1. IC7.1: Monitoring Model Accuracy

Instructor Notes: Welcome to Winter AWOC Instructional Component 7, Lesson 1.

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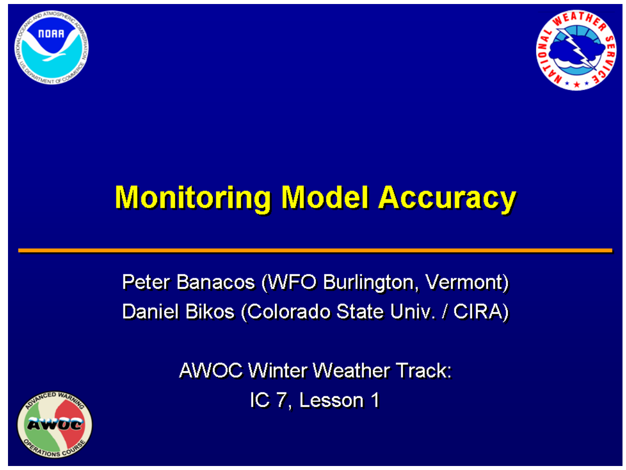

2. Outline

Instructor Notes: In this presentation, we'll discuss the benefits of diagnosis in improving upon model forecasts, especially in the short-range (24 hrs. or less). We'll show case examples of potential problem areas in numerical model forecasts pertinent to winter weather forecasting. Lastly, we'll provide basic guidelines for taking corrective action(s) in the official forecast.

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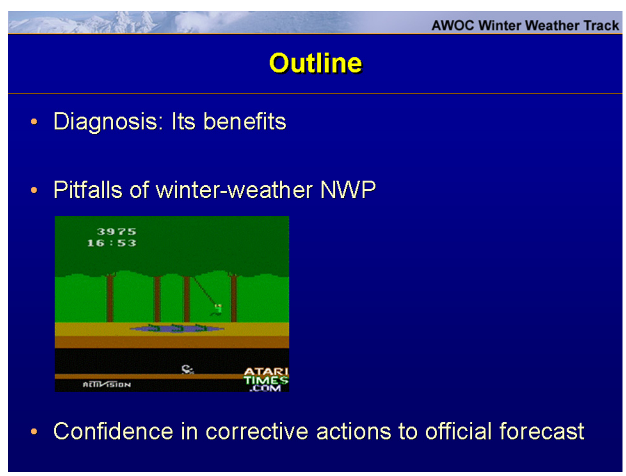

3. Learning Objectives

Instructor Notes: What tangible aspects of the model forecast are often critical to winter weather forecasting? The goal of this talk is to focus on those facets of the models that typically have the most problems, and yield the greatest impact upon sensible winter weather elements (i.e., surface winds, P-type, QPF). A primary objective of this talk is to "survey" these NWP problem areas and provide a framework for recognizing them, especially within the realm of short-term forecasting. Fundamentally, this requires physical understanding of the process(es) involved and application of good diagnostic skills on the forecast desk.

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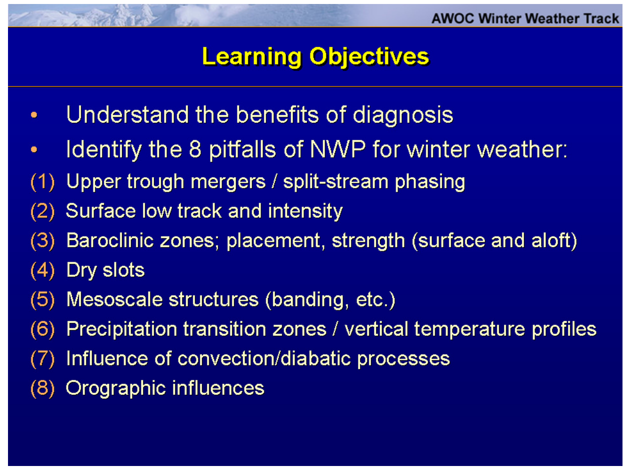

4. Performance Objectives

Instructor Notes: For each of the eight pitfalls of NWP, you will be able to demonstrate: an understanding the impact, how to assess the pitfall, knowing when and what corrective action is needed, understanding how hazards change, and awareness of false indications.

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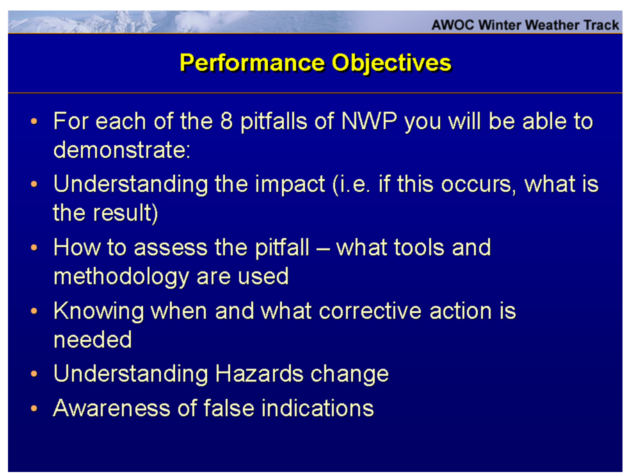

5. NWP Shapes our Expectations

Instructor Notes: Output from numerical models is one of the cornerstones of modern meteorology. Numerical models largely establish our expectations for how an event will unfold. However, models will never be able to represent the atmosphere perfectly, for some of the reasons listed here. It is up to the forecaster to interpret the output and make adjustments/improvements to the guidance where possible. We have the ability to improve upon them if we understand their potential shortcomings (e.g., model physics), properly diagnose observational trends in the short-term, and apply our conceptual understanding of the atmosphere to the various forecast challenges we encounter.

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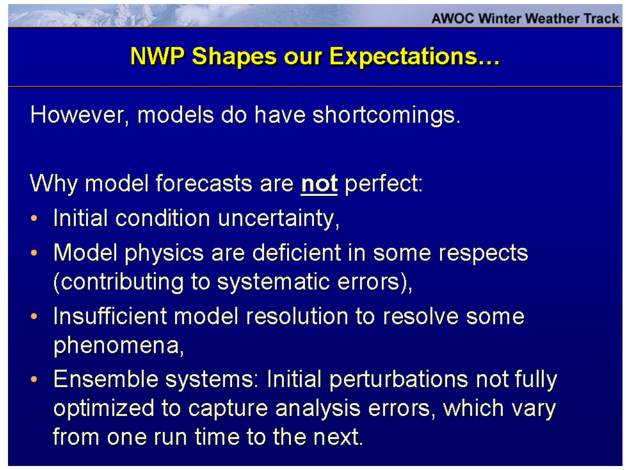

6. Mindset

Instructor Notes: Our ability to improve on "the models", especially for short-term forecasts, depends critically on our diligence and ability in interpreting observational data, in fitting our physical and conceptual understanding to the observational trends, combining that with our understanding of the particular model's physics and biases, and then making adjustments accordingly to produce the best short-term forecast possible. Our mindset at the forecast desk should be one that incorporates all of these areas for winter weather forecasting, as it is for forecasting non-winter weather related events.

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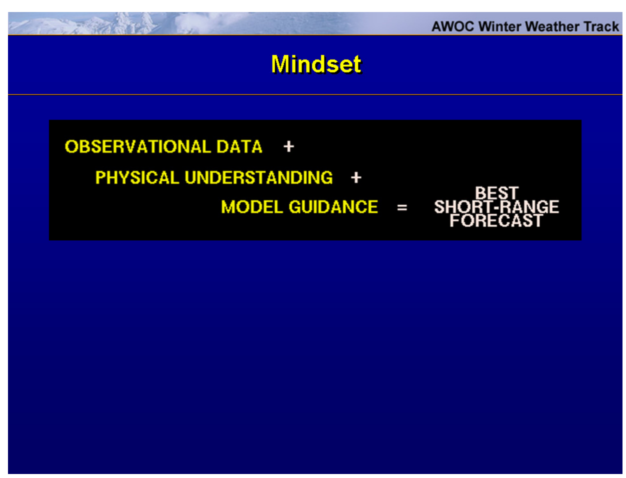

7. Integration of Data for Short-Term Forecasts

Instructor Notes: Potentially useful information comes to the forecaster from many disparate sources. It may be a spotter report in the field, ACARS data, some aspect of imagery interpretation, etc. When we talk specifically about short-term forecasting, the useful information coming into the forecast office often exceeds what can be assimilated objectively by a numerical modeling system. We will often see mesoscale details emerge which are unresolvable by the models, but can be a source of "value added" information provided by the human forecaster. Thus, the forecaster engrossed in doing good diagnostic work can often see trends that are not apparent or included in the model's view of the situation. This situation is particularly true for mesoscale, convective, or boundary layer processes. The key is in the forecaster maintaining a high level of situational awareness through "cross utilization" of information from as many sources as possible, in conjunction with their knowledge of the models (e.g., physics, biases, etc.) and atmospheric processes.

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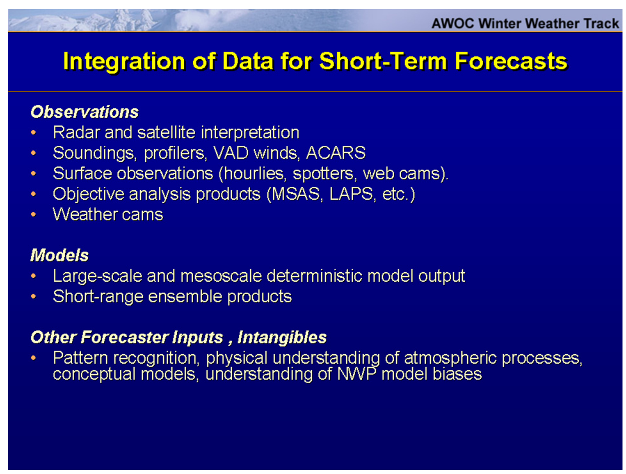

8. Utilization of Observations

Instructor Notes: This quote boils down the importance of gathering meteorological information from disparate sources. The fact that this quote is as relevant now as it was 20+ years ago suggests that humans will be an integral component in the short-term forecast process for many years to come.

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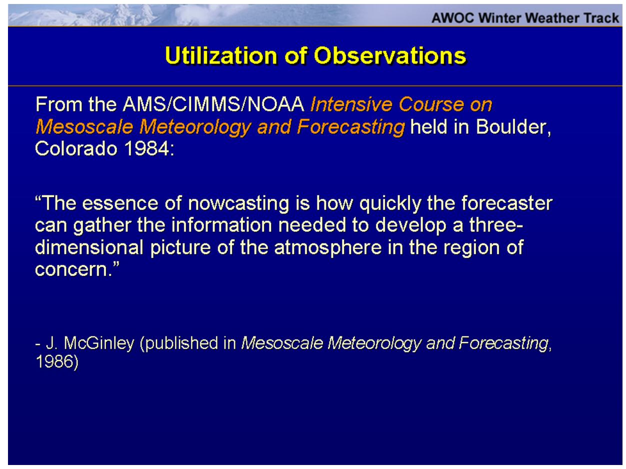

9. Relative Value of Model vs. Observational Data

Instructor Notes: At long time ranges, much of the forecast process involves analysis of various model solutions and interpretation of ensemble products. As we move closer to an "event", however, the value of using observational data increases relative to the models. In the nowcast time range, the observations hold more relative value than the models in terms of providing forecast information to the user community (e.g. "A mesoscale snow band producing 1-2"/hr. snowfall will migrate from line A at 12z, to line B at 15z."). We need to interpret observational trends to maximize mesoscale forecast details. It is critical that forecasters increasingly shift their attention to observational trends as important events approach (less than 24 hrs., especially less than 12 hrs.) to determine the mesoscale details and things the models may not be picking up on. This is one area where the human forecaster can contribute considerable value to the forecast.

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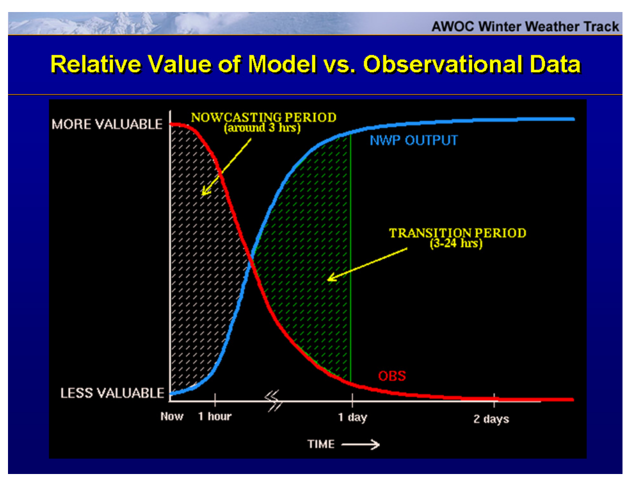

10. Upper Trough Mergers, Phasing

Instructor Notes: We transition now to discuss the 8 pitfalls of winter weather NWP, beginning with synoptic-scale aspects. For the most part, NWP does well with synoptic-scale systems. However, an exception exists for split flow situations in which the amplification of a full latitude feature depends critically on the timing of features merging from two separate branches in the mid-tropospheric flow. In the short-term, one valuable method for assessment is to overlay water vapor (WV) imagery on 500-300mb height and vorticity information from the model of interest, to see how well the model appears to be handling large-scale features evident in WV imagery. Such a comparison may add or decrease confidence in the model solution indicating a potential merger. Such an analysis might then form the basis for the need to modify an existing forecast. Note: Mergers occur within the same branch of jet. (The Colorado Blizzard is such an example, show later under the orographic section). Phasing occurs between branches which are initially split (see example on the next slide).

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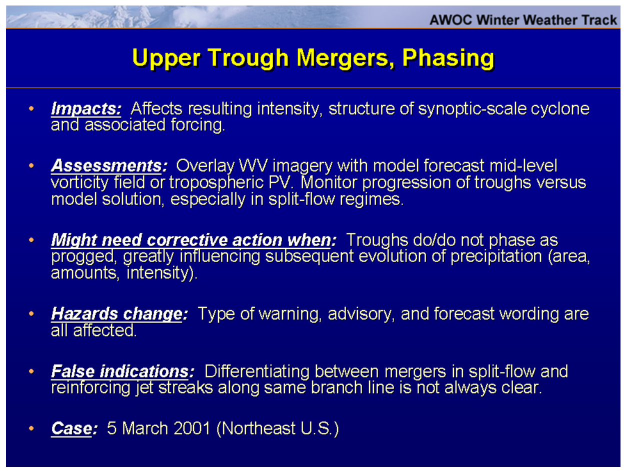

11. Classic Phasing: 22-23 Feb. 1987 500mb Heights/ Vorticity N. American Reanalysis

Instructor Notes: In the North American reanalysis data, we can see an example of classic phasing of two shortwave troughs in the northern and southern streams. In this loop, the troughs phase to produce one continuous filament of 500 mb vorticity extending from the Great Lakes southward to the central Gulf Coast states. Subsequent surface cyclogenesis was quite focused and strong (not shown).

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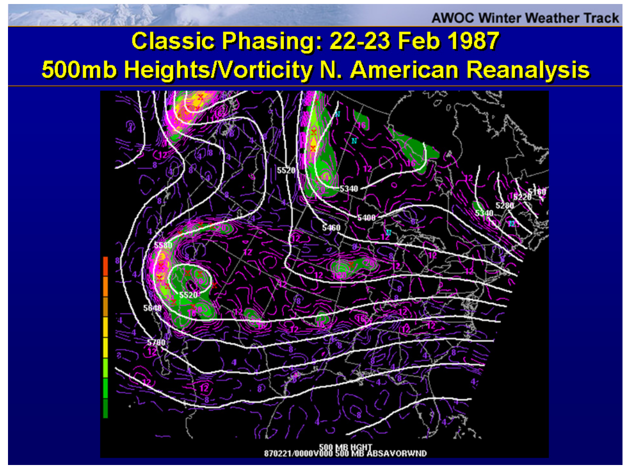

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12. Not Quite In-Phase: 3-6 March 2001 500mb Heights/Vorticity AVN 00Z 3 March Run

Instructor Notes: In a classic “near miss” event, the models had difficulty determining if a closed low over the Great Lakes region would fully phase with a slow moving trough moving into the Southeastern U.S. This particular solution from the AVN (00z/3rd) shows considerable interaction between the two features in question, although phasing is not complete. Such situations should always be viewed with caution, and with a lower degree of forecaster confidence than usual. This situation might imply being somewhat more reserved on forecasting “specifics” (p-type, snow amounts). This is especially true when various model runs show different solutions, and/or if the run-to-run continuity is lacking. Because the timing of the two separate features is so critical to the outcome, the lack of run-to-run continuity is often the case. This uncertainty would also manifest itself in ensemble solutions with large standard deviations in, say, the 500mb height forecasts among the ensemble members (or more visually through the so-called “spaghetti” plots). Ensembles are valuable in determining whether a consensus exists, or if a particular NAM or GFS run happens to be an outlier.

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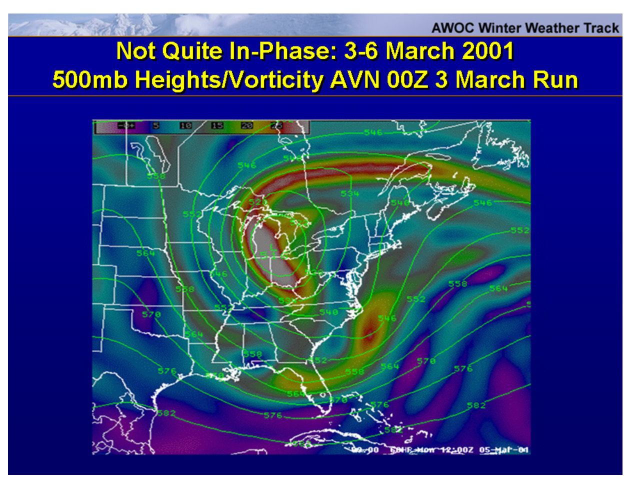

13. Not Quite In-Phase: 3-6 March 2001 WV Imagery

Instructor Notes: The water vapor imagery for the forecast period of interest shows that the two main features remain distinct from one another (i.e., phasing does not occur). In fact, the features are more distinct than was suggested by the 00z 03 March run of the AVN. The lack of phasing resulted in a significant snow event over interior New England and New York, but not for the cities of Boston, New York, or Philadelphia, as was suggested by some model solutions. The main point to remember is to view potential phasing events in split-flow with a lower degree of confidence than you might otherwise. Also, at short time-scales, use WV imagery to see any significant departures in how the features/phasing is progressing relative to a particular model solution. ***Note:*** In the online presentation a quiz question is available under the "Show URL" button for this slide.

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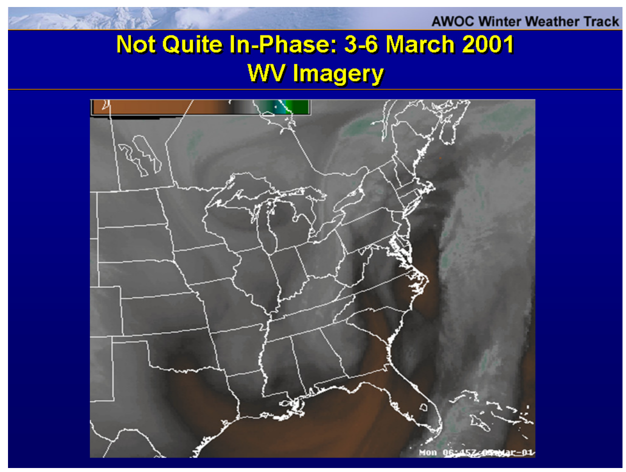

14. Surface Cyclone Intensity

Instructor Notes: Departures in surface cyclone intensity have large implications upon the wind field and amount/distribution of QPF. Comparisons between subjectively or objectively analyzed surface maps for isobars, isallobars, and frontal positions, can often yield valuable information and give a sense of how the models are trending versus reality. Any unexpected "bursts" in cloud top cooling or CG lightning activity (signifying convection) can also act as indications that the models may not be handling the thermodynamic or dynamic structure of the cyclone properly. This should act as a cue for the forecaster to scrutinize as much available information in imagery, (e.g., ACARS) to get a better sense for the underlying processes.

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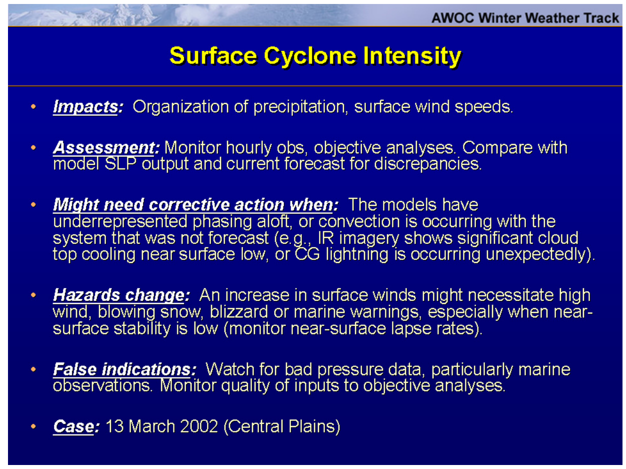

15. Surface Cyclone Intensity13-14 March 2002

Instructor Notes: Here, the Eta is too slow in deepening the surface low over southeast Colorado. By 3z/14th, the observed central pressure (per MSAS) is 5 mb lower than the Eta forecast, and by 09z, we see that the Eta is too quick to eject the low-pressure center eastward away from the immediate lee of the Rockies. This situation results in significant errors in the surface wind and temperature fields late in the forecast period. The baroclinic zone in the ETA is displaced too far south (i.e., low-levels are colder than observed in METARs). Wind directions and magnitudes are also “off” in vicinity of the frontal zone. This demonstrates the importance of keeping up with observational trends to determine if the model forecast might be in error.

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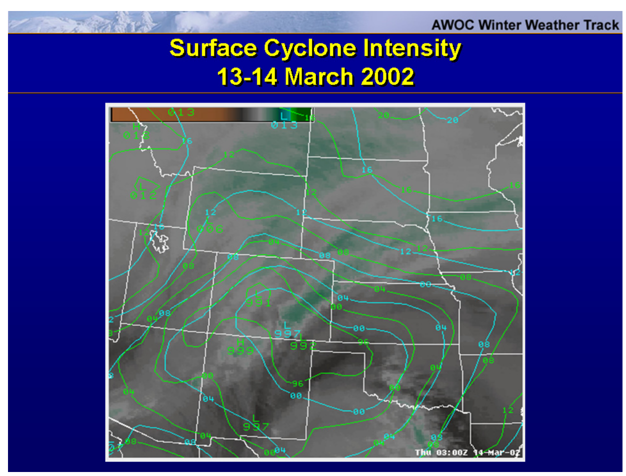

16. Baroclinic Zones

Instructor Notes: The positioning and intensity of low- to midlevel baroclinic zones play an instrumental role in the potential for banded precipitation and in the surface cyclogenesis process. It is of utmost importance, therefore, to ensure that the models are adequately initializing the position and strength of any areas of enhanced midlevel baroclinicity, especially if precipitation is expected. Since the spacing between rawinsondes is relatively large, and because the models rely in part on a first-guess field from the previous run cycle, it is possible for the model to initialize midlevel frontal zones erroneously. Also, the impact of the model convective parameterization scheme can significantly alter the character of the quasi-horizontal temperature field aloft near convection.

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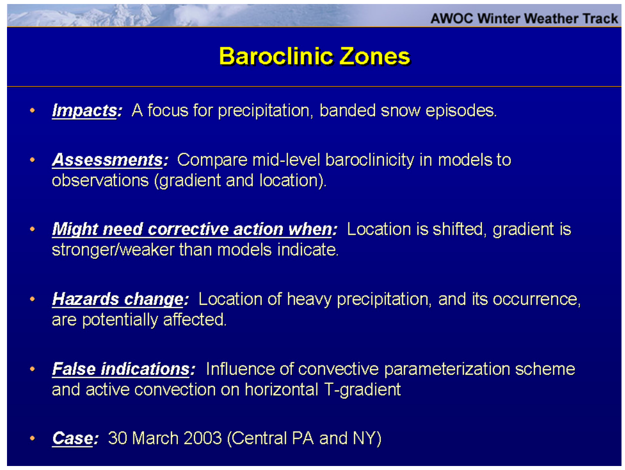

17. Baroclinic Zones (Cont.)

Instructor Notes: Here we see an example where the Eta model analysis (0 hr. forecast) has underrepresented the magnitude of the southeast/northeast oriented baroclinic zone in vicinity of the central Appalachians. Comparing the 700mb analysis to the temperature data from the 12 UTC rawinsondes, we see that Pittsburgh, PA (PIT) has an observed temperature of –15 degrees C instead of about –13 degrees C in the analysis. Also, Dulles International in far northern Virginia (IAD) has an observed temperature of +1 degrees C though the Eta analysis shows about –2 degrees C. This combined with quasi-horizontal convergence at this time suggests that frontogenesis was underdone in the model within the baroclinic zone.

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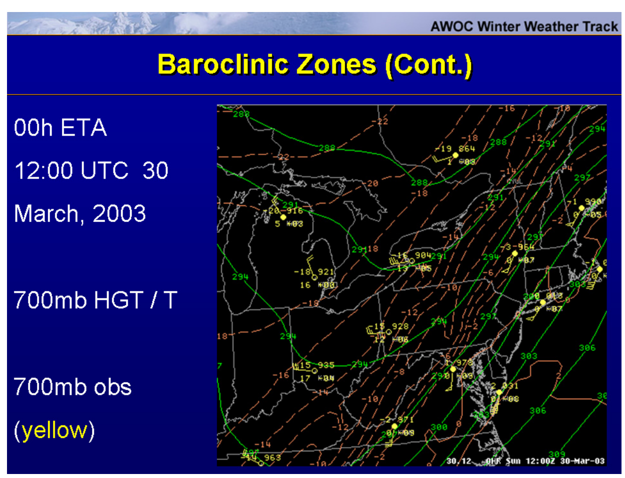

18. Baroclinic Zones (Cont.)

Instructor Notes: The maximum upward vertical motion and QPF is displaced eastward from where it was observed (shown on following slide).

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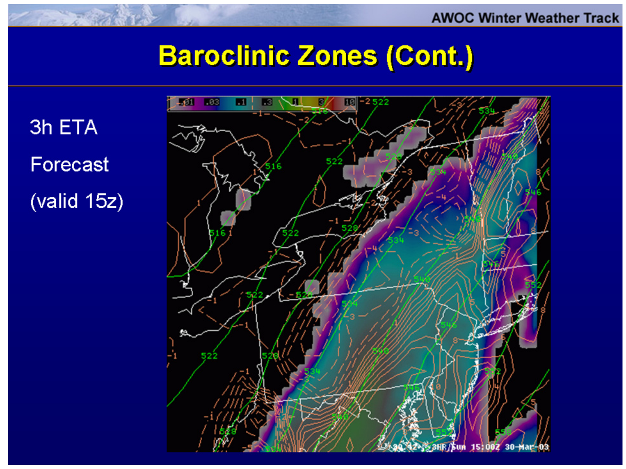

19. Baroclinic Zones (Cont.)

Instructor Notes: The Eta model QPF and UVV fields did not suggest a mesoscale snow band, as was observed in the mosaic radar imagery. The band also appears to be displaced westward from where the Eta suggested the heaviest precipitation would occur. These shortcomings are due, in part, to the inadequate initialization of the mid-level baroclinic zone as shown in the earlier slide. Identification of this type of error can help the forecaster better anticipate mesoscale banding potential not shown when the model is under representing a baroclinic zone. Also, it provides a physical basis (i.e., the resultant frontogenesis was likely stronger than progged) for believing the QPF amount and distribution is not correct in the numerical model.

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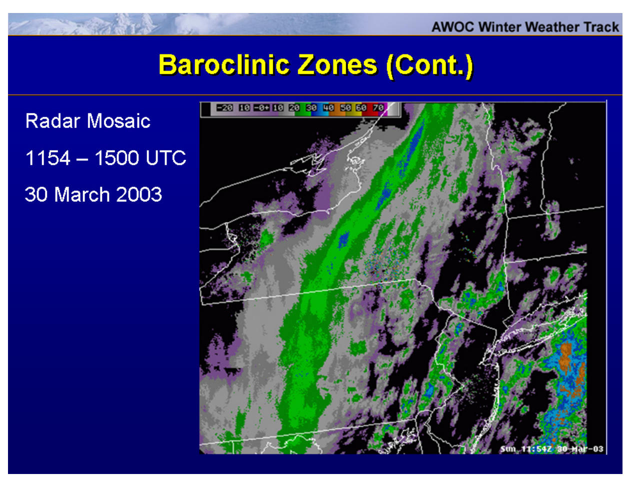

20. Surface Cyclone Track

Instructor Notes: The surface cyclone track is widely recognized as being critical to the outcome of precipitation amounts and precipitation type. For short-term purposes, analysis of satellite imagery and examination of hourly surface analyses remain among the best ways to monitor model accuracy in this regard.

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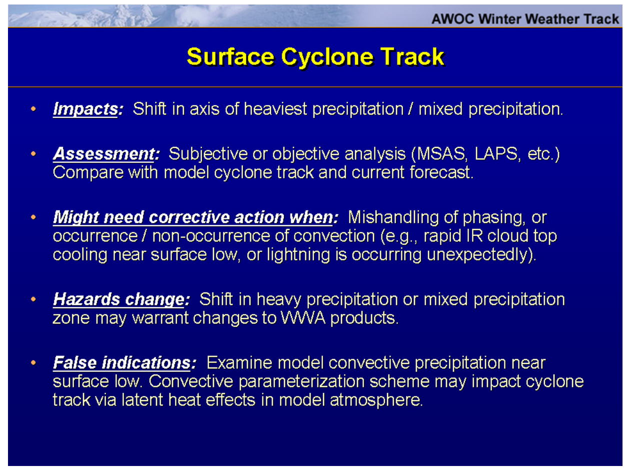

21. Dry Slots

Instructor Notes: The unexpected rapid evolution of a midlevel dry slot associated with a synoptic-scale cyclone, can significantly alter expected winter precipitation duration and intensity. These details are not always handled well by the numerical models, and it is important to analyze observational data (e.g., surface observations, WV imagery) to monitor these trends and take corrective action(s) as appropriate.

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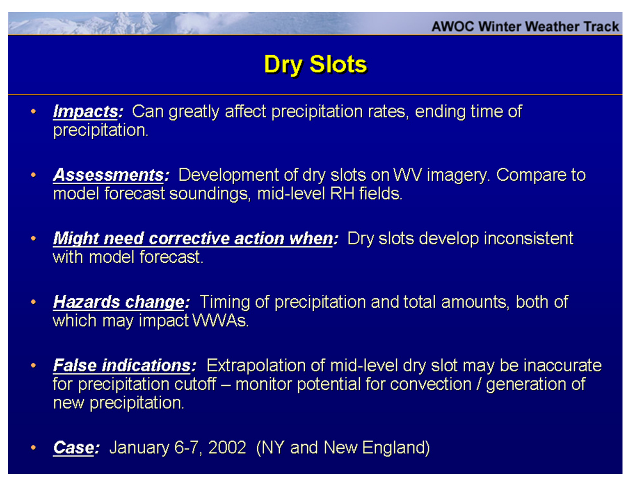

22. Dry Slots (Cont.): 6-7 January 2002

Instructor Notes: Loop of Eta model output, which is used to compare to reality in the next 2 slides.

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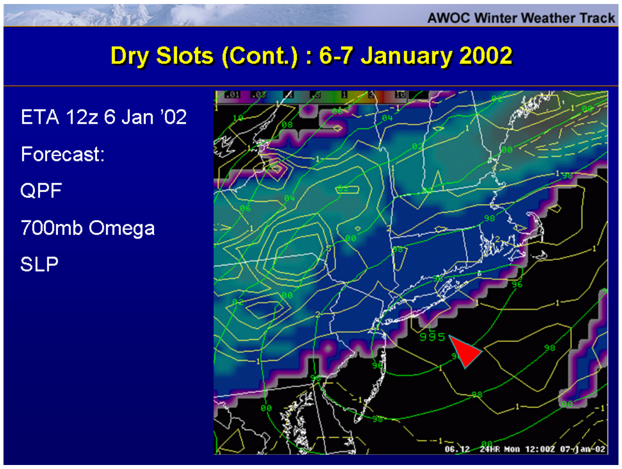

23. Dry Slots (Cont.): 6-7 January 2002

Instructor Notes: Water vapor imagery indicates that the dry slot moves north-north-eastward across southern New England much faster than was suggested in the Eta UVV/QPF fields.

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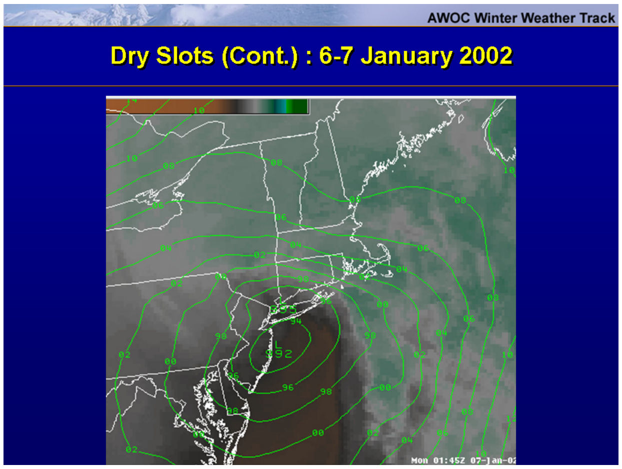

24. Dry Slots (Cont.): 6-7 January 2002

Instructor Notes: This radar mosaic imagery also bares out that the precipitation moves northward through southern New England faster than was suggested by the Eta, with the precipitation ending early due to the dry slot.

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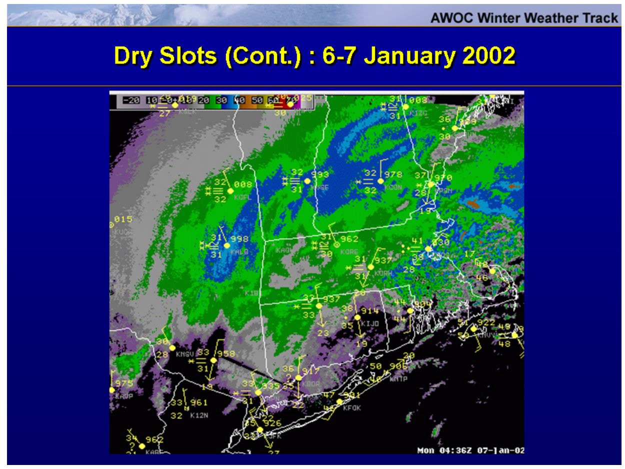

25. Precipitation Transition Zones

Instructor Notes: Precipitation type (P-type) and the spatial placement of P-type transition zones can have a significant impact on the forecast and can be a source of error in the models depending upon how well boundary layer temperatures, temperature advection, and any diabatic effects are being handled. The quality of the initialization of these factors is also crucial to the accuracy of the spatial distribution of various precipitation types in any numerical modeling system. There is no case study included for this type of error.

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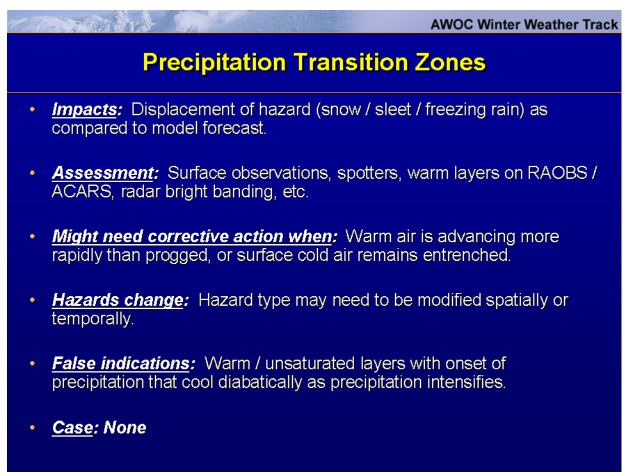

26. Mesoscale Banding

Instructor Notes: Mesoscale snow bands represent a significant winter weather hazard and can be associated with intense snowfall rates well in excess of 1”/hr. The current generation of numerical models is not always able to resolve the spatially narrow vertical motion axis and band of relatively high precipitation amounts associated with mesoscale bands. Mesoscale bands can manifest themselves in several different ways. Axes of quasi-stationary frontogenesis and deformation, or translation of these fields along the long axis of the mesoscale band, will often result in prolonged heavy precipitation in one location and locally heavy snow accumulations. The physics of these bands have been covered in an earlier IC.

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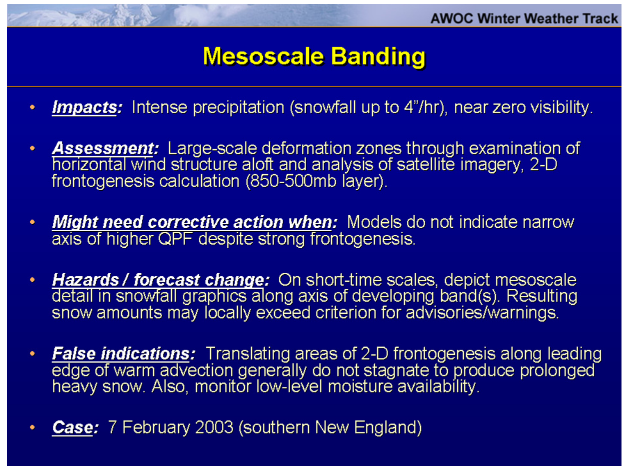

27. Mesoscale Banding (Cont.)

Instructor Notes: For this coastal cyclone case, the RUC upward vertical motion and QPF field suggests that maximum precipitation will occur near or just offshore of the southeastern Massachusetts coast, with precipitation amounts gradually tapering off to the north and west. The model QPF/UVV forecast does not hint at any banded precipitation structure during the forecast. This RUC forecast is also representative of the Eta's handling of the situation.

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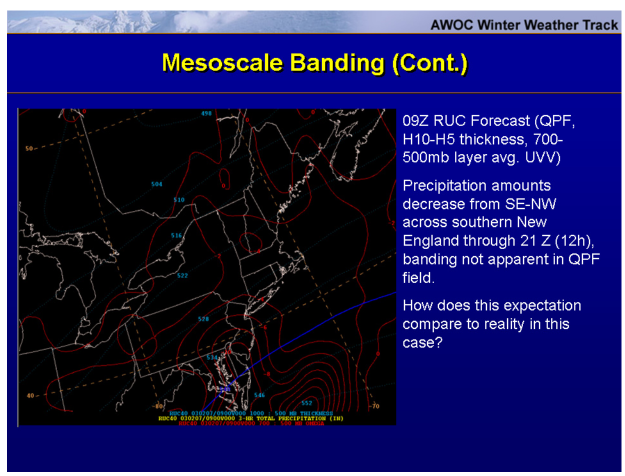

28. Mesoscale Banding (Cont.)

Instructor Notes: The observed radar mosaic loop overlaid with the 700 mb frontogenesis field from the same RUC run indicates a frontogenetically forced band of moderate to heavy precipitation occurring north and west of the precipitation maximum indicated in the model QPF/UVV output (previous slide). Some of this discrepancy is a function of insufficient horizontal resolution in the model. However, the point is that it often benefits the forecast to examine the model frontogenesis field specifically to correct for the lack of frontal scale detail in the UVV/QPF output. This also contributes to a better understanding of how important mesoscale dynamics are unfolding in the model, and how that will relate to the mesoscale organization as might appear on radar.

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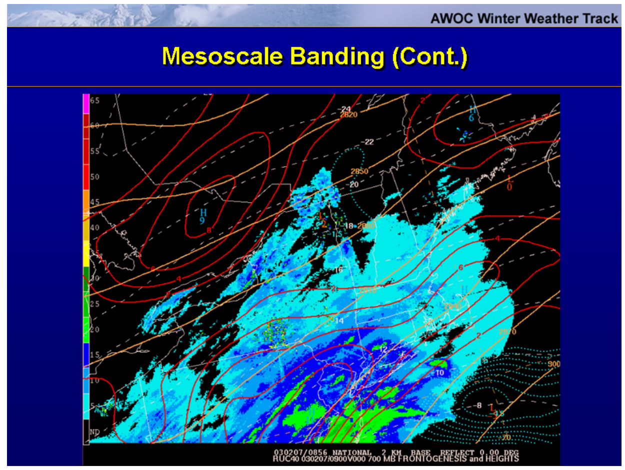

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29. Mesoscale Banding (Cont.)

Instructor Notes: Resulting snow accumulations reflect the mesoscale structure apparent on radar but not in model QPF field. We find that this mesoscale band produced significant snowfall to the tune of 12-16” over Boston and its southern suburbs. Snowfall rates at BOS reached 2”/hr. for four consecutive hours from 16-20 UTC, and were 1”/hr. or greater for seven consecutive hours. Beware the model that depicts strong frontogenesis and has precipitation but does not show an axis of higher precipitation. The resolution of the model may be inadequate to show the mesoscale circulation associated with some bands (Note: very high resolution models such as workstation Eta and WRF may better resolve narrow bands). ***Note:*** In the online presentation a quiz question is available under the “Show URL” button for this slide.

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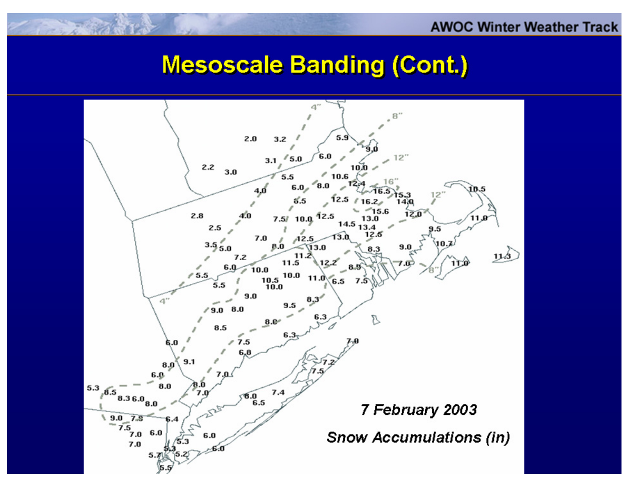

30. Convection/Diabatic Effects

Instructor Notes: Convection can wreck havoc on the models. It is difficult to decipher what effects are real and what might be a function of the model itself (e.g., a function of the convective parameterization scheme). The influence of convection can impact a wide range of spatial scales. The enhanced magnitude of convective motions can impact local vertical temperature profiles and effect precipitation type. On the synoptic-scale, convection can enhance the surface cyclogenesis process, especially over relatively warm water such as the Gulf Stream. When convection is active, our confidence in the model's ability to handle the details accurately is generally going to be lower than otherwise, and our situational awareness needs to be high to counteract these potential deficiencies.

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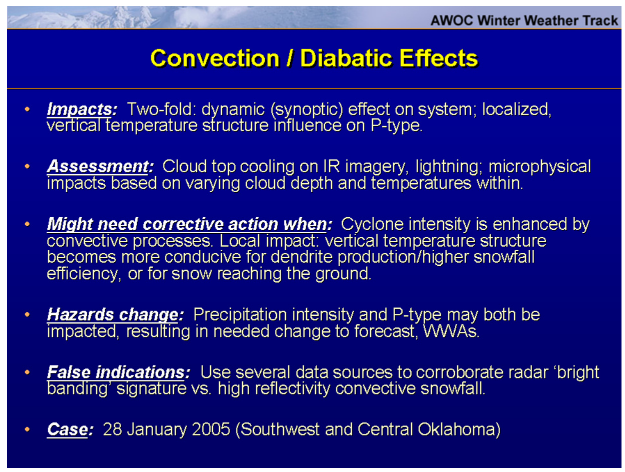

31. Convection/Diabatic Effects (Cont.)

Instructor Notes: On January 28, 2005, a rather sharp shortwave trough was located over the southern High Plains. The 700mb analysis at 12z indicates minimal cold temperature advection across Central OK. A band of precipitation, driven by midlevel differential vorticity advection (not shown), was moving from southwest to northeast between 08-16 Z, with embedded high reflectivity elements in the radar mosaic. The models generally indicated a thermodynamic structure supportive of rain (not shown).

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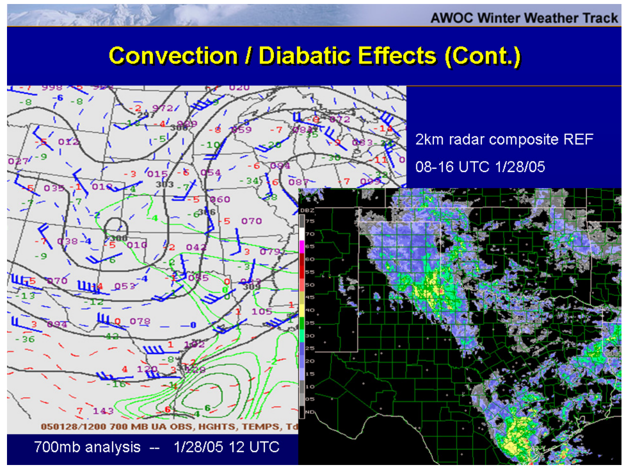

32. Convection/Diabatic Effects (Cont.)

Instructor Notes: The observed soundings from Fort Sill (FSI, in SW Oklahoma) and Norman (OUN, in central OK) are juxtaposed on a skew-T. First note that the low-level wind profile shows veering with height, a general sign of horizontal warm advection from the SFC through 700mb at FSI. Secondly, both the FSI and OUN soundings show saturated conditions in the 850-700mb layer. The layer temperature is above 0 degrees C in the OUN sounding. However, where the moderate to heavy convective precipitation is occurring at FSI, the sounding has locally cooled and become isothermal near 0 degrees C. This is likely a result of latent heat of melting, associated with a large amount of falling snowflakes. Eventually, the latent/diabatic cooling is sufficient to eliminate the warm nose in the sounding, and the falling snowflakes no longer melt aloft but now reach the ground. Since substantial (i.e., very heavy) precipitation is necessary to make this effect appreciable, the snowfall rates are often heavy for short periods of time, and can substantially impact travel conditions. The narrowly focused axis of upward vertical motion caused the heavy snow to be of short duration (a few hours) before ending.

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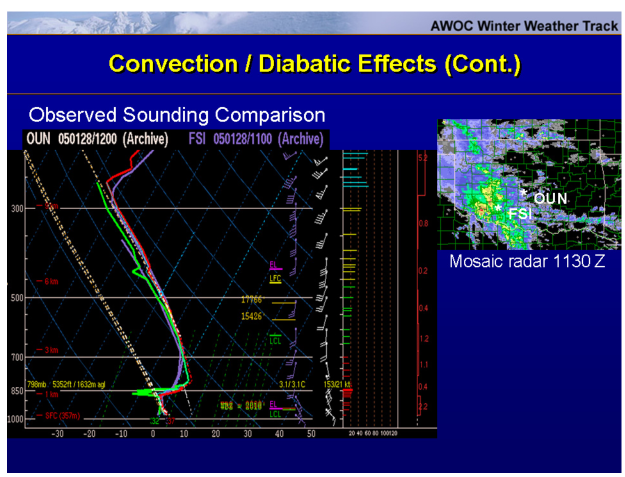

33. Convection/Diabatic Effects (Cont.)

Instructor Notes: In Oklahoma City, where these diabatic effects were later felt, 2.5 inches of snow fell in a short period of time, even though the surface temperature never fell below 33 degrees F. Liquid equivalent precipitation was 0.3” (liquid equivalent ratio of 8.3 to 1).

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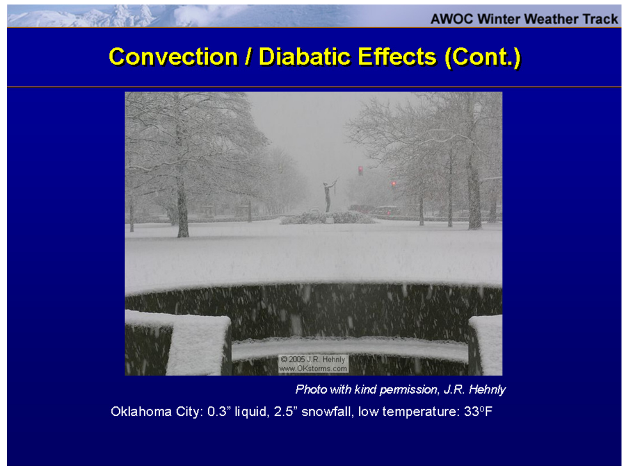
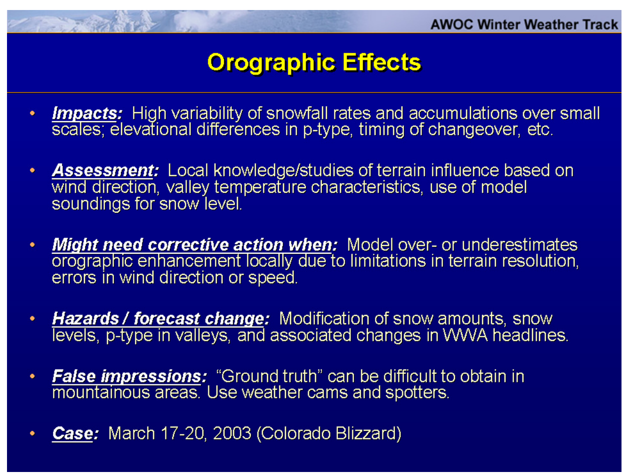


34. Orographic Effects

Instructor Notes: Orographic effects are an area in which local human expertise at the WFO level can result in improvement over NWP guidance.

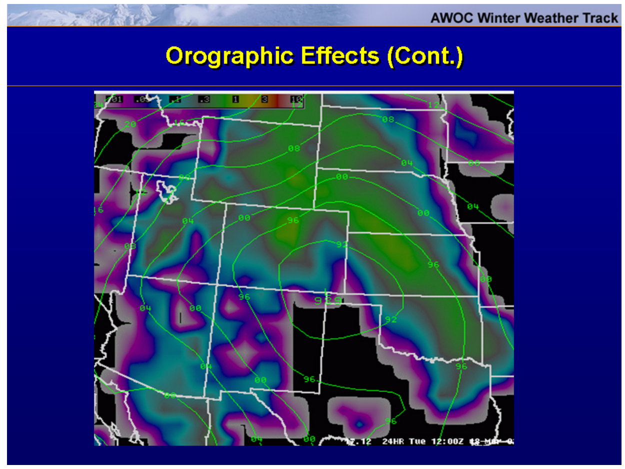
Student Notes:



35. Orographic Effects (Cont.)

Instructor Notes: The Eta model forecast from 12z 17 March 2003 shows a maximum in precipitation along the front range of Colorado and Wyoming through 30 hours.

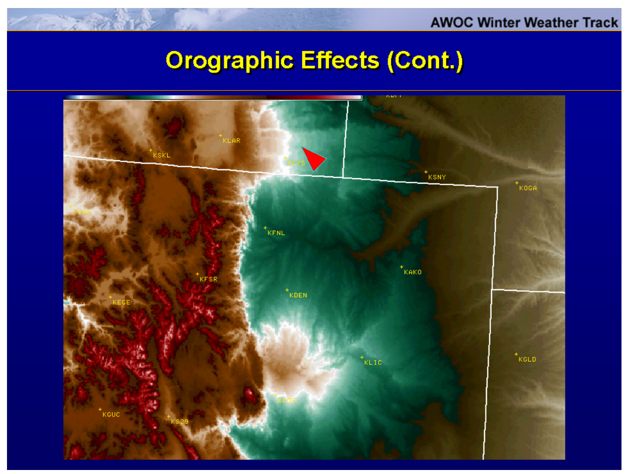
Student Notes:



36. Orographic Effects (Cont.)

Instructor Notes: The upslope nature of the low-level easterly winds contributes to enhanced upward vertical motion and highest snow amounts along the eastern slopes of the Rockies in this case. As we'll see in the next slide, there was also an elevational dependency on precipitation type, with mostly rain out over the plains.

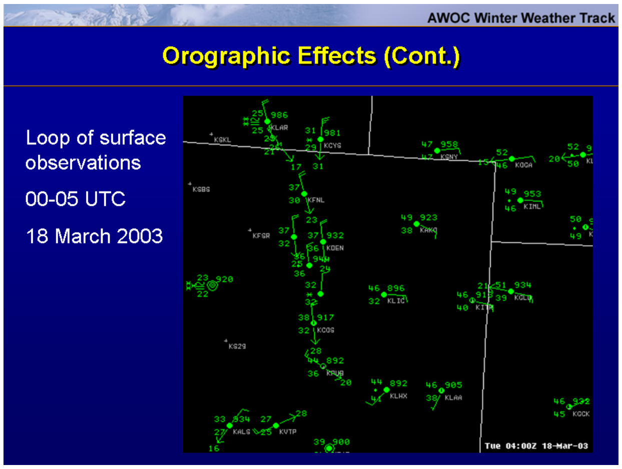
Student Notes:



37. Orographic Effects (Cont.)

Instructor Notes: Marginal surface temperatures at the start of the event suggest elevation will play a role in precipitation type, in addition to the role of the orography in providing upslope enhancement to precipitation amounts.

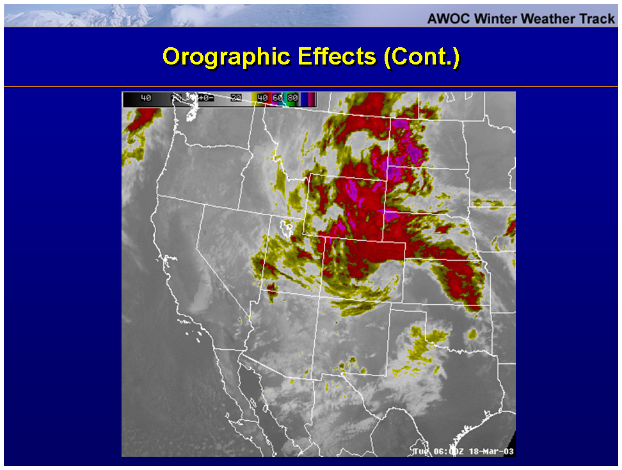
Student Notes:



38. Orographic Effects (Cont.)

Instructor Notes: Midlevel vorticity center is quasi-stationary across southeast Colorado, which allows for a prolonged period of easterly to southeasterly flow into central Colorado. Trajectories from the east and southeast allow for ample low-level moisture advection. A shortwave trough rotates westward around the northern periphery of the trough into northeastern Colorado, and is associated with cloud top cooling and expansion of the upper-level cloud canopy. General enhancement/expansion of cold cloud tops north of the stationary midlevel vorticity center suggests favorable large-scale support for precipitation across northcentral CO.

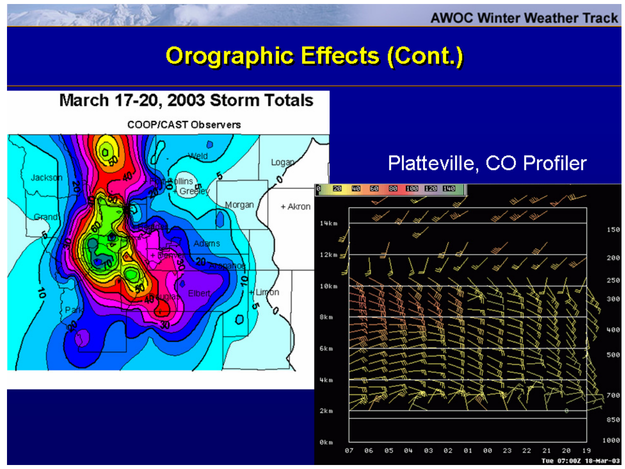
Student Notes:



39. Orographic Effects (Cont.)

Instructor Notes: The profiler time-height cross-section indicates a considerable increase in deep-layer easterly flow over time during the evening of March 18. The final snow accumulation map indicates snow confined to the higher elevations (the Palmer and Cheyenne ridges and adjacent mountains to the west, which receive the maximum benefit of the low-level upslope enhancement).

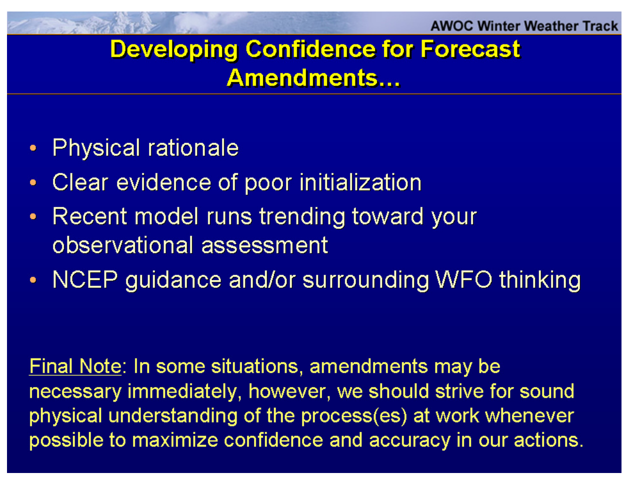
Student Notes:



40. Developing Confidence for Forecast Amendments

Instructor Notes: It is important to have solid reasoning when making adjustments to forecast products, particularly any watches, warning or advisory products which have greater public visibility and societal impact. This slide lists factors that contribute positively to our confidence in making changes to a weather forecast. For example, when the consensus opinion supports a forecast change, and when we have both solid evidence and physical rationale for making a change, we can have more confidence in making a change to the current forecast that will be for the better. We must always be aware that there exists a delicate balance between providing consistency in our products - which is also valued by customers - versus maximizing accuracy in light of ever present uncertainties. We should keep in mind that many customers value consistency in the product as much as accuracy. Therefore, so-called flip-flops should be minimized to the extent possible. ***Note:*** In the online presentation a quiz question is available under the “Show URL” button for this slide.

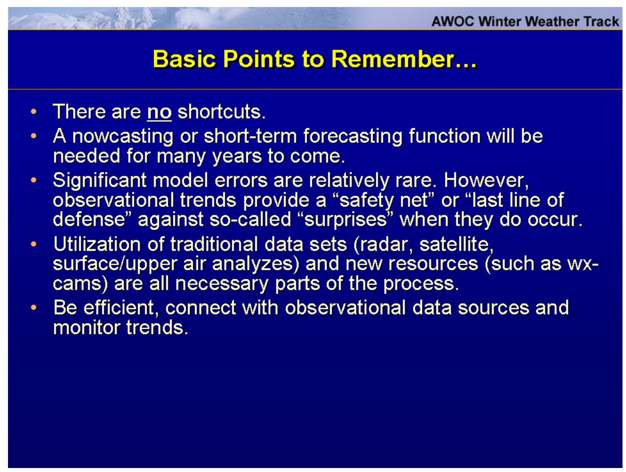
Student Notes:



41. Basic Points to Remember

Instructor Notes: Quality short-term forecasting requires carefully analysis of observational trends and comparison to model output – we can become more efficient in the analysis process with practice, but there aren't any "shortcuts", per se. Good analysis skills of a wide array of data sources remains necessary. We must be able to gather the necessary information efficiently to develop a complete three-dimensional picture of the weather situation. The optimal mindset of short-term forecasting is one that integrates model output with observational data sources, and physical understanding of atmospheric processes relevant to the situation. By doing this, we are in an ideal position to make adjustments to the model forecasts and incorporate mesoscale details that may otherwise be missed.

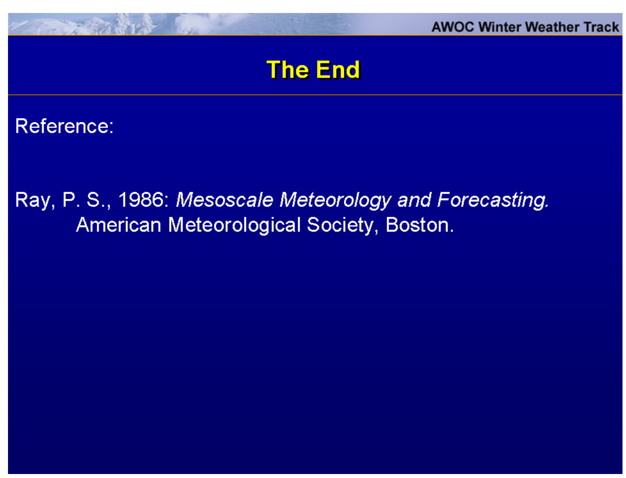
Student Notes:



42. The End

Instructor Notes: Here is the complete reference cited earlier during the presentation.

Student Notes:



43. Have any Questions????

Instructor Notes: If you have any questions about this lesson, first ask your local AWOC facilitator. If you need additional help, send an E-mail to the address provided. When we answer, we will CC your local facilitator and may consider your question for our FAQ page.

Student Notes: