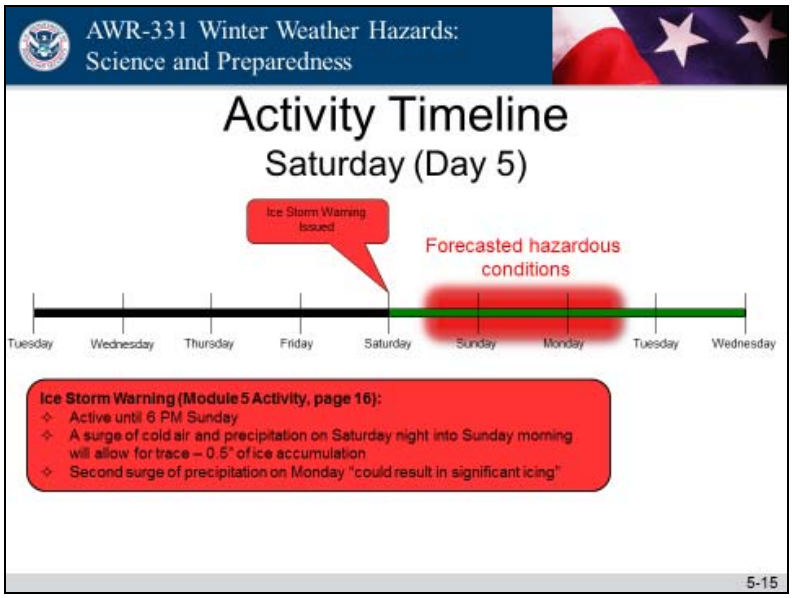
Slide 5-14. Class Discussion

What challenges do you expect from two separate freezing rain events?

Do you expect your incident complexity to rise as the event proceeds into the workweek?

Generate a public statement to disseminate to local media pertaining to the potential for hazardous weather.

Participant Notes:



Slide 5-15. Activity Timeline, Saturday (Day 5)

At 02:19 PM on Saturday (Day 5), the National Weather Service issued the following Ice Storm Warning:

"...ICE STORM WARNING IN EFFECT UNTIL 6 PM CST SUNDAY...
...WINTER STORM WATCH REMAINS IN EFFECT FROM SUNDAY EVENING THROUGH LATE MONDAY NIGHT...

THE NATIONAL WEATHER SERVICE HAS ISSUED AN ICE STORM WARNING...WHICH IS IN EFFECT UNTIL 6 PM CST SUNDAY FOR YOUR COUNTY

NUMEROUS SHOWERS AND ISOLATED THUNDERSTORMS HAVE DEVELOPED ALONG AND NORTH OF THE AREA THIS EVENING... AND THIS AREA OF PRECIPITATION EXTENDS SOUTHWESTWARD OF THE AREA. TEMPERATURES HAVE CONTINUED TO FALL WITH THE FREEZING LINE MAKING STEADY PROGRESS SOUTHWARD... AND AS THIS OCCURS...FREEZING RAIN HAS DEVELOPED ACROSS PORTIONS OF THE REGION.

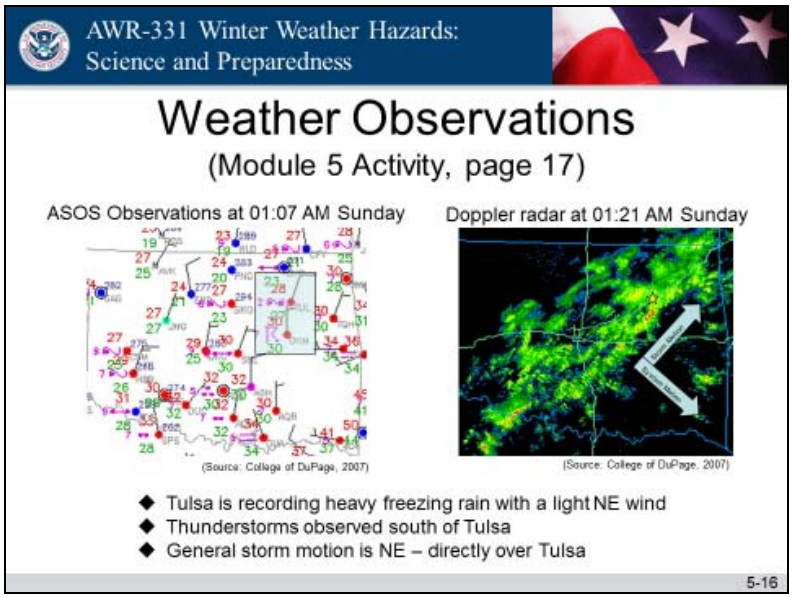
ICE ACCUMULATION TOTALS WILL LIKELY VARY WIDELY...HOWEVER ACCUMULATIONS UP TO ONE HALF INCH WILL BE POSSIBLE ON ELEVATED SURFACES. AS TEMPERATURES CONTINUE TO COOL THROUGH SUNDAY MORNING...ROADWAYS WILL BECOME INCREASINGLY LIKELY TO MAINTAIN AN ICE COATING. UTILITY OPERATIONS ARE EXPECTED TO BECOME INCREASINGLY STRESSED AS ICE LOADS ON POWER LINES.

Participant Notes:

A WINTER STORM WATCH REMAINS IN EFFECT FOR ADDITIONAL ICE POTENTIAL ON MONDAY. AN ICE STORM WARNING MEANS SEVERE WINTER WEATHER CONDITIONS ARE EXPECTED OR OCCURRING. SIGNIFICANT AMOUNTS OF ICE ACCUMULATIONS WILL MAKE TRAVEL DANGEROUS OR IMPOSSIBLE. TRAVEL IS STRONGLY DISCOURAGED.

A WINTER STORM WATCH MEANS HEAVY SNOW OR A SIGNIFICANT ACCUMULATION OF ICE OR SLEET IS EXPECTED IN THE WATCH AREA DURING THE NEXT 24 TO 36 HOURS. RESIDENTS IN THE WATCH AREA SHOULD PREPARE NOW FOR WINTER STORM CONDITIONS. MAKE SURE YOUR CAR IS WINTERIZED AND IN GOOD WORKING ORDER. ALSO MAKE SURE YOU HAVE AN ADEQUATE SUPPLY OF FOOD...WATER AND THE NECESSARY MEDICATION TO LAST THROUGH THE DURATION OF THE WINTER STORM."

Participant Notes:



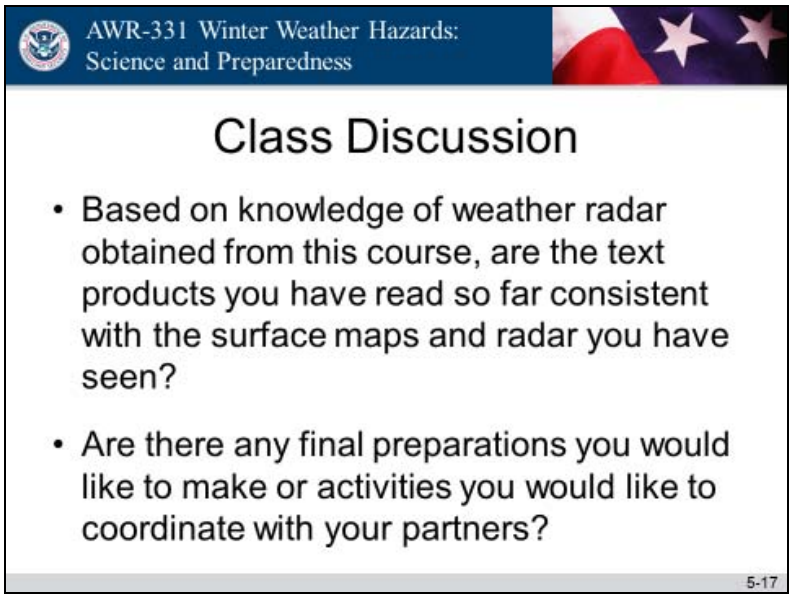
Slide 5-16. Weather Observations

Above are two images that describe the current weather conditions at Tulsa.

On the left is an ASOS observation plot of western Oklahoma at 01:07 AM on Sunday, December 9. All official ASOS station locations are plotted alongside the wind speed, wind direction, temperature, dew point, and weather condition noted next to the location. A small box has been placed over Tulsa and Okmulgee, a town to the south of Tulsa. Tulsa is recording heavy freezing rain with a temperature of 28°F, dew point of 27°F, and 10 knots NNE wind. Okmulgee is recording a thunderstorm with a temperature of 30°F, dew point of 30°F, and five knots north wind.

On the right is Doppler radar reflectivity at 01:21 AM on Sunday, December 9. Tulsa has been marked on this map with a small yellow star. A scattered band of light to heavy precipitation, oriented from the SW to the NE, is present over Tulsa and Okmulgee. The band is moving to the NE.

Participant Notes:

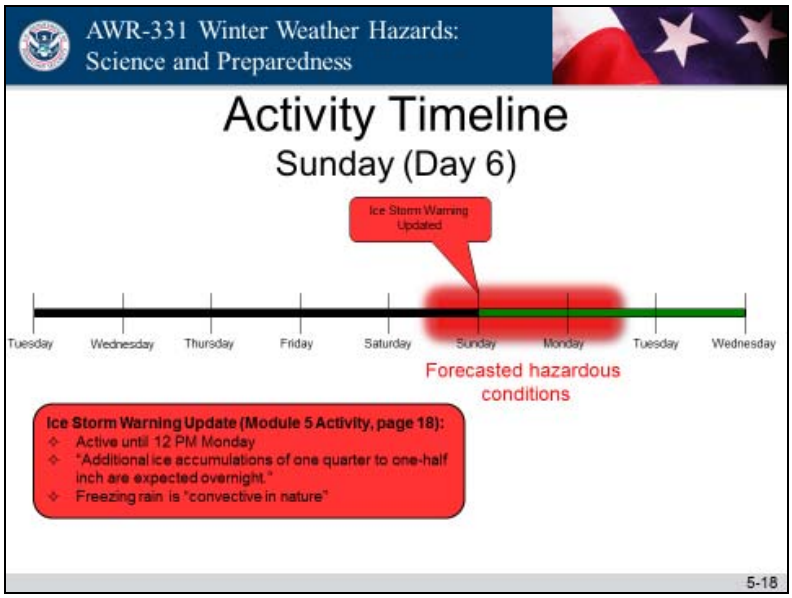


Slide 5-17. Class Discussion

Based on knowledge of weather radar obtained from this course, are the text products you have read so far consistent with the surface maps and radar you have seen?

Are there any final preparations you would like to make or activities you would like to coordinate with your partners?

Participant Notes:



Slide 5-18. Activity Timeline, Sunday (Day 6)

At 03:30 PM on Sunday (Day 6), the National Weather Service issued the following Ice Storm Warning:

"...ICE STORM WARNING NOW IN EFFECT UNTIL 12 PM CST MONDAY...

...WINTER STORM WATCH NOW IN EFFECT FROM MONDAY AFTERNOON THROUGH LATE MONDAY NIGHT...

THE ICE STORM WARNING IS NOW IN EFFECT UNTIL 12 PM CST MONDAY FOR THE FOLLOWING COUNTIES...

IN ARKANSAS...BENTON.

IN OKLAHOMA...
OSAGE...WASHINGTON...NOWATA...CRAIG...OTTAWA...PAWNEE...
TULSA...ROGERS...MAYES...DELAWARE...CREEK...OKFUSKEE...
OKMULGEE...WAGONER...CHEROKEE...MUSKOGEE...MCINTOSH.

A LARGE BAND OF FREEZING RAIN WITH EMBEDDED THUNDERSTORMS EXTENDED FROM NORTHEAST OKLAHOMA INTO WESTERN NORTH TEXAS THIS AFTERNOON. THIS ACTIVITY WILL CONTINUE TO SPREAD NORTHEAST THROUGH THE OVERNIGHT HOURS. TEMPERATURES ACROSS THE WARNING

Participant Notes:

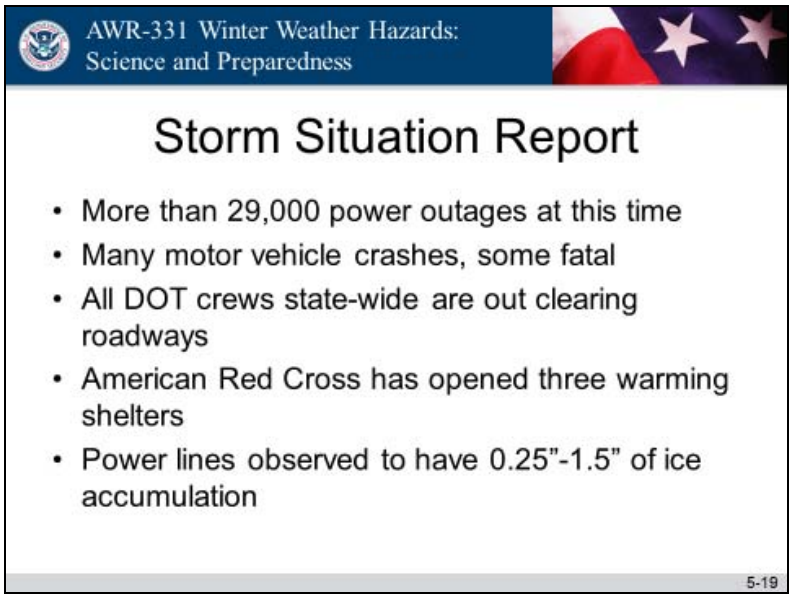
AREA WILL REMAIN BELOW FREEZING...WITH SIGNIFICANT ICE ACCUMULATIONS UPWARDS OF A HALF INCH LIKELY. MUCH OF THE ICE ACCUMULATION WILL REMAIN ON ELEVATED SURFACES SUCH AS BRIDGES...OVERPASSES...TREES AND POWER LINES...BUT TRAVEL PROBLEMS MAY DEVELOP OVERNIGHT AS TEMPERATURES CONTINUE TO SLOWLY COOL.

PRECIPITATION IS EXPECTED TO TAPER OFF BY LATE MORNING ON MONDAY.

AN ICE STORM WARNING MEANS SEVERE WINTER WEATHER CONDITIONS ARE EXPECTED OR OCCURRING. SIGNIFICANT AMOUNTS OF ICE ACCUMULATIONS WILL MAKE TRAVEL DANGEROUS OR IMPOSSIBLE. TRAVEL IS STRONGLY DISCOURAGED."

✔ **Knowledge Check:** Why does it matter that freezing rain is "convective in nature"? How might this understanding change or influence your organizations' response?

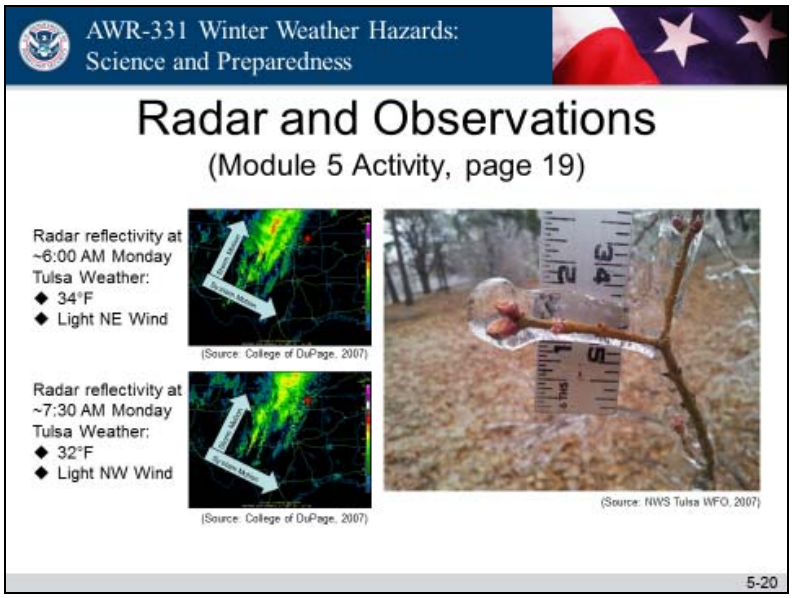
Participant Notes:



Slide 5-19. Storm Situation Report

The information on this slide was taken from actual situation reports issued by OK Emergency Management, OKDOT, and other partners.

Participant Notes:

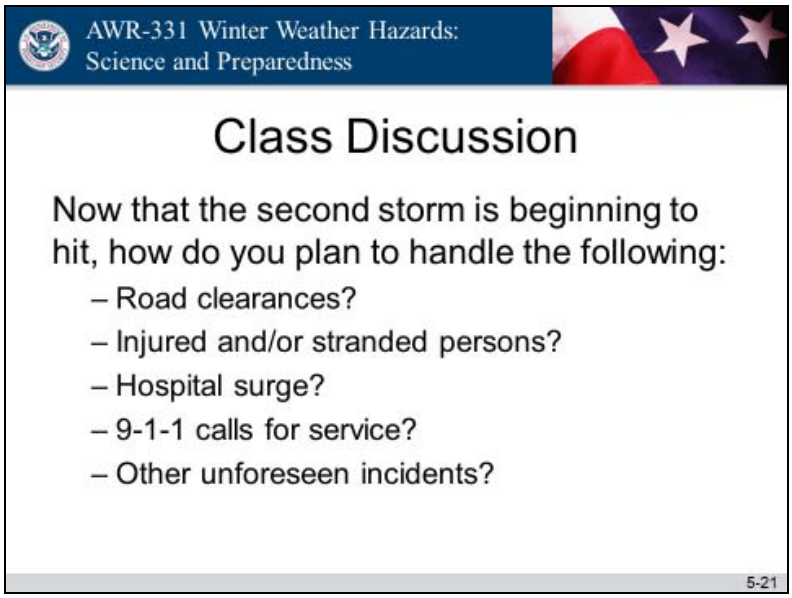


Slide 5-20. Radar and Observations

The above picture on the right, captured by the Tulsa NWS WFO, displays the thickness of the ice that had fallen by Monday, December 10. The ice, having accumulated over a small twig, is measured at approximately one inch.

To the left of the photograph are two Doppler radar reflectivity images displaying precipitation near Tulsa at approximately 06:00 AM on Monday, December 10 (top image), and at approximately 07:30 AM also on Monday, December 10 with Tulsa being denoted with a small yellow star in both images. There is a large shield of light-moderate precipitation moving toward Tulsa, as noted by the arrow, in both images.

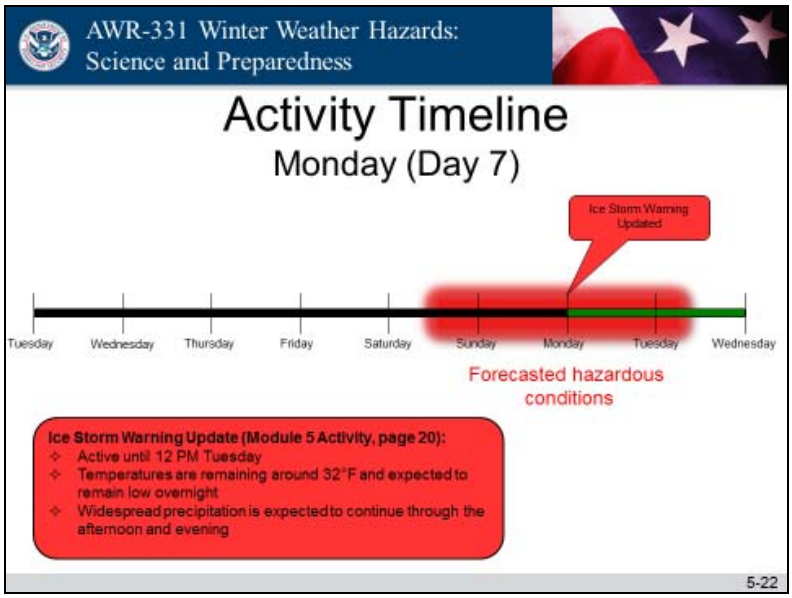
Participant Notes:



Slide 5-21. Class Discussion

This slide is meant to encourage discussion and should assess participants' understanding of winter weather hazards and associated preparedness/response activities. Participants should reference the content and recommendations outlined in Module 4, especially the Winter Storm Event Timeline to inform and justify their decisions.

Participant Notes:



Slide 5-22. Activity Timeline, Monday (Day 7)

At 03:30 PM on Monday (Day 7), the National Weather Service issued the following Ice Storm Warning:

"...ICE STORM WARNING NOW IN EFFECT UNTIL 12 PM CST TUESDAY...

THE ICE STORM WARNING IS NOW IN EFFECT UNTIL 12 PM CST TUESDAY FOR THE FOLLOWING COUNTIES...

IN OKLAHOMA...
OSAGE...WASHINGTON...NOWATA...CRAIG...OTTAWA...PAWNEE...
TULSA...ROGERS...MAYES...CREEK.

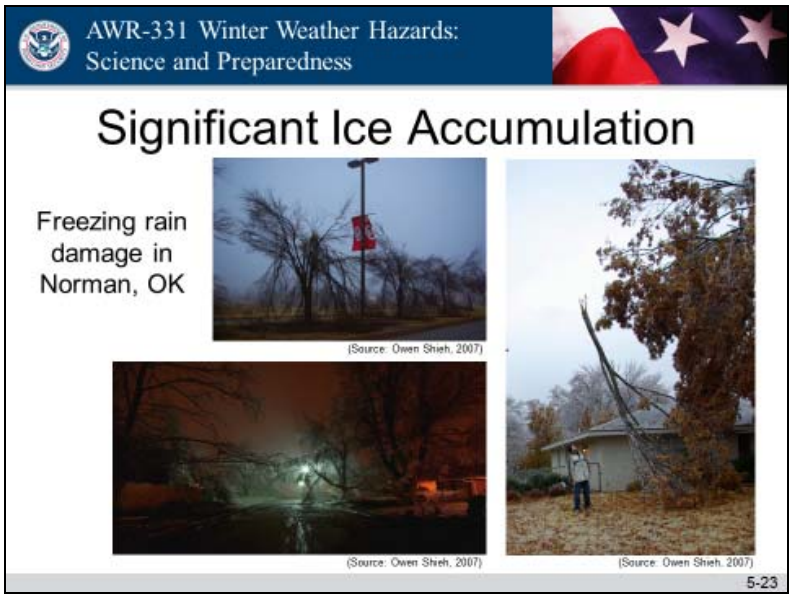
TEMPERATURES ARE EXPECTED TO REMAIN WITHIN A FEW DEGREES OF FREEZING DURING THE OVERNIGHT HOURS...WITH LITTLE WARMING EXPECTED DURING THE MORNING HOURS TUESDAY. WIDESPREAD PRECIPITATION IS EXPECTED TO SPREAD INTO EASTERN OKLAHOMA BY THE AFTERNOON...ALONG WITH A SURGE OF COLDER AIR BACK SOUTHWARD. THIS WILL LIKELY PLACE AREAS ALONG AND NORTH OF THE INTERSTATE 44 CORRIDOR NEAR FREEZING...WITH THE POTENTIAL FOR ADDITIONAL ICE ACCUMULATIONS.

Participant Notes:

THERE REMAINS CONSIDERABLE UNCERTAINTY IN HOW WARM TEMPERATURES WILL BE PRECEDING THE NEXT ROUND OF PRECIPITATION. SHOULD WARMER TEMPERATURES DEVELOP...THEN THE WARNING MAY BE CANCELLED. HOWEVER GIVEN THE ONGOING IMPACTS FROM THE ICING...ANY ADDITIONAL ACCUMULATIONS WILL IMMEDIATELY PROVE PROBLEMATIC.

SIGNIFICANT ICE ACCUMULATION ON TREES AND POWER LINES HAVE CAUSED NUMEROUS POWER OUTAGES ACROSS THE AREA. DO NOT TOUCH DOWNED LINES AND REPORT ANY POWER OUTAGES TO YOUR ELECTRIC COMPANY. TRAVEL IS HIGHLY DISCOURAGED DUE TO THE DOWNED TREES AND POWER LINES...AND SLICK ROADWAYS."

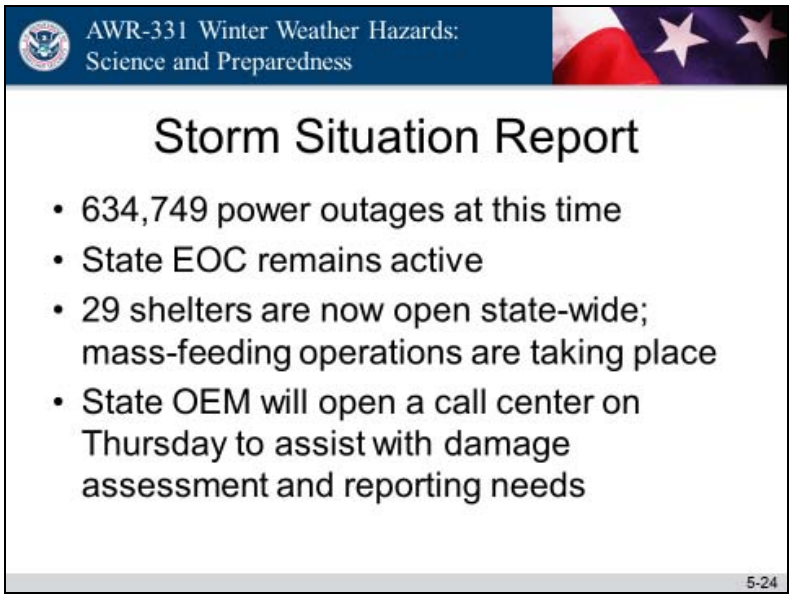
Participant Notes:



Slide 5-23. Significant Ice Accumulation

These photos were taken in Norman, Oklahoma.

Participant Notes:

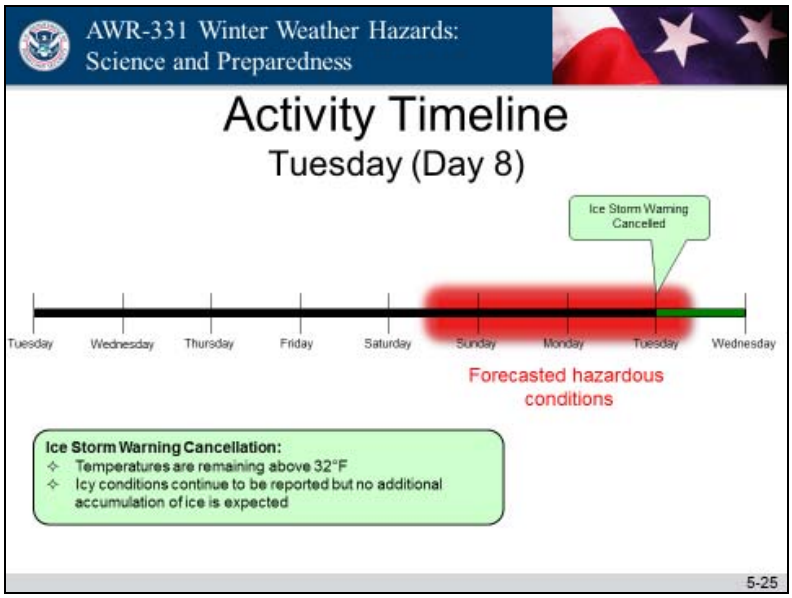


Slide 5-24. Storm Situation Report

The information on this slide was taken from actual situation reports issued by OK Emergency Management, OKDOT, and other partners.

The included data should be used by participants to refine their operations and inform future decision making.

Participant Notes:



Slide 5-25. Activity Timeline, Tuesday (Day 8)

At 04:08 AM on Tuesday (Day 8), the National Weather Service cancelled the Ice Storm Warning for Tulsa County.

"...ICE STORM WARNING IS CANCELLED...

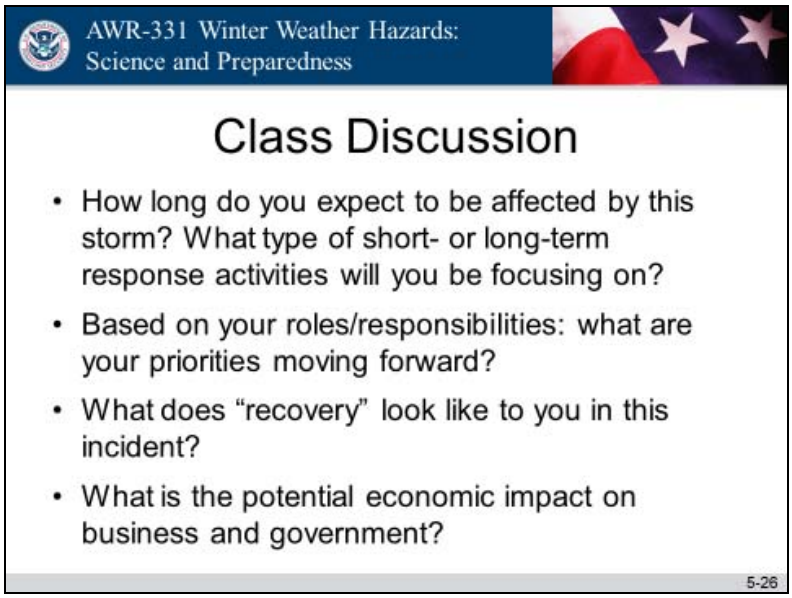
THE NATIONAL WEATHER SERVICE IN TULSA HAS CANCELED THE ICE STORM WARNING FOR THE FOLLOWING COUNTIES...

IN OKLAHOMA...
OSAGE...WASHINGTON...NOWATA...CRAIG...OTTAWA...PAWNEE...
TULSA...ROGERS...MAYES...CREEK.

ICY CONDITIONS ARE STILL BEING REPORTED IN SOME AREA OF NORTHEAST OKLAHOMA NORTHWEST OF INTERSTATE 44. BUT ADDITIONAL ACCUMULATIONS OF FREEZING RAIN ARE NOT EXPECTED TODAY.

MOTORISTS ARE URGED TO CONTINUE TO USE CAUTION AND WATCH FOR SLICK SPOTS TODAY. FALLING ICE FROM POWER LINES AND TREES CAN STILL CAUSE DAMAGE AS WINDS INCREASE LATER TODAY. "

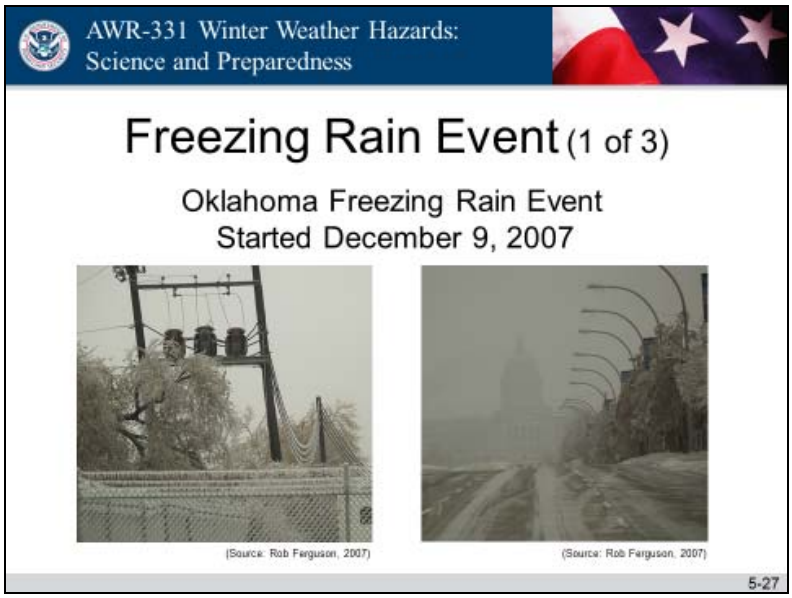
Participant Notes:



Slide 5-26. Class Discussion

This slide should generate discussion among participants in the area of recovery and more long-term objectives.

Participant Notes:



Slide 5-27. Freezing Rain Event (1 of 3)

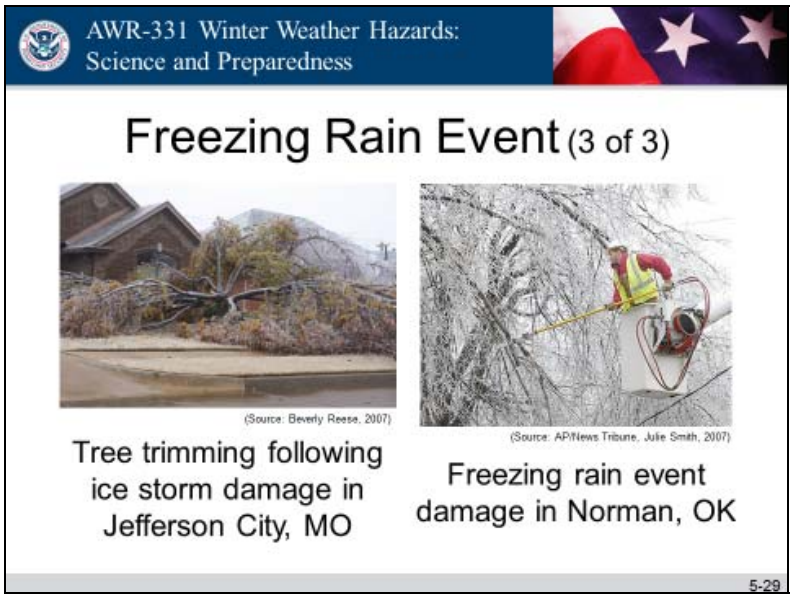
These photos were taken in Oklahoma.

Participant Notes:

Slide 5-28. Freezing Rain Event (2 of 3)

This photo was taken in Moore, Oklahoma.

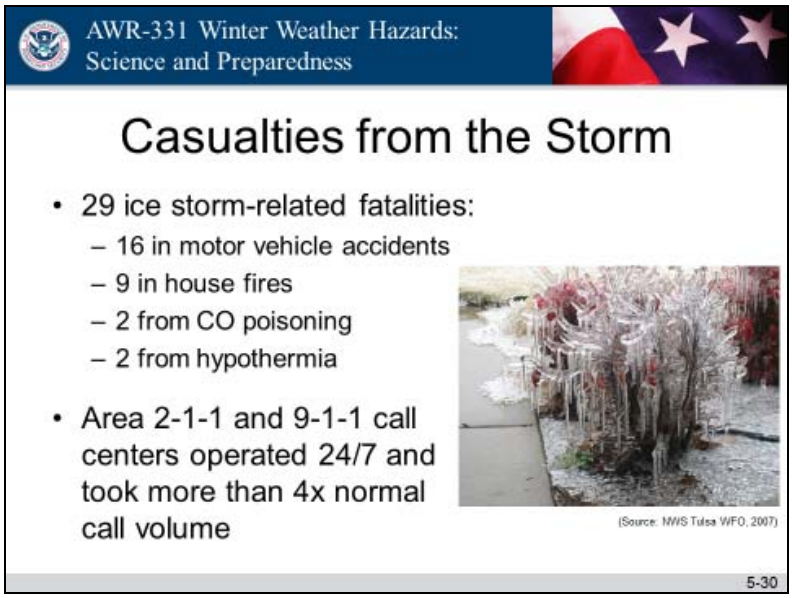
Participant Notes:



Slide 5-29. Freezing Rain Event (3 of 3)

These photos were taken in Norman, Oklahoma (top left photo), and Jefferson City, Missouri (bottom right photo).

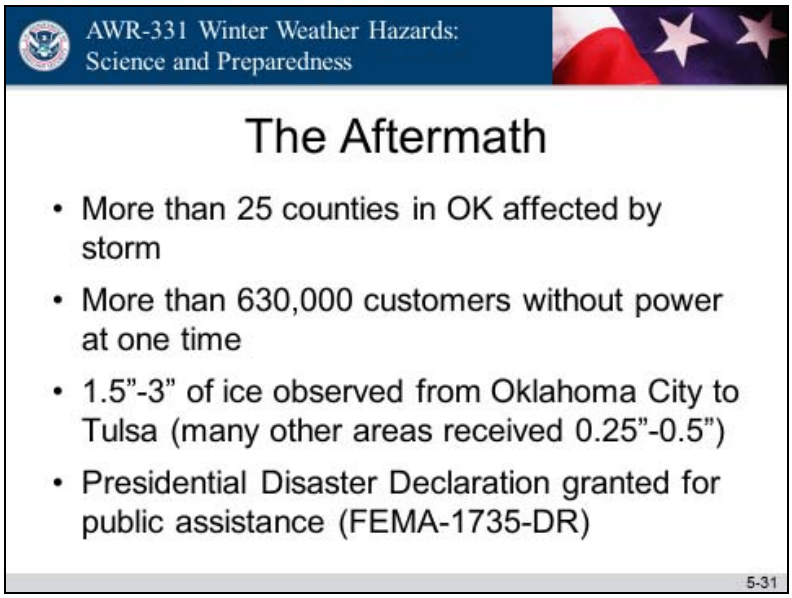
Participant Notes:



Slide 5-30. Casualties from Storm

This slide highlights the casualties from this specific ice storm.

Participant Notes:

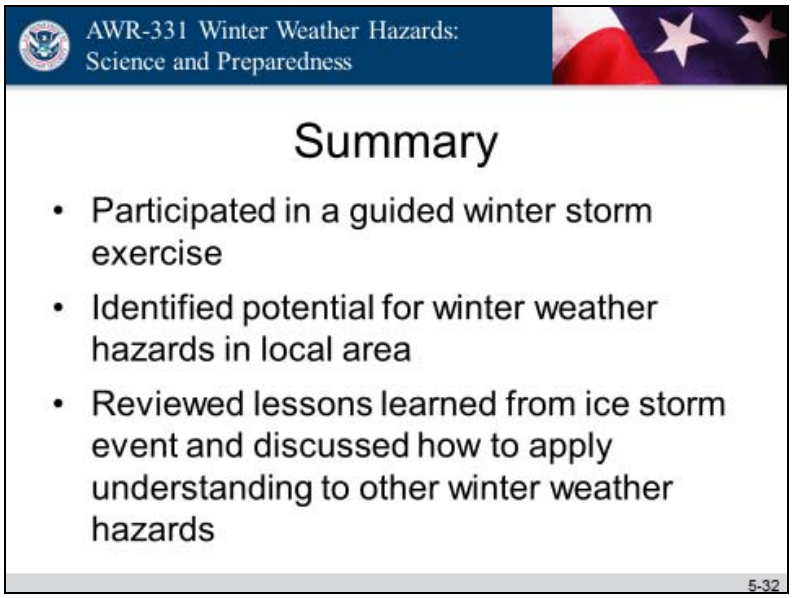


Slide 5-31. The Aftermath

The data presented in this slide highlights the extreme potential of ice and freezing rain to cripple a sizable area.

For more information on this storm and the hazards/effects and lessons learned outlined in this activity, visit the information pages listed in the resources section of Module 5.

Participant Notes:



Slide 5-32. Summary

This module provided participants the opportunity to engage in a guided winter storm activity/discussion, develop both strategic and tactical decision making for a winter storm event, and also encouraged participants to use historical data and case studies to better prepare for potential storms and hazards in their jurisdiction.

AWR-331 Winter Weather Hazards: Science and Preparedness

Module 6: Evaluation and Conclusion

Version 1.0

FEMA

This page is intentionally left blank.

Module 6: Evaluation and Conclusion – Administration Page

Slide 6-1. Evaluation and Conclusion

Duration

45 minutes

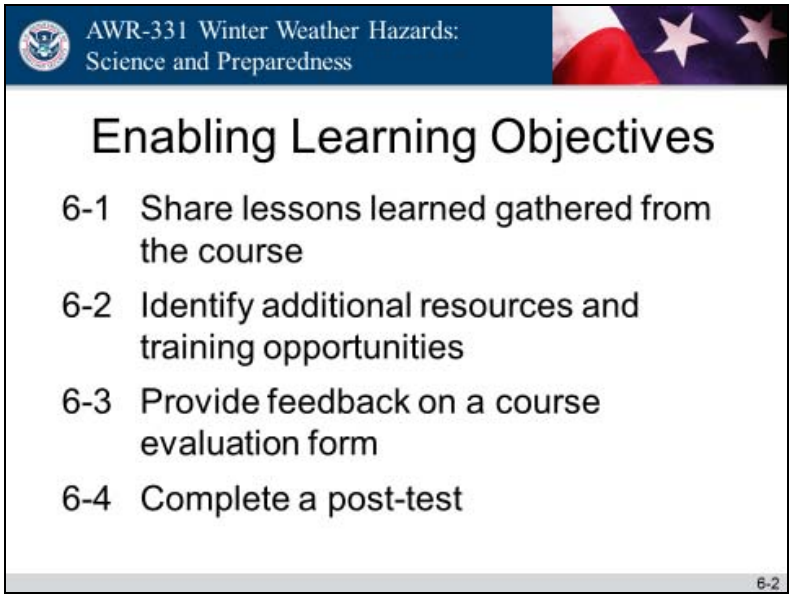
Scope Statement

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; and
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/
  - Course Evaluation Forms
  - Post-test answer sheet corresponding to post-test version

Instructor-to-Participant Ratio

2:40

Reference List

Not applicable

Practical Exercise Statement

Not applicable

Assessment Strategy

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

Winter Weather Hazards: Science and Preparedness

Icon Map

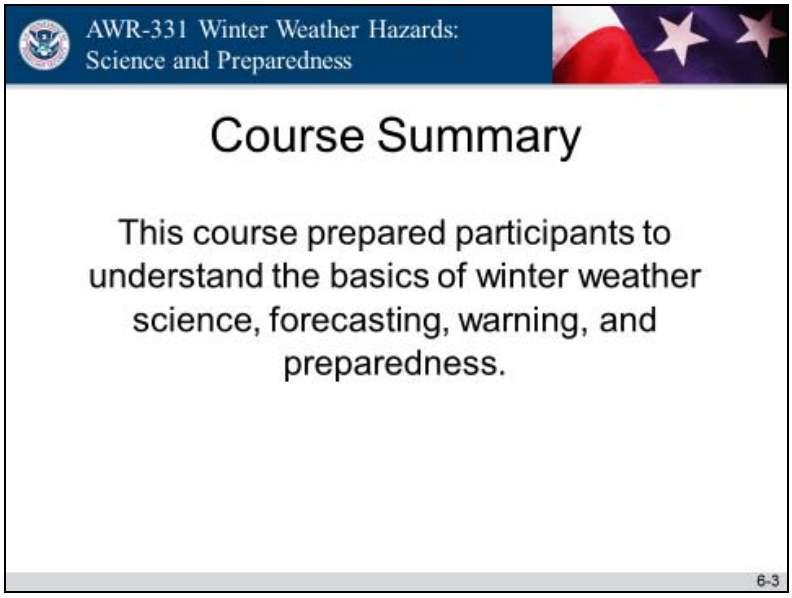
Knowledge Check: Used when it is time to assess participant understanding.

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

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

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

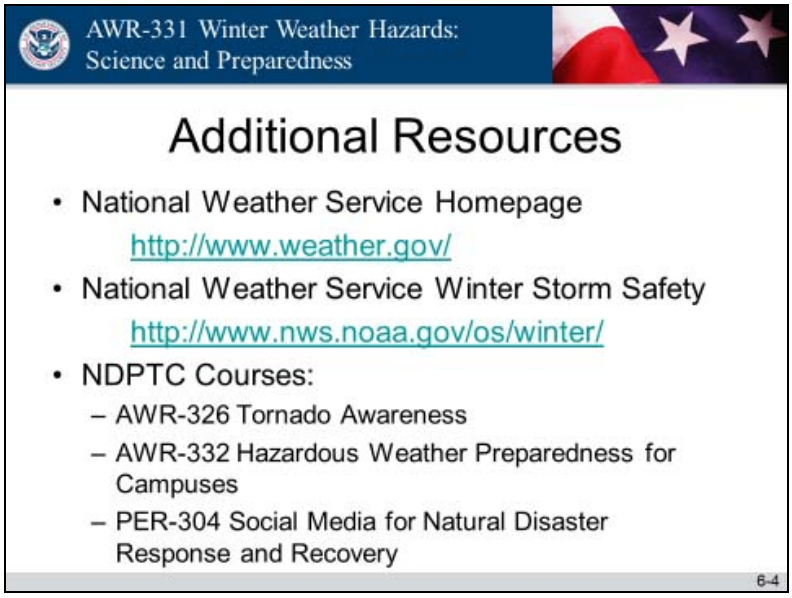
Participant Notes:



Slide 6-3. Course Summary

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

Participant Notes:



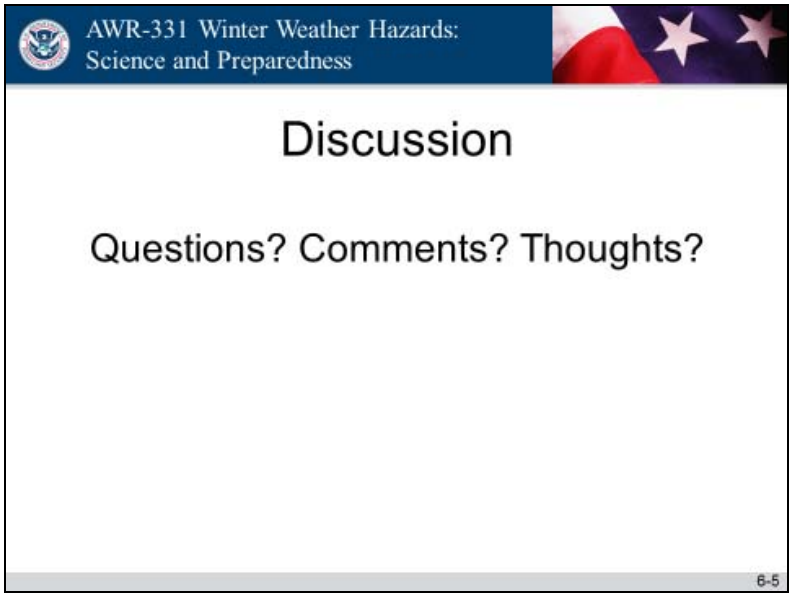
Slide 6-4. Additional Resources

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

- National Weather Service Homepage:
  http://www.weather.gov/
  National Weather Service Winter Storm Safety:
  http://www.nws.noaa.gov/os/winter/

Participants are also encouraged to participate in future NDPTC courses. Participants for this course may be particularly interested in AWR-326 Tornado Awareness, AWR-332 Hazardous Weather Preparedness for Campuses, and PER-304 Social Media for Natural Disaster Response and Recovery. These classes may be scheduled free of charge by contacting NDPTC.

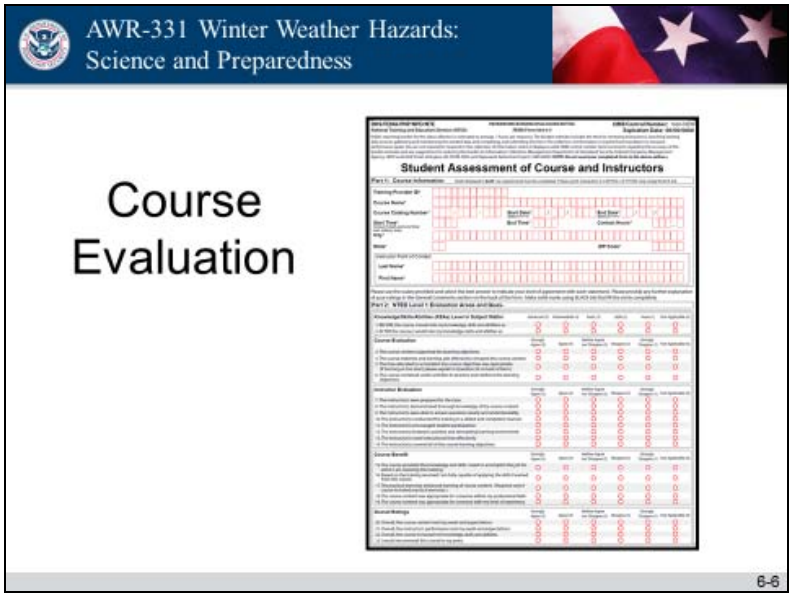
Participant Notes:



Slide 6-5. Discussion

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

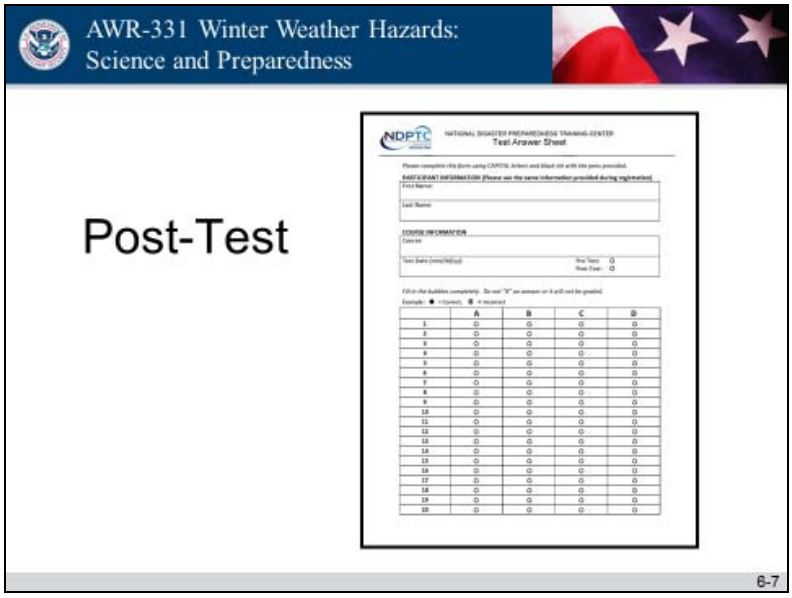
Participant Notes:



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 10 minutes to complete the form.

Participant Notes:

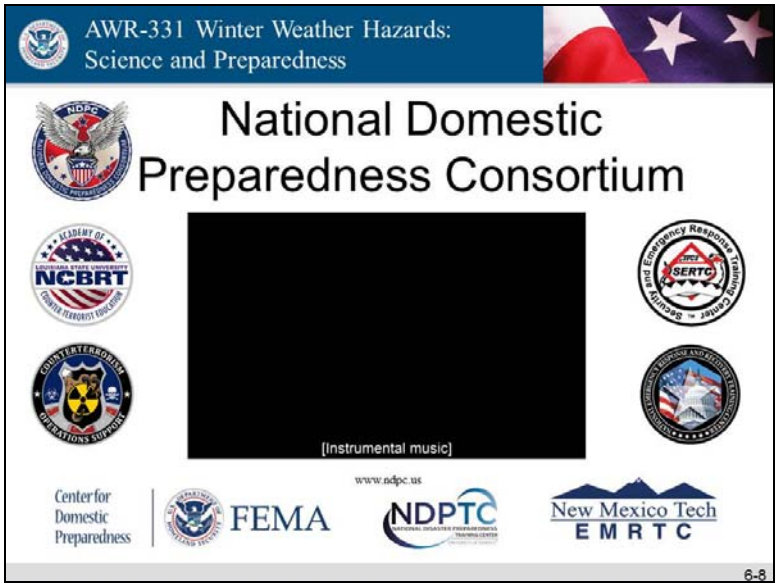


Slide 6-7. Post-Test

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 10 minutes to complete the post-test, and should work independently to complete the answers.

Participant Notes:



Slide 6-8. National Domestic Preparedness Consortium

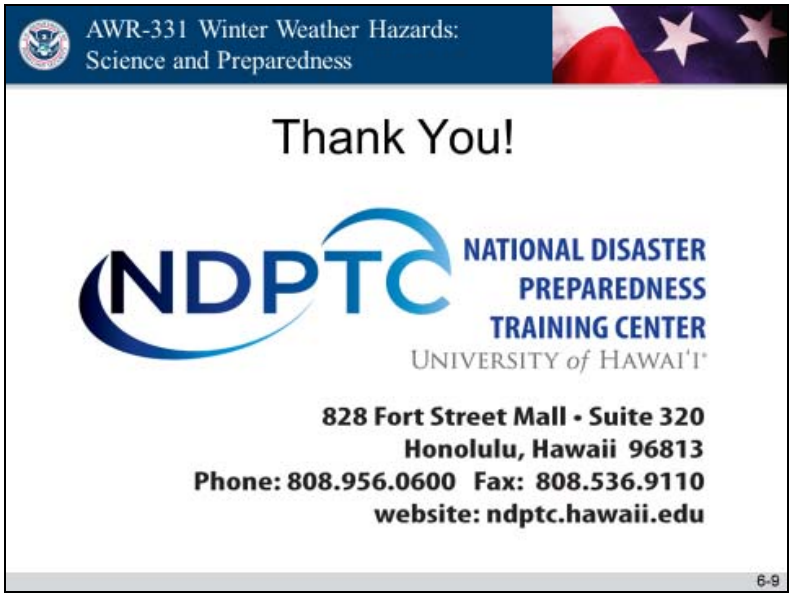
The National Domestic Preparedness Consortium (NDPC) is a professional alliance sponsored through the Department of Homeland Security/FEMA National Preparedness Directorate.

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);
- US 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.

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.

This page is intentionally left blank.

AWR-331 Winter Weather Hazards: Science and Preparedness

Appendices

Version 1.0

FEMA

This page is intentionally left blank.

AWR-331 Winter Weather Hazards: Science and Preparedness

Appendix A: Meteorology Terminology

Version 1.0

FEMA

This page is intentionally left blank.

Appendix A: Meteorology Terminology

Advisory: "Statements issued by a weather service that discuss weather situations of inconvenience that do not carry the danger of warning criteria, but, if not observed, could lead to hazardous situations." (Source: The American Meteorological Society, 2015)

Anthropogenic Forcing: Human-influenced contribution to climate change

Blizzard Condition: "A severe weather condition characterized by high winds and reduced visibilities due to falling or blowing snow. The U.S. National Weather Service specifies sustained wind or frequent gusts of 16 m per second (30 kt or 35 mi per hour) or greater, accompanied by falling and/or blowing snow, frequently reducing visibility to less than 400 m (0.25 mi) for 3 hours or longer. Earlier definitions also included a condition of low temperatures, on the order of -7°C (20°F) or lower, or -12°C (10°F) or lower (severe blizzard). The name originated in the United States but it is also used in other countries. In the Antarctic the name is given to violent autumnal winds off the ice cap." (Source: The American Meteorological Society, 2015)

Climate Change: "Climate change may be due to natural external forcings, such as changes in solar emission or slow changes in the earth's orbital elements; natural internal processes of the climate system; or anthropogenic forcing." (Source: The American Meteorological Society, 2015)

Climate Variability: "The temporal variations of the atmosphere-ocean system around a mean state. Typically, this term is used for timescales longer than those associated with synoptic weather events (i.e., months to millennia and longer). The term "natural climate variability" is further used to identify climate variations that are not attributable to or influenced by any activity related to humans." (Source: The American Meteorological Society, 2015)

Cold Front: "The leading edge of a relatively cold air mass." (Source: The American Meteorological Society, 2015)

Cold Wave: "As used in the U.S. National Weather Service, a rapid fall in temperature within 24 hours to temperatures requiring substantially increased protection to agriculture, industry, commerce, and social activities. Therefore, the criterion for a cold wave is twofold: the rate of temperature fall, and the minimum to which it falls. The latter depends upon region and time of year." (Source: The American Meteorological Society, 2015)

Convection: "Motion caused only by density differences within the fluid; on a sunny day with a little wind where the ground temperature rises…convection take place." (Source: The American Meteorological Society, 2015)

Cyclone: In the northern hemisphere, a cyclone is a low-pressure system that rotates counter-clockwise, or cyclonically, around the center of low pressure.

Derecho: A widespread convectively-induced straight-line windstorm. Specifically, the term is defined as any family of downburst clusters produced by an extratropical mesoscale convective system. Derechos may or may not be accompanied by tornadoes. Such events were first recognized in the Corn Belt region of the United States, but have since been observed in many other areas of the mid-latitudes." (Source: The American Meteorological Society, 2015)

Doppler Radar: "A radar that detects and interprets the Doppler effect in terms of the radial velocity of a target." Doppler radars are popularly understood to provide an image of local precipitation and winds. (Source: The American Meteorological Society, 2015)

Downburst: "An area of strong, often damaging winds produced by one or more convective downdrafts over an area from less than 1 to 400 km in horizontal dimensions." (Source: The American Meteorological Society, 2015)

Drought: "A period of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance. Drought is a relative term, therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, there may be a shortage of precipitation during the growing season resulting in crop damage (agricultural drought), or during the winter runoff and percolation season affecting water supplies (hydrological drought)." (Source: The American Meteorological Society, 2015)

Dual-Polarization Doppler Radar: A radar capable of transmitting both vertically and horizontally polarized microwave waves.

El Niño: A significant increase in sea surface temperature over the eastern and central equatorial Pacific that occurs at irregular intervals, generally ranging between two and seven years. El Niño conditions, which are often characterized by "warm events," most often develop during the early months of the year and decay during the following year. The term was originally applied by fishermen of northern Peru to a warm annual southward coastal current that develops shortly after the Christmas season; hence the Spanish name referring to "the Christ Child." The name subsequently became more commonly used in reference to the occasional very strong coastal warmings that are associated with torrential rains in the desert coastal regions of southern Ecuador– northern Peru. The current definition of El Niño developed following the discovery that the coastal warmings are simply part of a larger-scale phenomenon arising from coupled ocean–atmosphere interactions across a broad expanse of the equatorial Pacific.

Eye: "In meteorology, usually the "eye of the storm" (hurricane, typhoon), that is, the roughly circular area of comparatively light winds found at the center of a severe tropical cyclone and surrounded by the eyewall. The winds increase gradually outward from the center but can remain very light up to the inner edge of the eyewall. No rain occurs and in intense tropical cyclones the eye is clear with blue sky overhead. Most, but not all, tropical cyclones with

maximum winds in excess of 40 m s^{-1}(78 knots) have eyes visible on satellite imagery. Eye diameters vary from 10 to more than 100 km." (Source: The American Meteorological Society, 2015)

Eyewall: "A ring of cumulonimbus that encircles the eye of a tropical cyclone." It is a region of intense winds and precipitation surrounding the eye of a tropical cyclone. (Source: The American Meteorological Society, 2015)

Extratropical Cyclone: "A cyclone of any intensity for which the primary energy source is baroclinic, that is, results from the temperature contrast between warm and cold air masses." (Source: National Hurricane Center, 2015)

Flash Flood: "A flood that rises and falls quite rapidly with little or no advance warning, usually as the result of intense rainfall over a relatively small area. Some possible causes are ice jams, dam failure, and topography." (Source: The American Meteorological Society, 2015)

Flood: "The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged." (Source: The American Meteorological Society, 2015)

Geomagnetic Storm: "A worldwide disturbance of the earth's magnetic field. Magnetic storms are frequently characterized by a sudden onset, in which the magnetic field undergoes marked changes in the course of an hour or less, followed by a very gradual return to normalcy, which may take several days. If extreme enough, they may interfere with the operation of electrical power lines and the operation of artificial satellites. Magnetic storms are caused by solar disturbances, though the exact nature of the link between the solar and terrestrial disturbances is not totally understood. They are more frequent during years of high sunspot number. Sometimes a magnetic storm can be linked to a particular coronal mass ejection. In these cases, the time between the ejection and onset of the magnetic storm is about one or two days. When these disturbances are observable only in the auroral zones, they may be termed polar magnetic storms." (Source: The American Meteorological Society, 2015)

Haboobs: "Also called 'dust storms'; An intense sandstorm or dust storm caused by strong winds, with sand and/or dust often lofted to heights as high as 1500 m (~5000 ft), resulting in a "wall of dust" along the leading edge of the haboob that can be visually stunning. There is commonly a rapid and significant reduction in visibility and an increase in wind speed following the passage of the leading edge of a haboob, which can last for tens of minutes to a few hours. Haboobs are often caused by an atmospheric gravity or density current, such as thunderstorm outflow, but can also occur as a result of strong synoptic gradient winds, such as following a dry line or dry frontal passage. When a haboob is caused by a strong density current, the leading edge wall of dust roughly conforms to the shape of the associated density current head. Haboobs occur fairly regularly in the arid and semiarid regions of the world and can occur in any dry region. Sometimes they deposit enormous quantities of sand and/or dust." (Source: The American Meteorological Society, 2015)

Hail: “Precipitation in the form of balls or irregular lumps of ice, always produced by convective clouds, nearly always cumulonimbus. An individual unit of hail is called a hailstone. By convention, hail has a diameter of 5 mm or more, while smaller particles of similar origin, formerly called small hail, may be classed as either ice pellets or snow pellets. Thunderstorms that are characterized by strong updrafts, large liquid water contents, large cloud-drop sizes, and great vertical height are favorable to hail formation. The destructive effects of hailstorms upon plant and animal life, buildings and property, and aircraft in flight render them a prime object of weather modification studies.” (Source: The American Meteorological Society, 2015)

Heat Wave: “A period of abnormally and uncomfortably hot and usually humid weather. To be a heat wave such a period should last at least one day, but conventionally it lasts from several days to several weeks. In 1900, A. T. Burrows more rigidly defined a "hot wave" as a spell of three or more days on each of which the maximum shade temperature reaches or exceeds 90°F. More realistically, the comfort criteria for any one region are dependent upon the normal conditions of that region. In the eastern United States, heat waves generally build up with southerly winds on the western flank of an anticyclone centered over the southeastern states, the air being warmed by passage over a land surface heated by the sun.” (Source: The American Meteorological Society, 2015)

Hydrometeor: “Any product of condensation or deposition of atmospheric water vapor, whether formed in the free atmosphere or at the earth's surface; also, any water particle blown by the wind from the earth's surface.” (Source: The American Meteorological Society, 2015)

Ice Storm: “A storm characterized by a fall of freezing liquid precipitation. The attendant formation of glaze on terrestrial objects creates many hazards.” (Source: The American Meteorological Society, 2015)

Instability: Environmental conditions where a layer of cold, dense air lies directly above a layer of less-dense, warm air.

Interdecadal Oscillation: A meteorological event that recurs once every few decades.

Intertropical Convergence Zone (ITCZ): “The axis, or a portion thereof, of the broad trade-wind current of the Tropics.” (Source: The American Meteorological Society, 2015)

Intraseasonal Oscillation: A meteorological event that recurs periodically within one season.

La Niña: The most common of several names given to a significant decrease in sea surface temperature ("cold events") in the central and eastern equatorial Pacific. La Niña is the counterpart to the El Niño "warm event," and its spatial and temporal evolution in the equatorial Pacific is, to a considerable extent, the mirror image of El Niño, although La Niña events tend to be somewhat less regular in their behavior and duration. (Source: The American Meteorological Society, 2015)

Lake-Effect Snow: "Localized, convective snow bands that occur in the lee of lakes when relatively cold airflows over warm water. In the United States this phenomenon is most noted along the south and east shores of the Great Lakes during arctic cold-air outbreaks." (Source: The American Meteorological Society, 2015)

Landslide: "A mass of earth material (soil, rock, etc.) moving rapidly down a steep slope." (Source: The American Meteorological Society, 2015)

Lift: Upward motion of air by instability or forcing.

Macroburst: A downburst that covers an area from 4 to 400km.

Meteorology: "The study of the physics, chemistry, and dynamics of the earth's atmosphere, including the related effects at the air–earth boundary over both land and the oceans. Fundamental topics include the composition, structure, and motion of the atmosphere. The goals ascribed to meteorology are the complete understanding and accurate prediction of atmospheric phenomena." (Source: The American Meteorological Society, 2015)

Mesoscale: "Pertaining to atmospheric phenomena having horizontal scales ranging from a few to several hundred kilometers, including thunderstorms, squall lines, fronts, precipitation bands in tropical and extratropical cyclones, and topographically generated weather systems such as mountain waves and sea and land breezes." (Source: The American Meteorological Society, 2015)

Microburst: "A downburst that covers an area less than 4 km along a side with peak winds that last 2–5 minutes." (Source: The American Meteorological Society, 2015)

Mid-Latitude Cyclone: "Any cyclonic-scale storm that is not a tropical cyclone, usually referring only to the migratory frontal cyclones of middle and high latitudes." (Source: The American Meteorological Society, 2015)

National Hurricane Center: NOAA National Weather Service Center for Environmental Prediction that forecasts and produces advisory products for tropical cyclones.

National Weather Service: NOAA entity tasked to "provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy." (Source: NOAA, 2015)

Natural Forcing: Natural contributions to climate change and variability

Numerical Weather Models: "The integration of the governing equations of hydrodynamics by numerical methods subject to specified initial conditions. Numerical approximations are fundamental to almost all dynamical weather prediction schemes since the complexity and

nonlinearity of the hydrodynamic equations do not allow exact solutions of the continuous equations." (Source: The American Meteorological Society, 2015)

Occluded Front: "1) A cold occlusion results when the coldest air is behind the cold front. The cold front undercuts the warm front and, at the earth's surface, coldest air replaces less cold air. 2) When the coldest air lies ahead of the warm front, a warm occlusion is formed, in which case the original cold front is forced aloft at the warm front surface. At the earth's surface, coldest air is replaced by less cold air. 3) A third and frequent type, a neutral occlusion, results when there is no appreciable temperature difference between the cold air masses of the cold and warm fronts. In this case frontal characteristics at the earth's surface consist mainly of a pressure trough, a wind-shift line, and a band of cloudiness and precipitation." (Source: The American Meteorological Society, 2015)

Sleet: "Generally transparent, globular, solid grains of ice that have formed from the freezing of raindrops or the refreezing of largely melted snowflakes when falling through a below-freezing layer of air near the earth's surface." (Source: The American Meteorological Society, 2015)

Space Weather: "The term is analogous to terrestrial meteorology in that it includes the study of planetary atmospheres and solar–weather relationships." (Source: The American Meteorological Society, 2015)

Storm Prediction Center: NOAA NWS Center for Environmental Prediction tasked with issuing forecast products related to severe thunderstorms, wildfires, lightning, significant winter weather, and tornadoes for the protection of life and property. (Source: The American Meteorological Society, 2015)

Storm Surge: "A rise and onshore surge of seawater as the result primarily of the winds of a storm, and secondarily of the surface pressure drop near the storm center. The magnitude of the surge depends on the size, intensity, and movement of the storm; the shape of the coastline; nearshore underwater topography; and the state of the astronomical tides. The storm surge is responsible for most loss of life in tropical cyclones worldwide." (Source: The American Meteorological Society, 2015)

Straight-Line Wind: "Current of air in which the ground-relative motion does not have any significant curvature. Used in the context of surface winds that inflict damage; to be distinguished from winds in tornadoes, which have significant curvature." (Source: The American Meteorological Society, 2015)

Synoptic: "A specific scale of atmospheric motion with a typical range of many hundreds of kilometers, including such phenomena as cyclones and tropical cyclones." (Source: The American Meteorological Society, 2015)

Thermocline: "A vertical temperature gradient, in some layer of a body of water, that is appreciably greater than the gradients above and below it; also a layer in which such a gradient occurs. The permanent thermocline refers to the thermocline not affected by the seasonal and diurnal changes in the surface forcing; it is therefore located below the yearly maximum depth of

the mixed layer and the influence of the atmosphere. The seasonal thermocline refers to the thermocline not affected by the diurnal changes in the surface forcing. In general, it is established each year by heating of the surface water in the summer, and is destroyed the following winter by cooling at the surface and wind-driven mixing. The diurnal thermocline refers to the thermocline that, in general, is established each day by heating of the surface water and is destroyed the following night by cooling and/or mixing." (Source: The American Meteorological Society, 2015)

Tornado: "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. On a local scale, the tornado is the most intense of all atmospheric circulations. Its vortex usually rotates cyclonically (on rare occasion anti-cyclonically rotating tornadoes have been observed) with wind speeds as low as 30 m s-1 (67 mph) to as high as 135 m s-1 (300 mph), and is generally < 2 km (1.25 mi) in diameter. Tornado intensity is often estimated on the basis of wind damage using the Enhanced Fujita Scale; however, this estimate can be refined using other measurements, especially in the absence of damage indicators. Some tornadoes may also contain secondary vortices (also referred to as suction vortices, sub-vortices, multiple, and satellite vortices).Tornadoes have been observed on all continents except Antarctica but are most common in the United States, where the average number of reported tornadoes is roughly 1000 per year, with the majority of them on the central plains and in the southeastern states (see Tornado Alley). They can occur throughout the year at any time of day. In the central plains of the United States they are most frequent in spring during the late afternoon." (Source: The American Meteorological Society, 2015)

Trade Winds: "The wind system, occupying most of the Tropics, that blows from the subtropical highs toward the equatorial trough; a major component of the general circulation of the atmosphere." (Source: The American Meteorological Society, 2015)

Tropical Cyclone: "The general term for a cyclone that originates over the tropical oceans. This term encompasses tropical depressions, tropical storms, hurricanes, and typhoons. At maturity, the tropical cyclone is one of the most intense and feared storms of the world; winds exceeding 90 m s^{-1}(175 knots) have been measured, and its rains are torrential. Tropical cyclones are initiated by a large variety of disturbances, including easterly waves and monsoon troughs. Once formed, they are maintained by the extraction of latent heat from the ocean at high temperature and heat export at the low temperatures of the tropical upper troposphere. After formation, tropical cyclones usually move to the west and generally slightly poleward, then may "recurve," that is, move into the mid-latitude westerlies and back toward the east. Not all tropical cyclones recurve. Many dissipate after entering a continent in the Tropics, and a smaller number die over the tropical oceans. Tropical cyclones are more nearly circularly symmetric than are frontal cyclones. Fully mature tropical cyclones range in diameter from 100 to well over 1000 km. The surface winds spiral inward cyclonically, becoming more nearly circular near the center. The wind field pattern is that of a circularly symmetric spiral added to a straight current in the direction of propagation of the cyclone. The winds do not converge toward a point but rather become, ultimately, roughly tangent to a circle bounding the eye of the storm. Pressure gradients, and resulting winds, are nearly always much stronger than those of extratropical storms. The cloud and rain patterns vary from storm to storm, but in general there are spiral bands in the outer vortex, while the most intense rain and winds occur in the eyewall. Occasionally, multiple eyewalls occur and evolve through a concentric eyewall cycle. Tropical

cyclones are experienced in several areas of the world. In general, they form over the tropical oceans (except the South Atlantic and the eastern South Pacific) and affect the eastern and equatorward portions of the continents. They occur in the tropical North Atlantic (including the Caribbean Sea and Gulf of Mexico), the North Pacific off the west coast of Mexico and occasionally as far west as Hawaii, the western North Pacific (including the Philippine Islands and the China Sea), the Bay of Bengal and the Arabian Sea, the southern Indian Ocean off the coasts of Madagascar and the northwest coast of Australia, and the South Pacific Ocean from the east coast of Australia to about 140°W. By international agreement, tropical cyclones have been classified according to their intensity as follows: 1) tropical depression, with winds up to 17 m s^{-1}(34 knots); 2) tropical storm, with winds of 18–32 m s^{-1}(35–64 knots); and 3) severe tropical cyclone, hurricane or typhoon, with winds of 33 m s^{-1}(65 knots) or higher. It should be noted that the wind speeds referred to above are 10-min average wind speeds at standard anemometer level (10 m), except that in the United States, 1-min average wind speeds are used." (Source: The American Meteorological Society, 2015)

Vortex: A rotating column of air.

Warm Front: The leading edge of a relatively warm air mass.

Warning: "Issued when a hazardous weather or hydrologic event is occurring, is imminent, or has a very high probability of occurring. A warning is used for conditions posing a threat to life or property." Official public safety warnings are issued by the National Weather Service. (Source: The American Meteorological Society, 2015)

Watch: "Issued when the risk of a hazardous weather or hydrologic event has increased significantly but its occurrence, location, and/or timing is still uncertain. It is intended to provide enough lead time so that those who need to set their plans in motion can do so." Watches are issued by the National Weather Service. (Source: The American Meteorological Society, 2015)

Weather Forecast Office: Local National Weather Service forecast office.

Wind Shear: Winds changing with direction and/or intensity with height.

AWR-331 Winter Weather Hazards: Science and Preparedness

Appendix B: Forecasting Activity

Version 1.0

FEMA

This page is intentionally left blank.

Appendix B: Forecasting Activity

Time

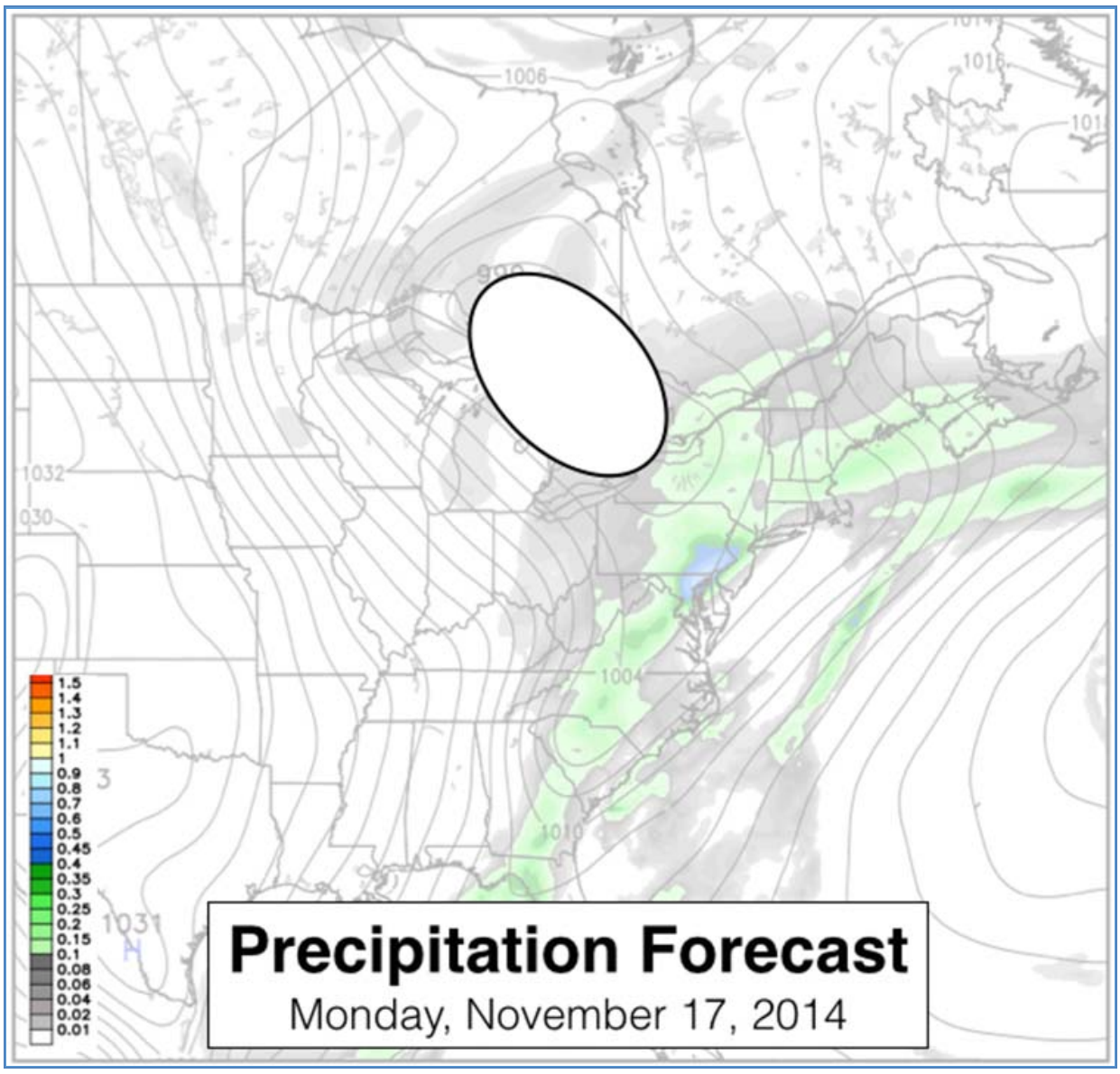
15 minutes

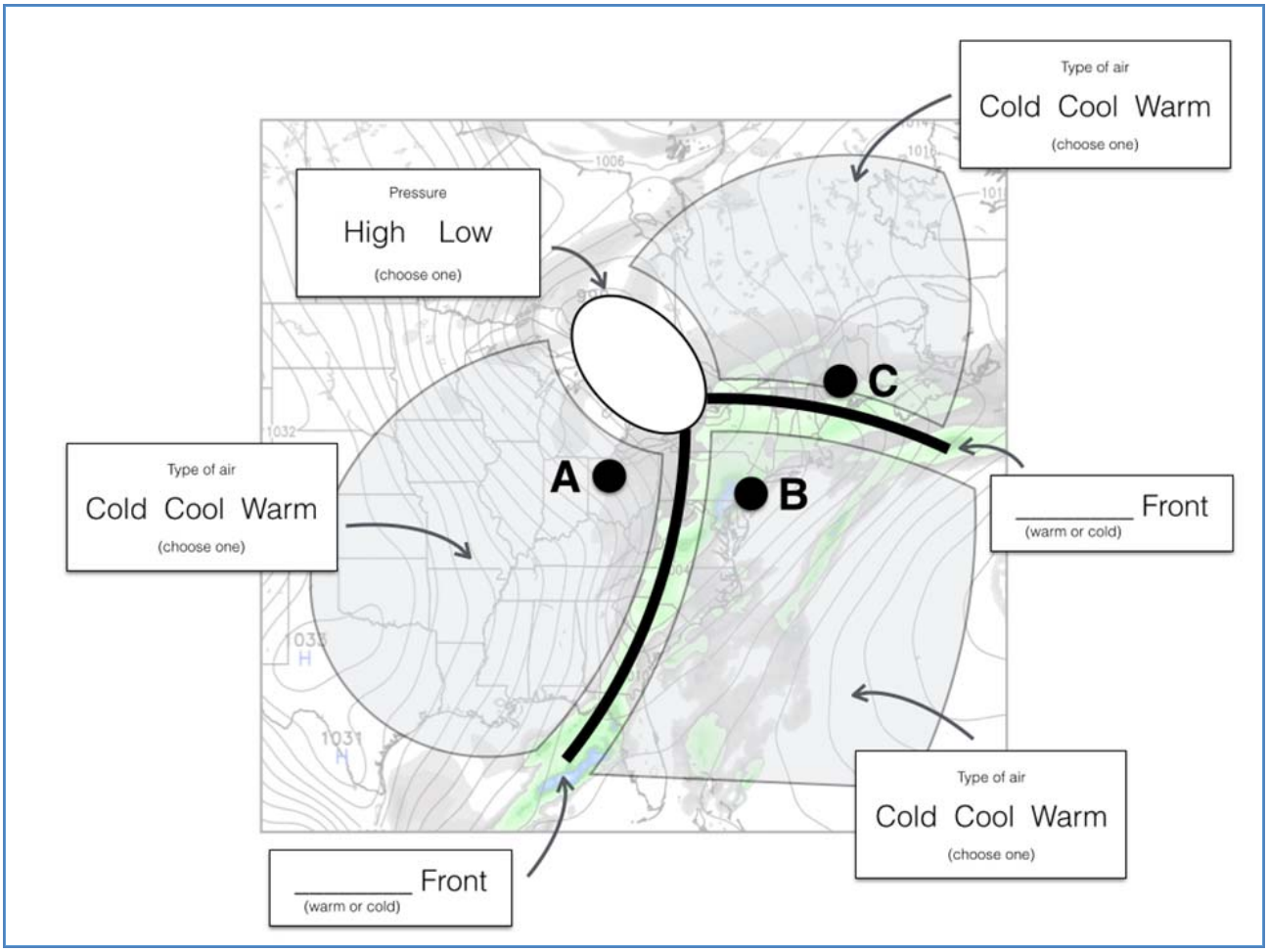
Practical Exercise Statement

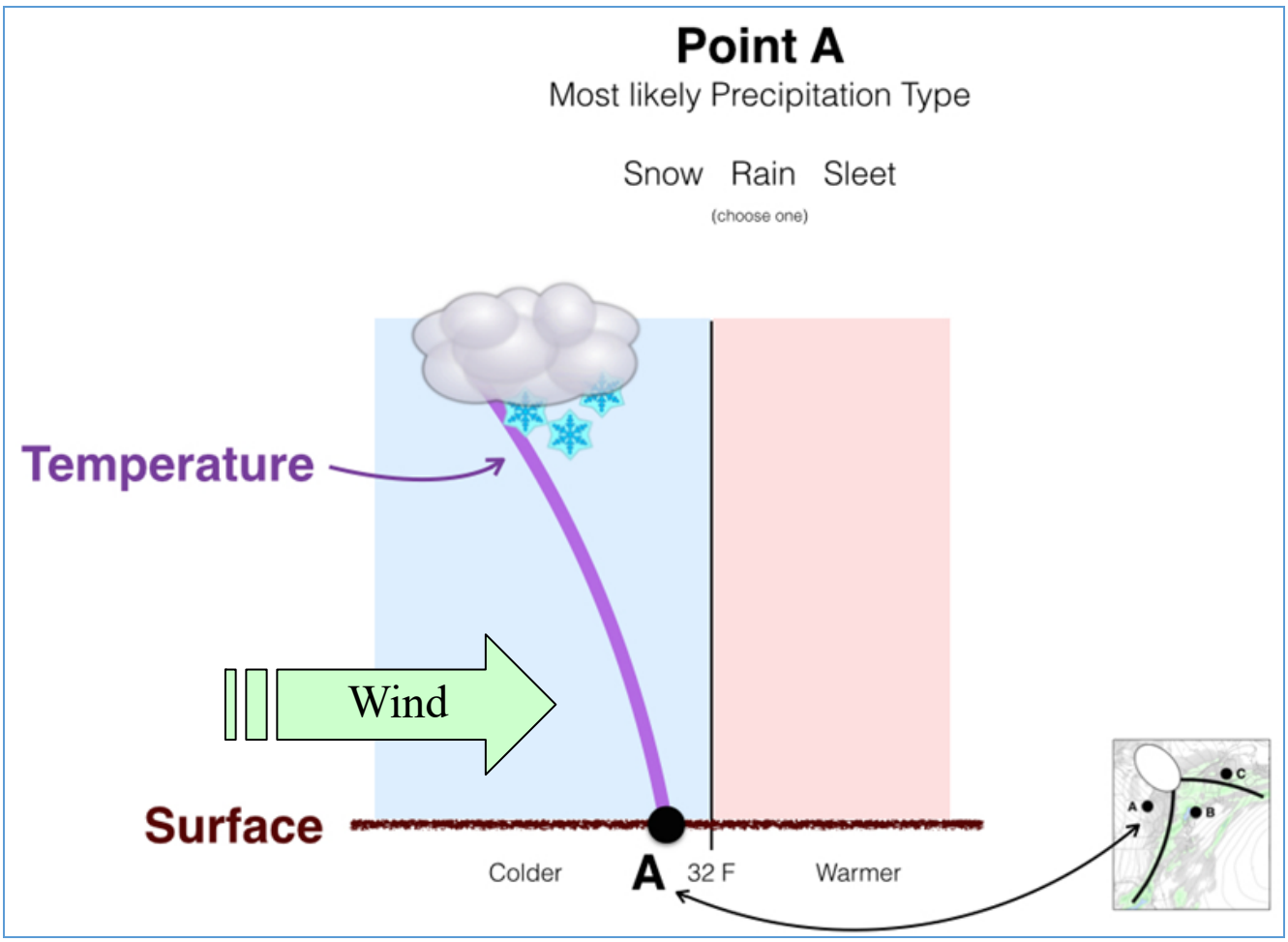
This activity provides an opportunity for participants to develop a stronger understanding of weather forecasting through an individual activity. Participants will consider horizontal and vertical temperature profiles of the atmosphere and forecast hazards and precipitation types accordingly. The objective of the activity is to use the knowledge and understanding gained from previous modules to better understand weather forecasts and the complexity of forecasting precipitation types.

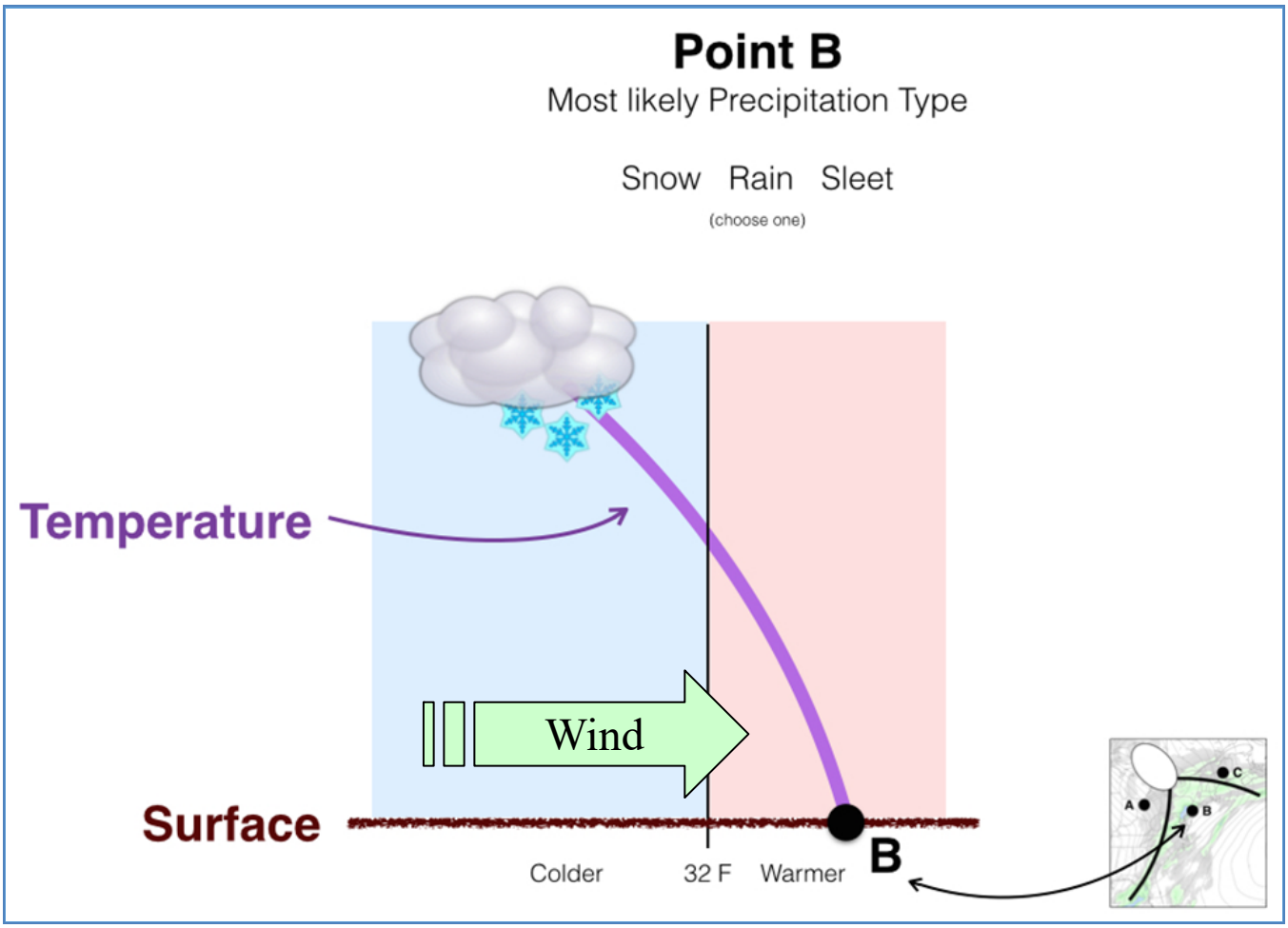
Actions to be Completed

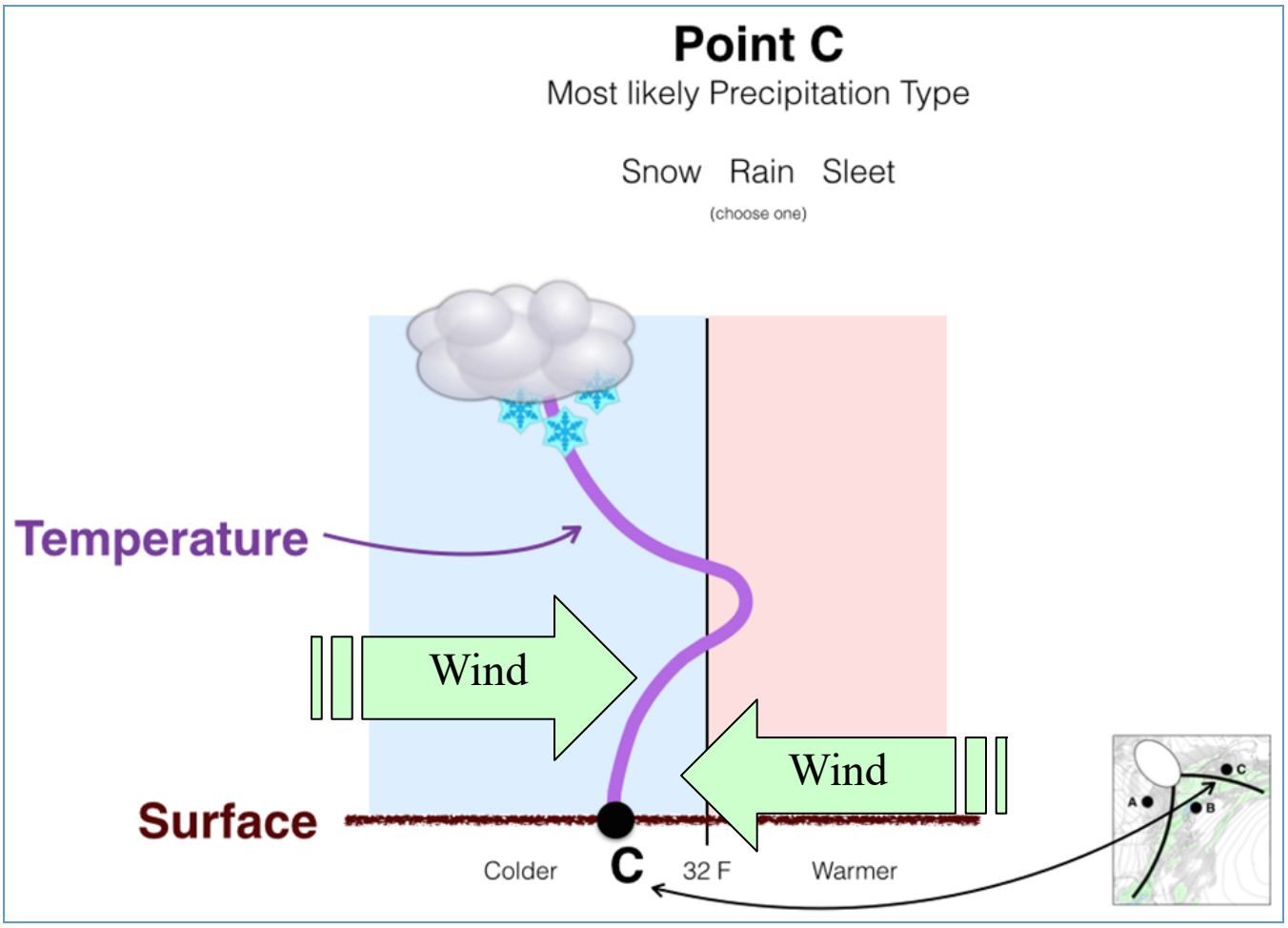
1. Break into small groups
2. Label the pressure, fronts, and air masses.
3. Determine the most likely type of precipitation falling at the time of this map for each point.
4. Discuss how the precipitation will likely change at each point as the storm moves northeast.


1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.08
0.06
0.04
0.02
0.01
Precipitation Forecast
Monday, November 17, 2014


Type of air
Cold Cool Warm
(choose one)
Pressure
High Low
(choose one)
C
A
B
Type of air
Cold Cool Warm
(choose one)
_____ Front
(warm or cold)
Type of air
Cold Cool Warm
(choose one)
_____ Front
(warm or cold)


Point A
Most likely Precipitation Type
Snow Rain Sleet
(choose one)
Temperature
Wind
Surface
Colder
A
32 F
Warmer
C
A
B


Point B
Most likely Precipitation Type
Snow Rain Sleet
(choose one)
Temperature
Wind
Surface
Colder
32 F
Warmer
B
A
B
C


Point C
Most likely Precipitation Type
Snow Rain Sleet
(choose one)
Temperature
Wind
Wind
Surface
Colder
C
32 F
Warmer
A
B
C

AWR-331 Winter Weather Hazards: Science and Preparedness

Appendix C: Winter Storm Activity

Version 1.0

FEMA

This page is intentionally left blank.

Appendix C: Winter Storm Activity

Time

60 minutes

Practical Exercise Statement

This exercise provides an opportunity for participants to work together in groups to role-play in a winter storm situation. Participants will consider the different decisions and courses of action that should be made prior to and during a winter storm. The objective of the activity is to use the knowledge and understanding gained from this course to understand when to make key preparedness decisions and to feel the surprise when encountering a situation that was not forecast correctly.

Actions to be Completed

1. Return to Activity 3 groups and analyze information presented in the following slides.
2. Respond to instructor and discussion prompts from the perspective of the profession assigned to your group.

Please do not proceed to the next page until instructed to do so.

Tuesday, Hazardous Weather Outlook

At 05:09 AM on Tuesday (Day 1), the National Weather Service issued the following Hazardous Weather Outlook:

"DAYS TWO THROUGH SEVEN...WEDNESDAY THROUGH MONDAY.
WEDNESDAY...NO HAZARDS.
THURSDAY...NO HAZARDS.
FRIDAY...NO HAZARDS.
SATURDAY...WINTER WEATHER POTENTIAL.
SUNDAY...WINTER WEATHER POTENTIAL.
MONDAY...WINTER WEATHER POTENTIAL.

EXTENDED DISCUSSION...
A COLD FRONT WILL MOVE ACROSS THE AREA WEDNESDAY... HOWEVER LIMITED MOISTURE AHEAD OF THE FRONT WILL PRECLUDE ANY RAIN. SHORTWAVE ENERGY PASSING TO THE NORTH ON THURSDAY WILL OFFER LOW CHANCES FOR RAIN MAINLY ACROSS NORTHEAST OKLAHOMA. THE UPPER PATTERN BECOMES MORE ACTIVE AS IT TRANSITIONS TO THE SOUTHWEST BY THE WEEKEND. A SHALLOW...BUT STRONG COLD FRONT WILL MOVE THROUGH ON SUNDAY. BEHIND THE BOUNDARY...A WINTRY PRECIPITATION EVENT IN THE FORM OF FREEZING RAIN WILL BE POSSIBLE ACROSS NORTHEAST OKLAHOMA SUNDAY AND INTO MONDAY.

EMERGENCY MANAGEMENT PLANNING STATEMENT...
INTERESTED PARTIES SHOULD MONITOR THE LATEST FORECASTS AND DISCUSSIONS CONCERNING THE POTENTIAL FOR FREEZING RAIN ACROSS NORTHEAST OKLAHOMA LATE IN THE WEEKEND AND EARLY NEXT WEEK."

Please do not proceed to the next page until instructed to do so.

Wednesday, Hazardous Weather Outlook

At 11:46 PM on Wednesday (Day 2), the National Weather Service issued the following Hazardous Weather Outlook:

"DAYS TWO THROUGH SEVEN...THURSDAY THROUGH TUESDAY.
THURSDAY...NO HAZARDS.
FRIDAY...NO HAZARDS.
SATURDAY...THUNDERSTORM POTENTIAL.
SUNDAY...THUNDERSTORM POTENTIAL...WINTER WEATHER POTENTIAL.
MONDAY...WINTER WEATHER POTENTIAL.
TUESDAY...WINTER WEATHER POTENTIAL.

EXTENDED DISCUSSION...
A COLD AIRMASS WILL SPREAD ACROSS THE AREA LATE IN THE WEEKEND...RESULTING IN SHARPLY COLDER TEMPERATURES LATE SUNDAY AND EARLY NEXT WEEK. SHOWERS AND THUNDERSTORMS WILL BE POSSIBLE ALONG THE FRONT ACROSS NORTHWEST ARKANSAS AND SOUTHEAST OKLAHOMA SATURDAY NIGHT INTO SUNDAY MORNING.
MOIST SOUTHWESTERLY FLOW ALOFT WILL BRING SEVERAL WAVES OF PRECIPITATION TO THE REGION...WHICH MAY FALL PRIMARILY AS FREEZING RAIN OR SLEET ACROSS MUCH OF NORTHEAST OKLAHOMA AND NORTHWEST ARKANSAS LATE SUNDAY INTO MONDAY. THE RAIN AND FREEZING RAIN THREAT WILL CONTINUE TUESDAY AS YET ANOTHER WAVE EJECTS OUT OF THE SOUTHWESTERN STATES.

EMERGENCY MANAGEMENT PLANNING STATEMENT...
INTERESTED PARTIES SHOULD MONITOR THE LATEST FORECASTS AND DISCUSSIONS CONCERNING THIS POTENTIAL WINTER WEATHER EVENT THIS WEEKEND INTO THE EARLY PART OF THE WORK WEEK."

Please do not proceed to the next page until instructed to do so.

Thursday Morning, Hazardous Weather Outlook

At 05:08 AM on Thursday (Day 3), the National Weather Service issued the following Hazardous Weather Outlook:

"DAYS TWO THROUGH SEVEN...FRIDAY THROUGH WEDNESDAY.
FRIDAY...NO HAZARDS.
SATURDAY...WINTER WEATHER POTENTIAL.
SUNDAY...WINTER WEATHER POTENTIAL.
MONDAY...WINTER WEATHER POTENTIAL.
TUESDAY...WINTER WEATHER POTENTIAL.
WEDNESDAY...WINTER WEATHER POTENTIAL.

EXTENDED DISCUSSION...
LOW CHANCES FOR RAIN WILL CONTINUE FOR THE NEXT SEVERAL DAYS AS WARM ADVECTION ENSUES AND MOISTURE INCREASES. A COLD FRONT WILL APPROACH THE AREA FRIDAY...AND WILL LIKELY STALL ACROSS NORTHEAST OKLAHOMA LATE FRIDAY AND SATURDAY. A STRONGER SHOT OF COLD AIR WILL EFFECTIVELY PUSH THIS BOUNDARY THROUGH SOUTHEAST OKLAHOMA BY LATE SUNDAY. A MUCH COLDER...BUT SHALLOW AIRMASS WILL BE IN PLACE ACROSS NORTHEAST OKLAHOMA BY SUNDAY. A STRONG UPPER SYSTEM WILL APPROACH THE WEST COAST LATE IN THE WEEKEND WITH MOIST SOUTHWESTERLY FLOW ALOFT MAINTAINED AHEAD OF THE APPROACHING LOW. A LARGE AREA OF PRECIPITATION IS EXPECTED TO DEVELOP ACROSS THE REGION NORTH OF THE FRONT SATURDAY NIGHT AND SUNDAY. THE THERMAL PROFILE STILL SUGGESTS THAT MUCH OF NORTHEAST OKLAHOMA WILL SEE PERIODS OF FREEZING RAIN AS EARLY AS SATURDAY NIGHT. THE SHALLOW COLD AIR WILL BE SLOW TO MODERATE AND PIECES OF UPPER ENERGY EJECT FROM THE UPPER LOW...WHICH WILL RESULT IN CONTINUED CHANCES FOR FREEZING RAIN THROUGH WEDNESDAY ACROSS NORTHEAST OKLAHOMA.

EMERGENCY MANAGEMENT PLANNING STATEMENT...
EMERGENCY MANAGEMENT GROUPS AND OTHER INTERESTED PARTIES SHOULD MONITOR THE LATEST FORECASTS AND DISCUSSIONS CONCERNING WINTER WEATHER POTENTIAL FOR THE EARLY TO MIDDLE PART OF NEXT WEEK."

Thursday Afternoon, Hazardous Weather Outlook

At 01:10 PM on Thursday (Day 3), the National Weather Service issued the following Hazardous Weather Outlook:

"...SIGNIFICANT ICING EVENT POSSIBLE ACROSS PARTS OF THE REGION BEGINNING BY SATURDAY NIGHT...
THIS OUTLOOK IS FOR NORTHWEST AND WEST CENTRAL ARKANSAS AS WELL AS MUCH OF EASTERN OKLAHOMA.
DAY ONE...THIS AFTERNOON AND TONIGHT.
WINTER WEATHER.
ICE ACCUMULATION.
RISK...LIMITED.
AREA...FAR NORTHEAST OKLAHOMA...MAINLY NEAR THE KANSAS BORDER.
ONSET...AFTER MIDNIGHT.

DISCUSSION...
A WARM AIR ADVECTION PATTERN SHOULD RESULT IN DEVELOPING PRECIPITATION ACROSS THE REGION DURING THE OVERNIGHT HOURS. TEMPERATURES AT THE SURFACE COULD BRIEFLY DIP TO NEAR FREEZING...RESULTING IN SOME LIGHT FREEZING RAIN LATE TONIGHT NEAR THE KANSAS BORDER.
SPOTTER AND EMERGENCY MANAGEMENT ACTION STATEMENT...
SPOTTER ACTIVATION NOT EXPECTED.

DAYS TWO THROUGH SEVEN...FRIDAY THROUGH WEDNESDAY.
FRIDAY...WINTER WEATHER POTENTIAL.
ATURDAY...THUNDERSTORM POTENTIAL...WINTER WEATHER POTENTIAL.
SUNDAY...WINTER WEATHER POTENTIAL.
MONDAY...WINTER WEATHER POTENTIAL.
TUESDAY...WINTER WEATHER POTENTIAL.
WEDNESDAY...WINTER WEATHER POTENTIAL."

Thursday Afternoon, Hazardous Weather Outlook (continued)

At 01:10 PM on Thursday (Day 3), the National Weather Service issued the following Hazardous Weather Outlook (continued):

"EXTENDED DISCUSSION...

A SIGNIFICANT WINTER WEATHER EVENT IS SHAPING UP FOR PARTS OF EASTERN OKLAHOMA AND NORTHWEST ARKANSAS OVER THE WEEKEND.

THE SHALLOW COOL AIRMASS CURRENTLY ACROSS THE AREA WILL LIFT SLOWLY NORTH ON SATURDAY...RESULTING IN A LARGE TEMPERATURE SPREAD ACROSS EASTERN OKLAHOMA AND NORTHWEST ARKANSAS. A REINFORCING SHOT OF COLDER AIR WILL EVENTUALLY PUSH THE BOUNDARY BACK SOUTH INTO SOUTHEAST OKLAHOMA OVERNIGHT SATURDAY. THERE APPEARS TO BE ENOUGH MOISTURE AND INSTABILITY TO SUPPORT A FEW THUNDERSTORMS NEAR THE FRONT IN SOUTHEAST OKLAHOMA...BUT SEVERE WEATHER IS NOT EXPECTED.

THE COLD SHALLOW AIRMASS IS EXPECTED TO SETTLE ACROSS MUCH OF REGION BY SUNDAY...WITH TEMPERATURES STRUGGLING TO REACH THE FREEZING MARK ACROSS PORTIONS OF NORTHEAST OKLAHOMA AND FAR NORTHWEST ARKANSAS. MOIST LOW-LEVEL WARM AIR ADVECTION SHOULD OVERRIDE THIS COOL AIRMASS...SETTING THE STAGE FOR SIGNIFICANT ICING OVER NORTHEAST OKLAHOMA BEGINNING LATE SATURDAY NIGHT INTO SUNDAY. IMPULSES OF ENERGY EJECTING FROM THE SOUTHWESTERN U.S. UPPER SYSTEM COULD RESULT IN SEVERAL ROUNDS OF WINTRY PRECIPITATION THROUGH THE EARLY PART OF NEXT WEEK. AT THIS TIME...AREAS ALONG AND NORTH OF INTERSTATE 44 APPEAR TO HAVE THE BEST CHANCES FOR SIGNIFICANT ICING.

EMERGENCY MANAGEMENT PLANNING STATEMENT...

THERE STILL REMAINS MUCH UNCERTAINTY AS TO THE TIMING AND PLACEMENT OF WINTRY PRECIPITATION...SO INTERESTED PARTIES SHOULD CONTINUE TO MONITOR THE LATEST FORECASTS AND DISCUSSIONS CONCERNING THIS POTENTIAL WINTER WEATHER EVENT."

Please do not proceed to the next page until instructed to do so.

Friday, Winter Storm Watch

At 02:19 PM on Friday (Day 4), the National Weather Service issued the following Winter Storm Watch:

"...WINTER STORM WATCH IN EFFECT FROM SUNDAY MORNING THROUGH LATE MONDAY NIGHT...

THE NATIONAL WEATHER SERVICE IN TULSA HAS ISSUED A WINTER STORM WATCH...WHICH IS IN EFFECT FROM SUNDAY MORNING THROUGH LATE MONDAY NIGHT FOR THE FOLLOWING COUNTIES...

IN OKLAHOMA... OSAGE...WASHINGTON...NOWATA...CRAIG...OTTAWA...PAWNEE... TULSA...ROGERS...CREEK.

A SECONDARY SURGE OF COLD AIR IS EXPECTED TO PUSH INTO THE AREA SATURDAY NIGHT INTO SUNDAY. PRECIPITATION SHOULD EXPAND IN COVERAGE FROM THE SOUTHWEST SATURDAY NIGHT...WITH A MIX OF LIGHT FREEZING RAIN AND RAIN EXPECTED TO DEVELOP BY SUNDAY MORNING MAINLY NORTH OF THE AREA. COLDER AIR WILL CONTINUE TO FILTER SOUTH ON SUNDAY...WITH THE FREEZING LINE POSSIBLY REACHING THE AREA BY LATE SUNDAY.

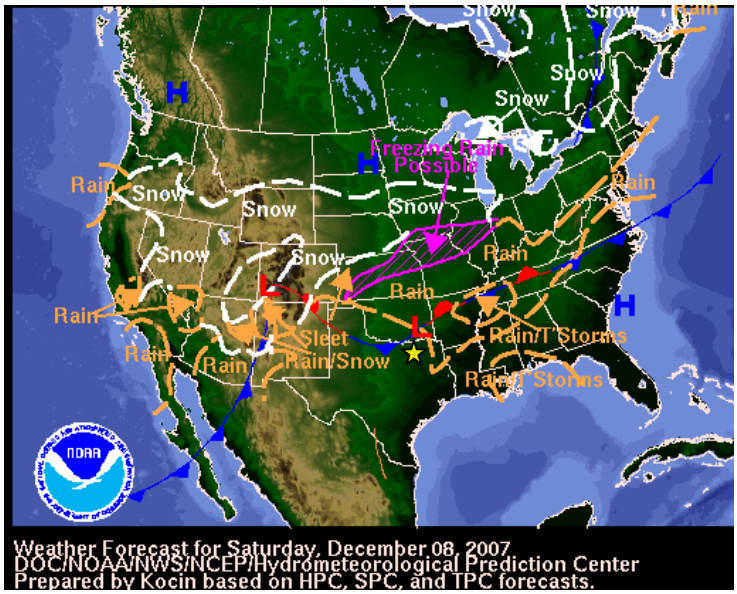
A SECONDARY WAVE OF PRECIPITATION IS EXPECTED BY MONDAY OR INTO MONDAY NIGHT. THIS COULD RESULT IN SIGNIFICANT ICING...WITH ICE ACCUMULATIONS OF A QUARTER TO ONE HALF-INCH POSSIBLE ACROSS AREAS IN THE WATCH.

THERE REMAINS MUCH UNCERTAINTY AT THIS TIME AS TO WHERE THE TRANSITION BETWEEN RAIN AND FREEZING RAIN WILL DEVELOP ACROSS THE AREA. THE WINTER STORM WATCH MAY BE ADJUSTED AS ADDITIONAL DATA BECOMES AVAILABLE.

A WINTER STORM WATCH MEANS HEAVY SNOW OR A SIGNIFICANT ACCUMULATION OF ICE OR SLEET IS EXPECTED IN THE WATCH AREA DURING THE NEXT 24 TO 48 HOURS. RESIDENTS IN THE WATCH AREA SHOULD PREPARE NOW FOR WINTER STORM CONDITIONS. MAKE SURE YOUR CAR IS WINTERIZED AND IN GOOD WORKING ORDER. ALSO MAKE SURE YOU HAVE AN ADEQUATE SUPPLY OF FOOD...WATER AND THE NECESSARY MEDICATION TO LAST THROUGH THE DURATION OF THE WINTER STORM."

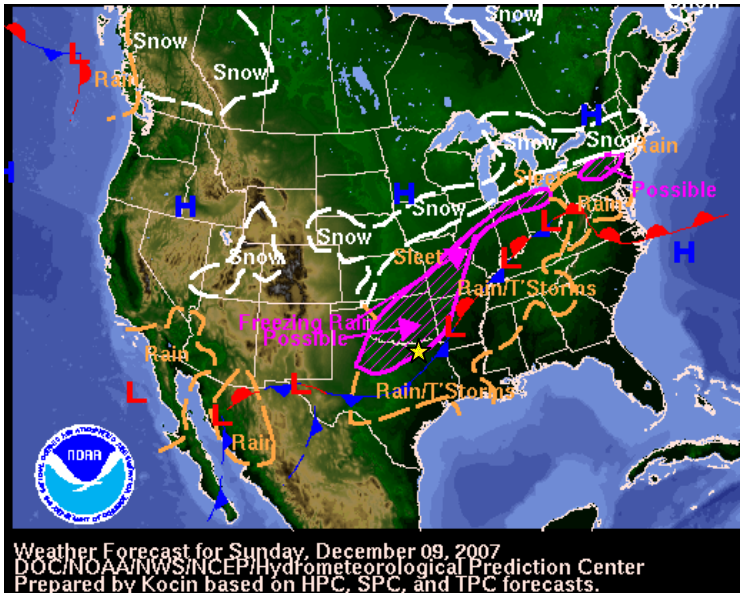
Please do not proceed to the next page until instructed to do so.

Surface Maps



(Source: WPC, 2007)

The above image displays a surface map forecast for Saturday, December 8, 2007.



(Source: WPC, 2007)

The above image displays a surface map forecast for Sunday, December 9, 2007.

Please do not proceed to the next page until instructed to do so.

Saturday, Ice Storm Warning

At 02:19 PM on Saturday (Day 5), the National Weather Service issued the following Ice Storm Warning:

"...ICE STORM WARNING IN EFFECT UNTIL 6 PM CST SUNDAY...
...WINTER STORM WATCH REMAINS IN EFFECT FROM SUNDAY EVENING THROUGH LATE MONDAY NIGHT...

THE NATIONAL WEATHER SERVICE HAS ISSUED AN ICE STORM WARNING...WHICH IS IN EFFECT UNTIL 6 PM CST SUNDAY FOR YOUR COUNTY

NUMEROUS SHOWERS AND ISOLATED THUNDERSTORMS HAVE DEVELOPED ALONG AND NORTH OF THE AREA THIS EVENING... AND THIS AREA OF PRECIPITATION EXTENDS SOUTHWESTWARD OF THE AREA. TEMPERATURES HAVE CONTINUED TO FALL WITH THE FREEZING LINE MAKING STEADY PROGRESS SOUTHWARD... AND AS THIS OCCURS...FREEZING RAIN HAS DEVELOPED ACROSS PORTIONS OF THE REGION.

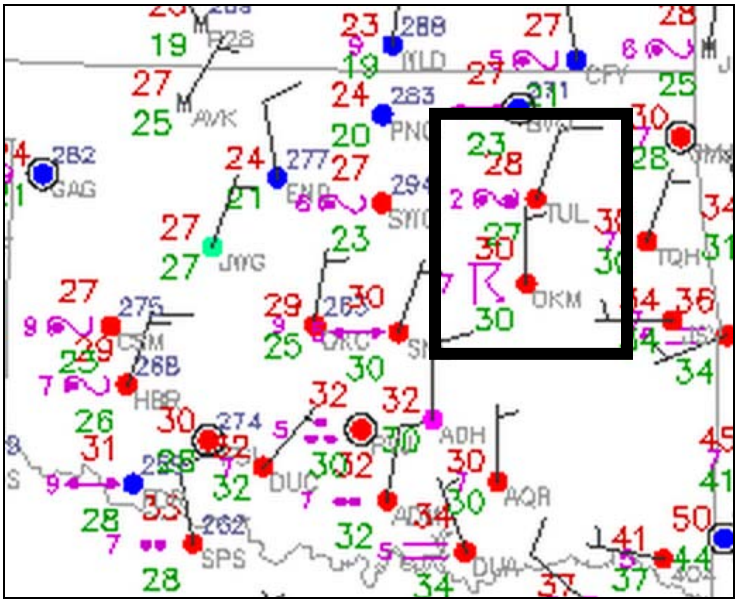
ICE ACCUMULATION TOTALS WILL LIKELY VARY WIDELY...HOWEVER ACCUMULATIONS UP TO ONE HALF INCH WILL BE POSSIBLE ON ELEVATED SURFACES. AS TEMPERATURES CONTINUE TO COOL THROUGH SUNDAY MORNING...ROADWAYS WILL BECOME INCREASINGLY LIKELY TO MAINTAIN AN ICE COATING. UTILITY OPERATIONS ARE EXPECTED TO BECOME INCREASINGLY STRESSED AS ICE LOADS ON POWER LINES.

A WINTER STORM WATCH REMAINS IN EFFECT FOR ADDITIONAL ICE POTENTIAL ON MONDAY. AN ICE STORM WARNING MEANS SEVERE WINTER WEATHER CONDITIONS ARE EXPECTED OR OCCURRING. SIGNIFICANT AMOUNTS OF ICE ACCUMULATIONS WILL MAKE TRAVEL DANGEROUS OR IMPOSSIBLE. TRAVEL IS STRONGLY DISCOURAGED.

A WINTER STORM WATCH MEANS HEAVY SNOW OR A SIGNIFICANT ACCUMULATION OF ICE OR SLEET IS EXPECTED IN THE WATCH AREA DURING THE NEXT 24 TO 36 HOURS. RESIDENTS IN THE WATCH AREA SHOULD PREPARE NOW FOR WINTER STORM CONDITIONS. MAKE SURE YOUR CAR IS WINTERIZED AND IN GOOD WORKING ORDER. ALSO MAKE SURE YOU HAVE AN ADEQUATE SUPPLY OF FOOD...WATER AND THE NECESSARY MEDICATION TO LAST THROUGH THE DURATION OF THE WINTER STORM."

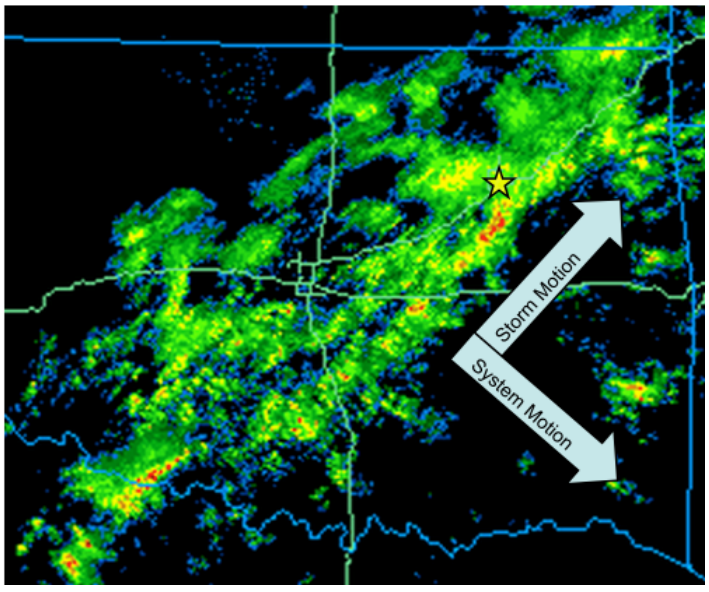
Please do not proceed to the next page until instructed to do so.

Sunday, Ice Storm Warning



(Source: College of DuPage, 2007)

The above image displays ground-based ASOS weather observations at 01:07 AM CST on Sunday, December 9, 2007.



(Source: College of DuPage, 2007)

The above image displays Doppler radar reflectivity at 01:21 AM on Sunday, December 9, 2007. Take note of the high reflectivity found south of Tulsa.

Please do not proceed to the next page until instructed to do so.

Sunday, Ice Storm Warning Update

At 03:30 PM on Sunday (Day 6), the National Weather Service issued the following Ice Storm Warning:

"...ICE STORM WARNING NOW IN EFFECT UNTIL 12 PM CST MONDAY...

...WINTER STORM WATCH NOW IN EFFECT FROM MONDAY AFTERNOON THROUGH LATE MONDAY NIGHT...

THE ICE STORM WARNING IS NOW IN EFFECT UNTIL 12 PM CST MONDAY FOR THE FOLLOWING COUNTIES...

IN ARKANSAS...BENTON.

IN OKLAHOMA... OSAGE...WASHINGTON...NOWATA...CRAIG...OTTAWA...PAWNEE... TULSA...ROGERS...MAYES...DELAWARE...CREEK...OKFUSKEE... OKMULGEE...WAGONER...CHEROKEE...MUSKOGEE...MCINTOSH.

A LARGE BAND OF FREEZING RAIN WITH EMBEDDED THUNDERSTORMS EXTENDED FROM NORTHEAST OKLAHOMA INTO WESTERN NORTH TEXAS THIS AFTERNOON. THIS ACTIVITY WILL CONTINUE TO SPREAD NORTHEAST THROUGH THE OVERNIGHT HOURS. TEMPERATURES ACROSS THE WARNING

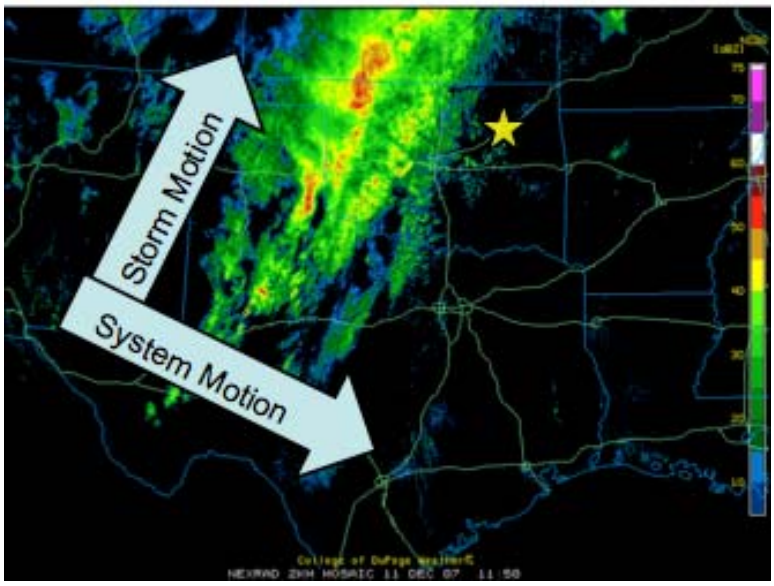
AREA WILL REMAIN BELOW FREEZING...WITH SIGNIFICANT ICE ACCUMULATIONS UPWARDS OF A HALF INCH LIKELY. MUCH OF THE ICE ACCUMULATION WILL REMAIN ON ELEVATED SURFACES SUCH AS BRIDGES...OVERPASSES...TREES AND POWER LINES...BUT TRAVEL PROBLEMS MAY DEVELOP OVERNIGHT AS TEMPERATURES CONTINUE TO SLOWLY COOL.

PRECIPITATION IS EXPECTED TO TAPER OFF BY LATE MORNING ON MONDAY.

AN ICE STORM WARNING MEANS SEVERE WINTER WEATHER CONDITIONS ARE EXPECTED OR OCCURRING. SIGNIFICANT AMOUNTS OF ICE ACCUMULATIONS WILL MAKE TRAVEL DANGEROUS OR IMPOSSIBLE. TRAVEL IS STRONGLY DISCOURAGED."

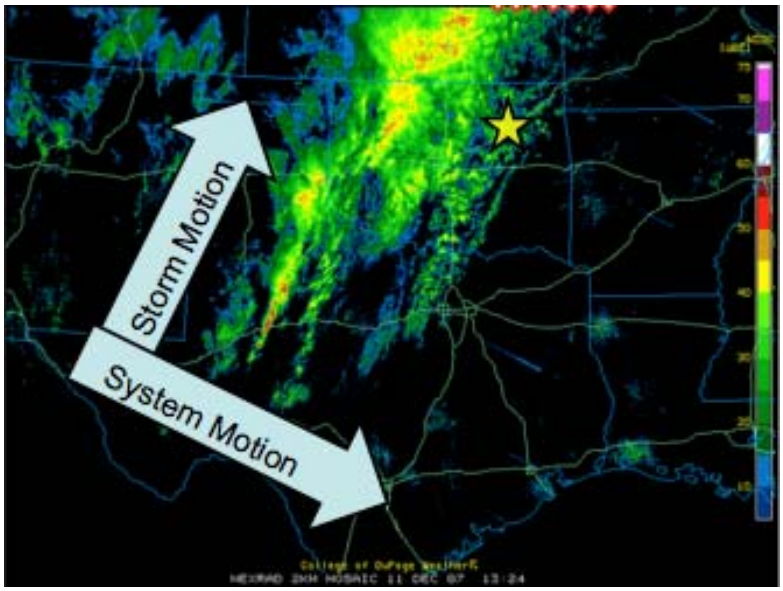
Please do not proceed to the next page until instructed to do so.

Monday, Ice Storm Warning Update Graphic



(Source: College of DuPage, 2007)

The above image displays Doppler radar reflectivity at 06:00 AM on Monday, December 10, 2007.



(Source: College of DuPage, 2007)

The above image displays Doppler radar reflectivity at 07:30 AM on Monday, December 10, 2007.

Please do not proceed to the next page until instructed to do so.

Monday, Ice Storm Warning Update

At 03:30 PM on Monday (Day 7), the National Weather Service issued the following Ice Storm Warning:

"...ICE STORM WARNING NOW IN EFFECT UNTIL 12 PM CST TUESDAY...

THE ICE STORM WARNING IS NOW IN EFFECT UNTIL 12 PM CST TUESDAY FOR THE FOLLOWING COUNTIES...

IN OKLAHOMA... OSAGE...WASHINGTON...NOWATA...CRAIG...OTTAWA...PAWNEE... TULSA...ROGERS...MAYES...CREEK.

TEMPERATURES ARE EXPECTED TO REMAIN WITHIN A FEW DEGREES OF FREEZING DURING THE OVERNIGHT HOURS...WITH LITTLE WARMING EXPECTED DURING THE MORNING HOURS TUESDAY. WIDESPREAD PRECIPITATION IS EXPECTED TO SPREAD INTO EASTERN OKLAHOMA BY THE AFTERNOON...ALONG WITH A SURGE OF COLDER AIR BACK SOUTHWARD. THIS WILL LIKELY PLACE AREAS ALONG AND NORTH OF THE INTERSTATE 44 CORRIDOR NEAR FREEZING...WITH THE POTENTIAL FOR ADDITIONAL ICE ACCUMULATIONS.

THERE REMAINS CONSIDERABLE UNCERTAINTY IN HOW WARM TEMPERATURES WILL BE PRECEDING THE NEXT ROUND OF PRECIPITATION. SHOULD WARMER TEMPERATURES DEVELOP...THEN THE WARNING MAY BE CANCELLED. HOWEVER GIVEN THE ONGOING IMPACTS FROM THE ICING...ANY ADDITIONAL ACCUMULATIONS WILL IMMEDIATELY PROVE PROBLEMATIC.

SIGNIFICANT ICE ACCUMULATION ON TREES AND POWER LINES HAVE CAUSED NUMEROUS POWER OUTAGES ACROSS THE AREA. DO NOT TOUCH DOWNED LINES AND REPORT ANY POWER OUTAGES TO YOUR ELECTRIC COMPANY. TRAVEL IS HIGHLY DISCOURAGED DUE TO THE DOWNED TREES AND POWER LINES...AND SLICK ROADWAYS."