1. Title Slide

Instructor Notes: This presentation will discuss some basics on road weather impacts, the strategies that departments of transportation (or DOTs) use to mitigate these impacts, and provide ideas on how NWS can support them during hazardous weather. This presentation should take approximately 30 minutes. NOTE: Gray speaker notes in italics surrounded by brackets (i.e., [show text]) indicate at what point during the speaker notes specific animations occur.

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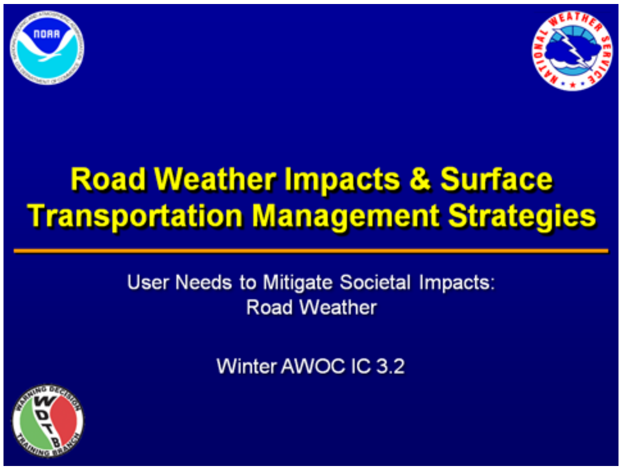

2. Lesson Outline

Instructor Notes: This training is organized in three parts. [show 1st bullet] The first section discusses weather impacts & DOT mitigation strategies. [show 2nd bullet] The second section present information on post-mortem and root cause analysis assignments from previous AWOC Core participants to identify general areas where the NWS might improve during winter weather events. [show 3rd bullet] Lastly, the third part of the discussion will focus on one particular topic related to the DOT community that can be problematic for public safety: high impact, sub-advisory events. [show last bullet] As with the previous lesson, the learning objectives for the complete course are available by clicking on the objectives tab along the top of the module window.

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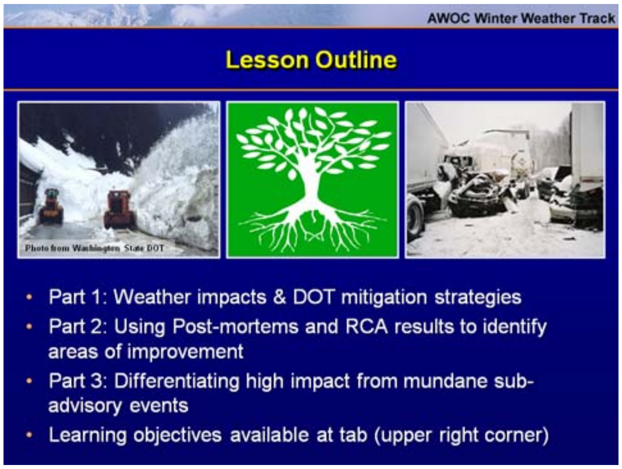

3. Weather is Nature's "Environmental Impact"

Instructor Notes: We all know that weather can cause significant problems for ground transportation. You may have experienced some of the problems coming into work today. However, this section of the course will look at adverse weather from a DOT's perspective. [show 1st bullet] DOTs look at weather as nature's environmental impact on roads. They implement various strategies to mitigate these impacts by focusing on the road system, not necessarily the weather. [show 2nd bullet] While DOTs may use new, automated technology to help them, the decision of what actions to take are still (by and large) made by people. [show 3rd bullet] DOT decision makers need good weather forecasts and observations if they are going to make good decisions. The better the information the NWS provides, the better that DOTs can do their jobs.

Student Notes:

4. Weather Impact Categories

Instructor Notes: From a DOT's point of view, all adverse weather impacts can be categorized four ways (Pisano and Goodwin, 2004). These impact categories are: [show upper left item] Reduced pavement friction (due to wet, snowy/slushy, or icy pavement), [show upper right item] Lowered visibilities (due to fog, smoke, or heavy precipitation), [show lower left item] Obstructed lanes (due to significant snow accumulations, water infiltration of the road surface, or even debris on the road due to strong winds/tornadoes), and [show lower right item] Damaged road infrastructure (potholes, washed out roads, or road restrictions due to freeze/refreeze conditions). The first three categories can be addressed during the event using various techniques. Infrastructure damage usually requires maintenance that can take days or months to complete.

Student Notes:

5. Reduced Capacity or Volume

Instructor Notes: Adverse weather impacts roadway operations by reducing the quality level from optimal efficiency. Reductions in capacity (or traffic volume) is one way this happens. Reductions in capacity can be direct or indirect. Direct causes result from the condition of the road environment, such as slippery roads causing traffic to slowdown. Indirect causes result from other factors such as any of the following: [show 1st bullet] - people changing travel plans (i.e., leaving earlier or later for a vacation), [show 2nd bullet] – travelers eliminating discretionary trips all together, [show 3rd bullet] - schools and businesses closing for the day, [show 4th bullet] - commuters leaving early (or late) for work to avoid "rush hour" congestion, and [show 5th bullet] - more commuters utilizing public transportation. [text box fades in] Even with these factors occurring, reductions in roadway capacity due to adverse weather will generally result in some congestion. Congestion due to adverse weather is most significant during the weekday morning and afternoon rush hour traffic times.

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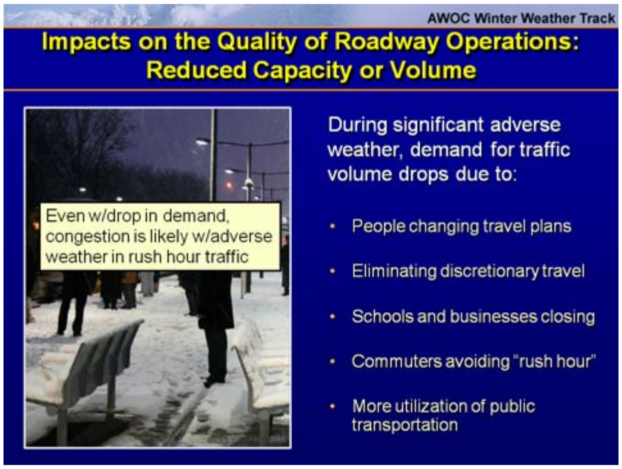

6. Lower Average & Free Flow Traffic Speeds

Instructor Notes: A second impact of adverse weather is a reduction in traffic speeds. Speed reductions can be apparent in both free flow and high volume conditions. These speed reductions can be significant both on freeways and primary traffic arteries when: [show left image/text] - heavy precipitation, especially snow and ice, makes roads slick and hazardous and [show right image/text] - when visibilities drop below 1/4 mile. As a result of the lower speeds, traffic is delayed. The increase in travel time (excluding additional delays from accidents) can be up to 50% in extreme cases (Stern et al., 2003).

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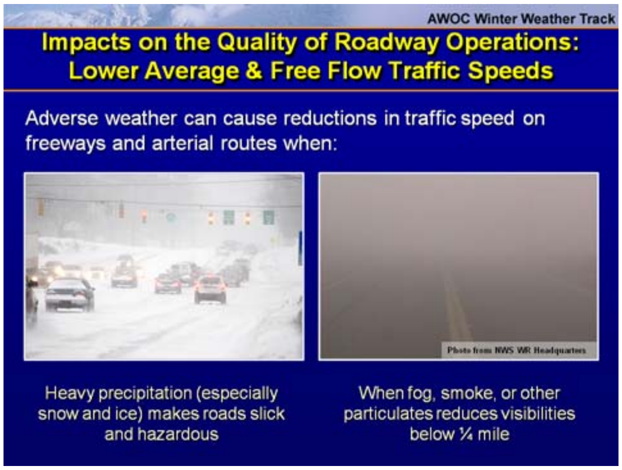

7. Changes in Driver Behavior

Instructor Notes: A third way that adverse weather impacts roadway quality is changes in driver behavior (Sterzin, 2004). In general, adverse weather will result in drivers: [show 1st sub bullet] increasing space between them and vehicle in front of them, [show 2nd sub bullet] decreasing desired speed, [show 3rd sub bullet] increasing gaps between nearby vehicles when changing lanes, and [show 4th sub bullet] avoiding sudden speed changes. [show last bullet] Drivers do not change their behavior uniformly. Some drivers are more cautious than others. As a result, as drivers begin changing their behavior, an increase in driver speed variance will occur. As driver speed variance increases, the accident rate also generally increases (Pisano and Goodwin, 2004). At least one small study by the Federal Highway Administration (FHWA, 2006) suggests that drivers in snowier climates are more likely to slow down voluntarily during adverse winter weather than drivers in warmer climates.

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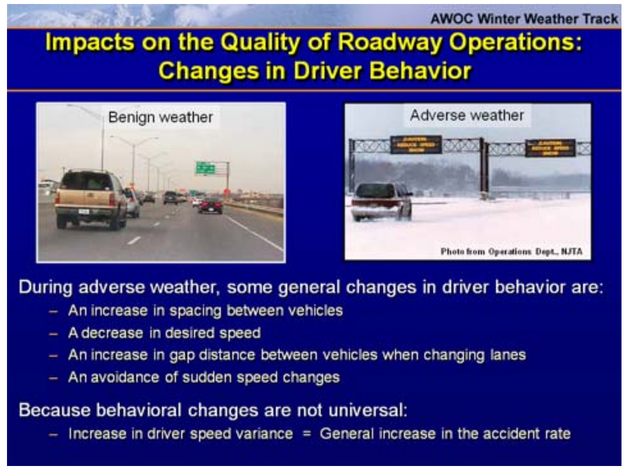

8. Mitigation Techniques & Their Goals

Instructor Notes: DOTs implement mitigation techniques to alleviate the pressure that adverse weather & its impact put on the road network. The ultimate goal of these mitigation techniques is to: [show 1st image] Improve traffic mobility by increasing capacity and making traffic flow more uniform, [show 2nd image] Increase public safety by reducing the number of accidents that occur, and [show 3rd image] Make road maintenance operations safer and more productive. These mitigation techniques, also known as management strategies, are often bundled together to create a comprehensive plan of attack that varies from event to event (FHWA, 2008).

Student Notes:

9. Techniques & Categories

Instructor Notes: All of the management strategies implemented by DOTs can be grouped into one of three categories. These categories are (FHWA, 2008): [show 1st image] Advisory management strategies, [show 2nd image] Control management strategies, and [show 3rd image] Treatment management strategies. [show 1st bullet] The specific management strategies that are implemented will vary from place to place depending on an area's specific needs. [show 2nd bullet] The more common strategies are the ones that have been around the longest. An example would be plowing, which was first implemented approximately 150 years ago. [show 3rd bullet] The less common strategies usually involve newer technology, but are rapidly being implemented throughout the U.S. as they prove their usefulness.

Student Notes:

10. Strategy Categories Based on Goals

Instructor Notes: When considering what mitigation activities belong in which category, the primary determinant is the goal of the strategy. [show 1st image] Advisory strategies try to influence drivers & the general public in their decision-making process. [show 2nd image] Control strategies work by restricting access to roads by reducing speeds, changing the number of lanes, or completely closing a road in order keep drivers safe. [show 3rd image] Treatment strategies apply resources to the road environment to improve overall driving conditions.

Student Notes:

11. Strategic vs. Tactical Timeframes

Instructor Notes: For DOTs to implement management strategies effectively, they need weather information both during the strategic and tactical phases of their operations. [show 1st bullet, left] Good weather forecasts are most relevant during the 24-48 hours prior to a hazardous weather event (FHWA, 2008), which is also known as the strategic timeframe. [show 2nd bullet, left] It's during this time that local DOT managers determine the specific management strategies they will implement, insure they have all of the equipment they need, and begin changing schedules to ensure appropriate staffing for the event. [show 1st bullet, right] During and just prior to the event (~0-3 hours) is the tactical time frame. [show 2nd bullet, right] At this point, DOT managers are sending out crews to specific locations and implementing specific advisory and control strategies to mitigate the adverse weather impacts. [show 3rd bullet, right] Whether or not the previous forecast was accurate, weather observations are in great demand during the tactical time frame. Even when unexpected adverse weather occurs, maintenance garages can usually get some crews out in 1-2 hours (Patterson, 2008).

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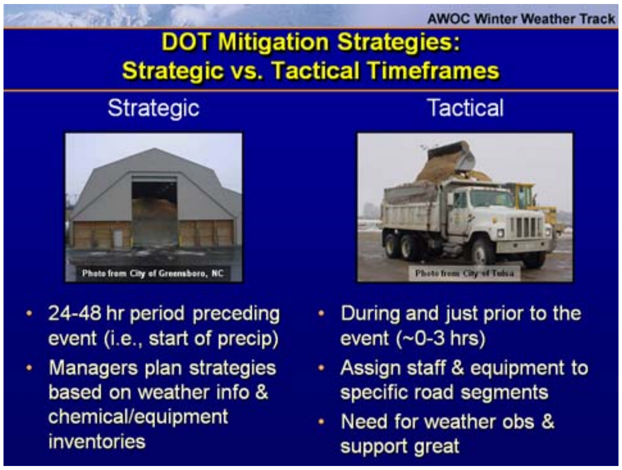

12. Quiz Question #1

Instructor Notes: Please take a few moments to answer the question shown.

Student Notes:

13. Current Support of DOTs: Event Dependent

Instructor Notes: Now that we have explained road weather events briefly from the DOT point of view, let’s look at NWS support of their operations during winter weather. To frame this part of our conversation, it helps to differentiate these events by perceived severity. [show image & bullets on left] On one end of the spectrum, there are warning-criteria events. These events are generally well forecast, with details often available to DOTs for their strategic planning purposes. From the DOT perspective, clarifying event details in NWS products & services would be most helpful. [show image & bullets on right] At the other end of the spectrum are sub-advisory events. These events, anything from a significant dusting up to 3-4”, occur much more frequently. Impacts from these events range from minimal to severe, depending on the situation. Significant impacts are more likely in areas where winter weather is less common. However, areas that regularly experience winter weather can still experience major traffic accidents during sub-advisory precipitation because the public often ignores these so-called “minor” weather events.

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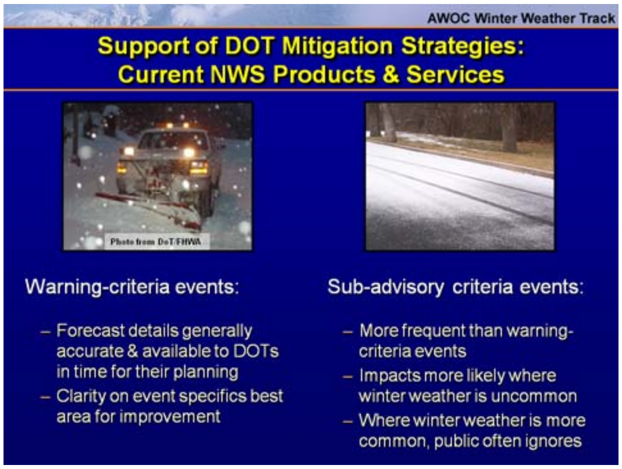

14. RCA & Post-Mortems: Warning Criteria Events

Instructor Notes: To further identify possible areas of improvement, I've analyzed the post-mortem and root cause analysis (RCA) exercises submitted over the last few years as part of AWOC Core. Since forecasters tended to submit examples from events that fell a little short in some area, these exercises can be beneficial for common areas of need. As you can see from this RCA-like flowchart, the most common problems cited during winter weather events were: Having appropriate staffing Poor forecasts Interoffice consistency A lack of quality observations Specific examples of forecast and observation issues are also provided. [show text box] Many of these topics are addressed in some form or another in other areas of AWOC Winter & Core. The next lesson in this topic will also look into the observation issue in more detail.

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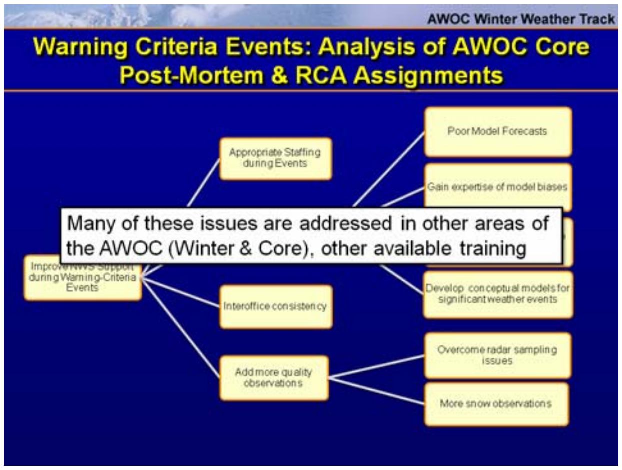

15. RCA & Post-Mortems: Sub-Advisory Events

Instructor Notes: Now let's look at some of the submissions for sub-advisory events. As might be expected, there were less submissions that fit this category than for the warning-criteria winter events. However, some of the issues cited were similar. For instance, having appropriate staffing on hand and problematic forecasts were mentioned for these events as well as for bigger events. Differences immerged in other areas. There was more of a focus on surface temperatures (both forecasts and observations) and being prepared for climatologically rare events. The role of road surface temperatures (RSTs) and air mass changes will be covered I more detail later in this lesson.

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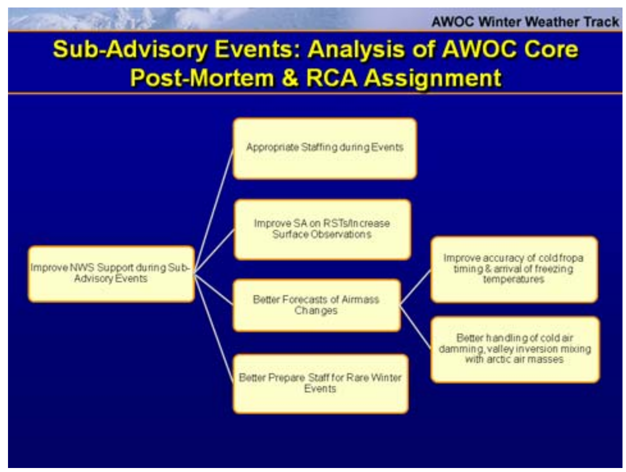

16. Warning-Criteria Vs. Sub-Advisory Events

Instructor Notes: [show 1st bullet] Warning-criteria and sub-advisory events differ in other ways, as well. Warning-criteria event details are often easier to forecast, with lead times of several days possible. [show 1st sub-bullet] Hazardous conditions during sub-advisory events, as a result, often occur with shorter lead times. [show 2nd sub-bullet] Significant sub-advisory events have a greater impact on DOT strategic planning because the details may not be well known until they are in the tactical time frame. [show 2nd bullet] Event severity is also judged differently between the two. [show 1st sub-bullet] Warning-criteria winter events are generally thought of as more severe as accumulation and precipitation rates increase. [show 2nd sub-bullet] Sub-advisory event severity, on the other hand, is more closely tied to road surface temperatures (RSTs) and visibility. Further complicating issues for sub-advisory events is that problematic conditions are often isolated and adequate observations may not be available.

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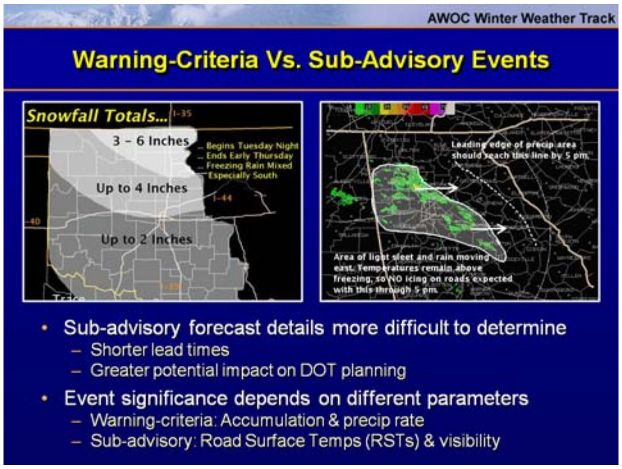

17. Quiz Question #2

Instructor Notes: Please take a few moments to complete the question shown.

Student Notes:

18. Significant vs. Mundane Sub-Advisory Events

Instructor Notes: Based on the previous discussion, and that many of the problem areas are already covered by other training, the remainder of this lesson will focus on issues with sub-advisory events. The primary problem with these so-called "minor" events is simply how do you tell a mundane one from a significant one? [show 1st bullet] As mentioned earlier, visibility and RSTs are the two most important parameters for determining sub-advisory event significance. Getting more data, especially in areas prone to problems, on these parameters will help NWS forecasters better support DOTs. For instance, RSTs are critical when temperatures cross freezing in the presence of water and/or ice on the road surface. Likewise, visibilities at or below ¼ mile result in the greatest impacts to the road environment. [show 2nd bullet] Before we move on, it's important to remember NWS policy on DOT support. NWS forecasters cannot provide specific RST forecasts to DOTs. However, NWS forecasters can indicate when significant weather will threaten travelers.

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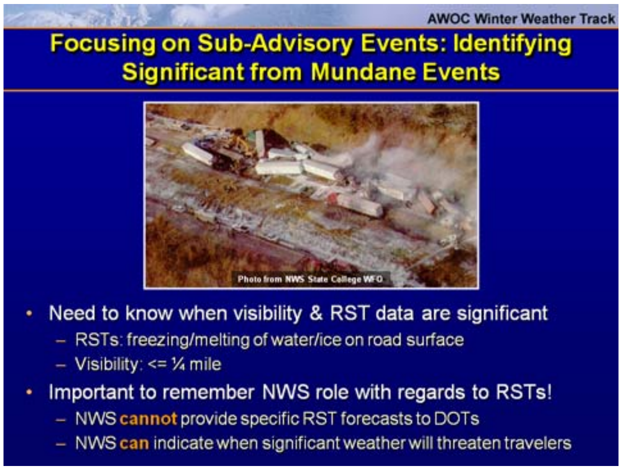

19. Sub-Advisory Event Example: 3/16/08

Instructor Notes: Here is an example of a sub-advisory, chain-reaction crash along I-40 near Flagstaff, AZ. [cue for accident site] This accident involved more than 100 vehicles and resulted in a 19 mile stretch of the highway being closed for 17 hours. Low visibilities, some icing of the road surfaces, and some sharp turns with drops in grade of 3-4% all were contributing factors to the crash. The accident resulted in two fatalities and 53 injuries. The reflectivity data from this case is not especially intense, even for winter precipitation. [cue FGZ airport] However, moderate snow and visibilities around ¼ to ½ mile were observed at the Flagstaff airport around the time of the crash. Several NOWs were issued in the hours prior to the accident, which occurred between noon and 1 pm on a Sunday. This time isn't considered a peak travel period, but the impacts to the road environment were still severe.

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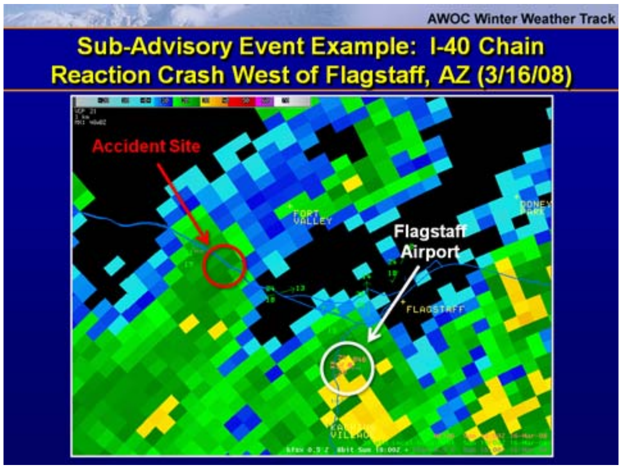

20. What Key Parameters Affect RSTs?

Instructor Notes: So let's take a moment to discuss these parameters in a little more detail, starting with RSTs. [show 1st bullet] RSTs are strongly influenced by boundary layer processes. [show 2nd bullet] Without getting into the gory details of the surface energy balance equation (National Research Council, 2003), the most important parameters are: [show 1st sub-bullet] Absorption of insolation; [show 2nd sub-bullet] Heat flux between the road, air, and soil; [show 3rd sub-bullet] Latent heat; and [show 4th sub-bullet] Anthropogenic effects. [show 3rd bullet] Other topics relevant to RSTs include: [show 1st sub-bullet] Diurnal cycle; [show 2nd sub-bullet] Road classification & construction materials; and [show 3rd sub-bullet] Significant frost formation. The next few slides will review some of these topics, including specific examples, and how they may factor into your decision-making process.

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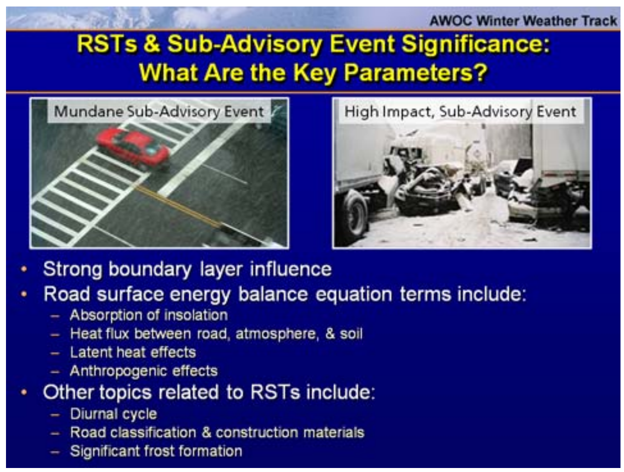
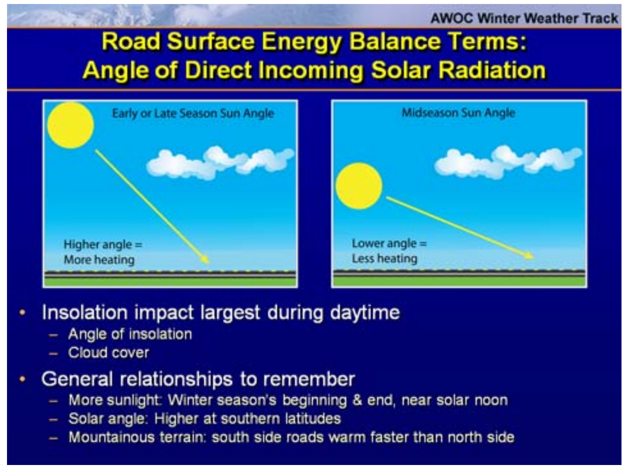


21. Angle of Direct Incoming Solar Radiation

Instructor Notes: [show 1st bullet] RSTs are impacted most directly by the absorption of insolation during the daytime. On a sunny day, the road surface warms much more quickly than the surrounding surfaces and air parcels (NRC, 2003). The two factors that most impact the rate of absorption during the day is the angle of insolation and cloud cover. Observational data on insolation are not as readily available as cloud cover data. [show 2nd bullet] When obs aren't available, consider these relationships to help you ballpark insolation intensity: Insolation will be greater at the beginning & end of the winter season and near solar noon Insolation angle is always higher in the U.S. as you move south during the winter Insolation will warm roads on the south side of a mountain faster than on the north side

Student Notes:



22. RSTs: Insolation & Diurnal Cycle Effects

Instructor Notes: So let's look at an example of how insolation absorption impacts RSTs (Moore and Miller, 2008). This data is from a road weather information system (RWIS) site in the Billings, MT metro area. [sunrise/noon/sunset labels appear] I've labeled sunrise, solar noon, & sunset to make interpretation easier. The data are for two autumn days where: Day 1 (Oct. 29th) is warmer than normal and Day 2 (Oct. 30th) is colder than normal. Except for the period overnight labeled "overcast", both days were sunny with few clouds. [boxes highlighting heating during the day appear] Notice how the RSTs warm up faster than air temperature when exposed to direct sunlight. On both days, the RST data is 5-15 C higher. [boxes with arrows appear] On Day 2, the RSTs even rise above freezing for several hours even though the air temperatures remained near -5 C. While the days were both clear, the overnight periods were different. [Day 1 box & text appear] On Day 1, the RSTs were colder than the air temperatures with clear skies. [Day 2 box & text appear] On Day 2, the RSTs were warmer than the air temps under cloudy skies.

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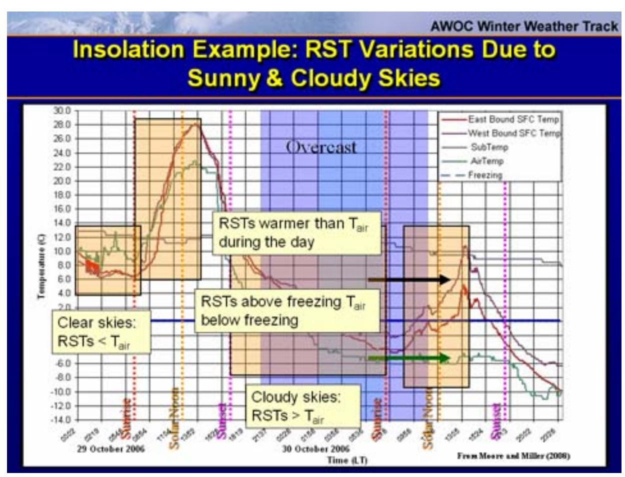
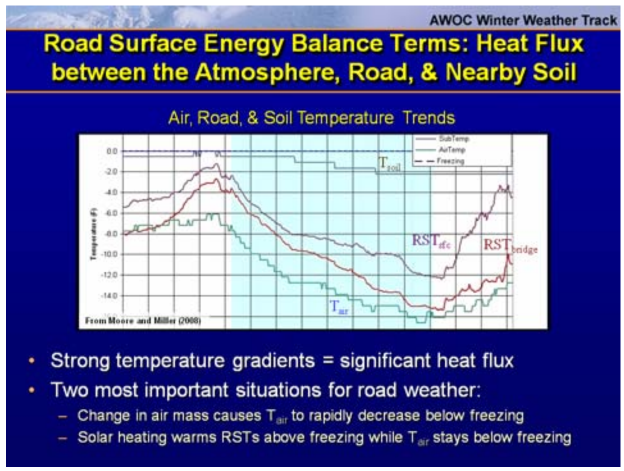


23. Heat Flux between the Air, Road, & Soil

Instructor Notes: [show 1st bullet] Sensible heat flux between the air, ground, and road will influence RST trends significantly when there are strong temperature gradients between one or more of these mediums. In these cases, heat flux works to restore the “road environment” to equilibrium by transferring heat from warm areas to cold areas in the system. [show 2nd bullet] Heat flux is most important to RST values and trends in two situations: [show 1st sub bullet] When there is a rapid decrease in air temperature (due to a change in air mass or significant web bulbing) below freezing and [show 2nd sub bullet] When solar heating warms RSTs above freezing while air temps remain below freezing. These situations result in the temperature gradient between the road and surrounding environment being maximized at near freezing temperatures.

Student Notes:



24. Heat Flux Example

Instructor Notes: Heat flux impacts RSTs most evidently near bridges and elevated roads. This example illustrates the point by showing a time series of road, air, & soil temperatures for a site near Billings, MT. Data from two RST sensors are shown: one located on a ground level road and one in a bridge. [text box appears] A substantial difference in RST is evident between the two sensors. The difference is most pronounced between road and bridge temperatures toward the end of the graph as insolation absorption increases RSTs and the temperature gradient between the air and soil is near a maximum.

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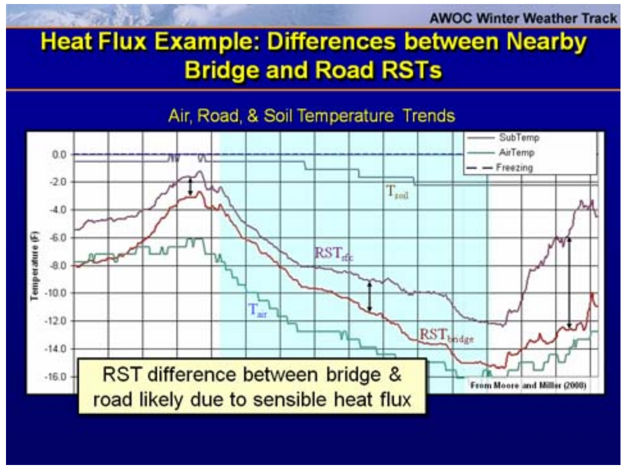

25. Precipitation & Latent Heat Impacts

Instructor Notes: A 3rd physical process that impacts RSTs is latent heat. [show 1st bullet] Precipitation and latent heat effects impact RSTs in important ways that may be overlooked by forecasters. [show 2nd bullet] In general, roads with liquid or frozen water require more energy to change their temperature because of water's higher specific heat. So they warm (and cool) more slowly then when they are dry. [show 3rd bullet] But, where latent heat effects are most significant is when phase changes are possible. If RSTs are relatively close to freezing, and precipitation is occurring, that latent heat effect will be magnified as the RSTs are expected to cross freezing in either direction.

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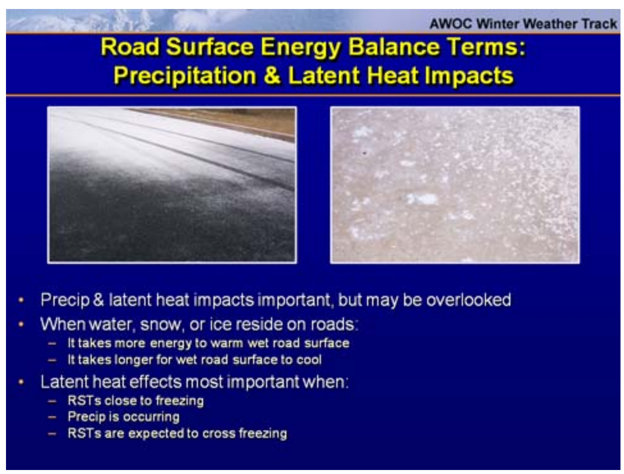

26. Precipitation & Latent Heat Example

Instructor Notes: So let's look at another example (Moore and Miller, 2008), this time for latent heat effects. [temp labels appear] The graphs shows air temperature in green and RSTs in red for a location in Montana. [rain label appears] The green bar at the top of the graph indicate when precipitation fell at the RWIS site. [vertical line appears] Around 2:30 am, freezing rain begins with both air and road temperatures below freezing. [1st arrow appears] By 3:00 am, the latent heat release of freezing the rain has warmed the roads to 32 F while air temperatures have remained constant. [2nd arrow appears] Over the next few hours, air temperatures slowly rise until they warm above freezing at 5:30 am. [3rd arrow appears] While air temps generally remain above freezing from this point forward, the RSTs remain at 32o F until nearly 9:30 am. In other words, it took about four hours for the above freezing air temperatures (and possibly some insolation absorption) to melt the ice on the roads. [text box appears] These four hours coincided with morning rush hour traffic and numerous accidents were reported. Without the RST observations, the length of time where hazardous conditions existed would likely have be underestimated.

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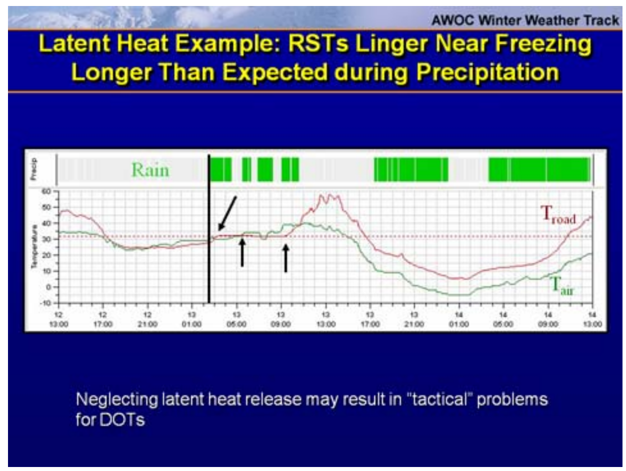

27. Example: A Mundane Sub-Advisory Event

Instructor Notes: Let's look at one more example. This time, we'll show a case where impacts were minimal. This event occurred in mid-October in the Billings, MT area (Moore and Miller, 2008). Precipitation starts as rain on the morning of the 16th and changes over to snow by around 4 pm. Light snow then continues at the RWIS site for about the next 24 hours. Overall, approximately 4" of snow fell throughout the event. [box & text appears] The box on the screen indicates a period of about 12 hours where air temperatures were at or below freezing. However, RSTs generally remained at or above freezing at that time and even warmed rapidly after sunrise. The number of accidents reported during this event were close to the daily average for the month (~5% of the monthly total) and no other significant impacts were reported.

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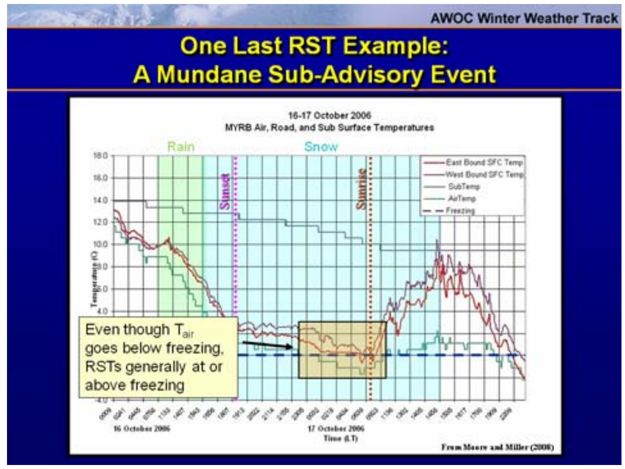

28. Quiz Question #3

Instructor Notes: Please take a few moments to complete the question shown.

Student Notes:

29. Conditions Impacting Visibility

Instructor Notes: Besides the problem of ice bonding to the road surface, the other weather condition that make sub-advisory events significant are low visibilities. [show 1st bullet] The cause of the low visibility can be due to intense winter precipitation or from fog. [show 2nd bullet] Visibility issues tend to be worse at night, but play a very significant role during day time hours since that's when most people are on the road. [show 3rd bullet] These events are most problematic when visibility changes suddenly and drivers have to change their behavior rapidly.

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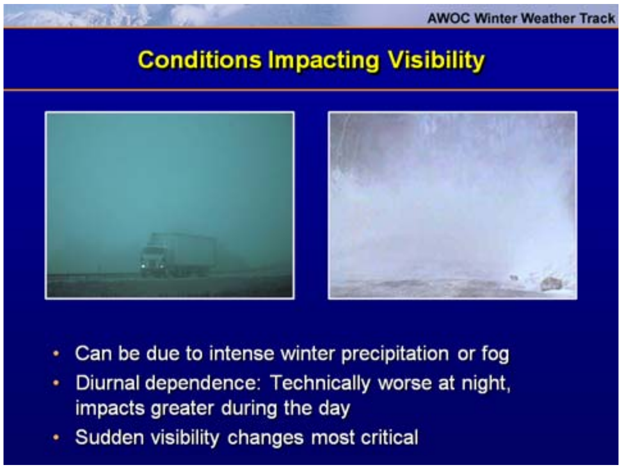

30. Visibility & Driver Behavior Changes

Instructor Notes: [show 1st bullet] Low visibilities impact the road environment primarily because they impact driver behavior. The impacts generally aren't seen until visibility drops below ¾ mile, but become dramatic at or below ¼ mile (Kyte et al., 2001; Alfelor, 2006). [show 2nd bullet] There are two separate behavioral issues at work here. Drivers who enter low visibility road conditions change their behavior at different rates. This causes an increase in speed variance, especially as the conditions are first encountered. The speed differences can be as much as 20-50% (Pisano and Goodwin, 2004). The end result is that the increase in speed difference increase the accident rate (Pisano et al., 2002; Cambridge Systematics, Inc and Mitretek System, Inc., 2003). The second problem is that drivers tend to underestimate their speed in foggy conditions. In fact, they usually start increasing their speed as they acclimate even if the conditions are still unsafe for that speed (Swonden et al., 199). [show 3rd bullet] Both of these problems contribute to a troubling statistic: crashes where low visibility is contributing factor are 3-4 times more likely to result in a fatality than accidents where adverse weather with higher visibilities (FHWA, 2008).

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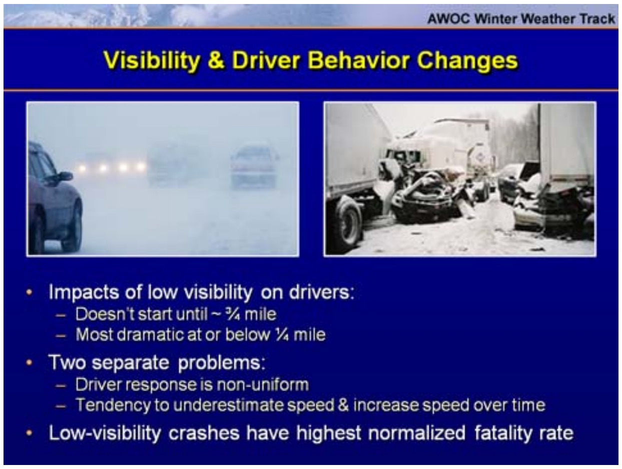
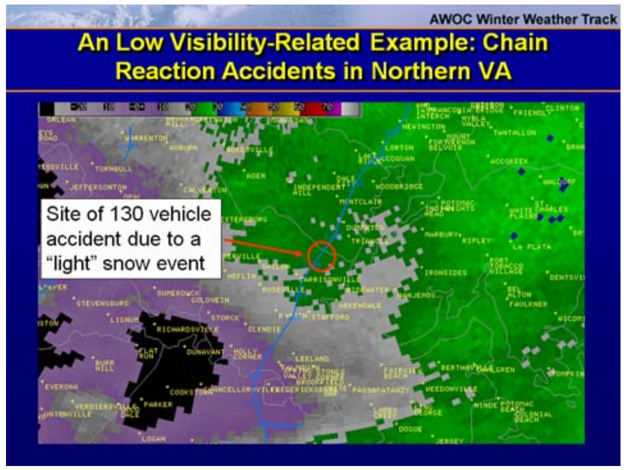


31. A Low Visibility-Related Example

Instructor Notes: This example is from a significant sub-advisory where low visibilities were common. The loop shows a 40-minute period during the short event that produced 2-3" of snow over northern VA. In the highlighted area, there was a multi-vehicle crash between Garrisonville and Dumfries along I-95 involving over 130 vehicles during "white out" conditions. At least 3 other multi-vehicle crashes involving at least 20 vehicles occurred over a two-hour period in the area between Washington D.C. and Richmond, VA.

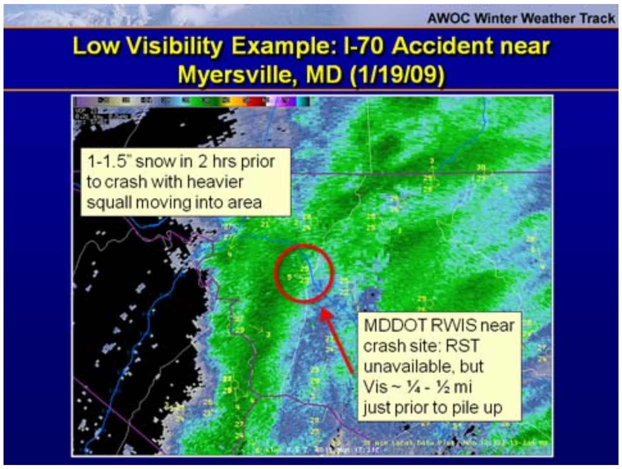
Student Notes:



32. Another Low Visibility Example: 1/19/09

Instructor Notes: Here is another example of a sub-advisory event where low visibilities were a contributing factor in a major pile-up along I-70 near Myersville, MD. [show 1st text box] About 1-1.5" of snow had fallen in the hour or two just prior to the accident. From the reflectivity data, it appears that another heavier squall is just moving into the area as the crash occurred. [show 2nd text box & cue] Surface temperatures are in the mid-20s at the Maryland DOT observation site near the crash. RST data weren't available for this site, but visibility data was consistently the ½-¼ mile prior to and during the time of the accident. The crash, which occurred around 12:30 PM local time, involved approximately 40 vehicles. There were two fatalities and one critical injury, and I-70 was closed for several hours after the event. The local office issued both a Special Weather Statement and Winter Weather Advisory in the 90 minute period leading up to the crash.

Student Notes:



33. Quiz Question #4

Instructor Notes: Please take a few moments to complete the question shown.

Student Notes:

34. In Summary

Instructor Notes: This lesson discussed several weather impacts to DOT operations. [show 1st bullet] DOTs works to mitigate these impacts by applying management strategies to optimize road operations during adverse weather. To support DOTs in your local area, it's important to know their strategic and tactical timeframes for implementing these strategies. [show 2nd bullet] The discussion then turned to how warning-criteria events differ from sub-advisory events. Event severity and the impacts that result differ depending on which type of winter event you are discussing. [show 3rd bullet] Finally the lesson focused more on sub-advisory events and the parameters that best indicate their severity: RSTs crossing freezing in the presence of precipitation and low visibility. Several physical processes that impact RSTs were discussed with examples. The changes in driver behavior that are specifically impacted by lower visibilities were also discussed.

Student Notes: