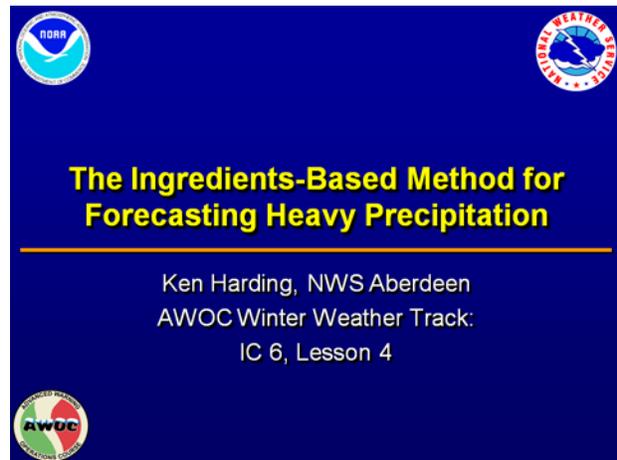

1. The Ingredients-Based Method for Forecasting Heavy Precipitation

Instructor Notes: Welcome to AWOC Winter Weather Track Instructional Component 6, lesson 4. My name is Ken Harding, and this lesson focuses on the ingredients based method for forecasting heavy precipitation. While we are concentrating on heavy snow in this version of AWOC, this method is applicable able to many heavy precipitation scenarios.

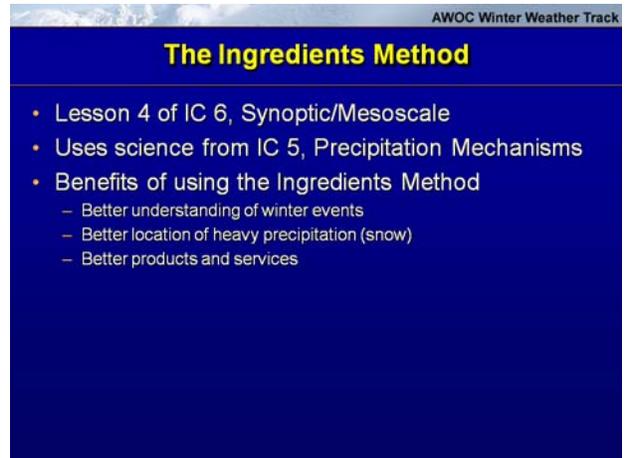
Student Notes:



2. The Ingredients Method

Instructor Notes: This is lesson 4 of instructional component 6, Synoptic/Mesoscale forecasting of precipitation type and amount. This lesson references much of the science from IC 5, precipitation forcing mechanisms and associated diagnosis for winter weather and other lessons of IC 6. The idea here is to put all of this science together in an orderly manner to better conceptualize the potential for heavy precipitation. When combined with microphysical information, this method is one method for heavy snow forecasting. This will allow us to produce better forecast and warning products for our customers.

Student Notes:



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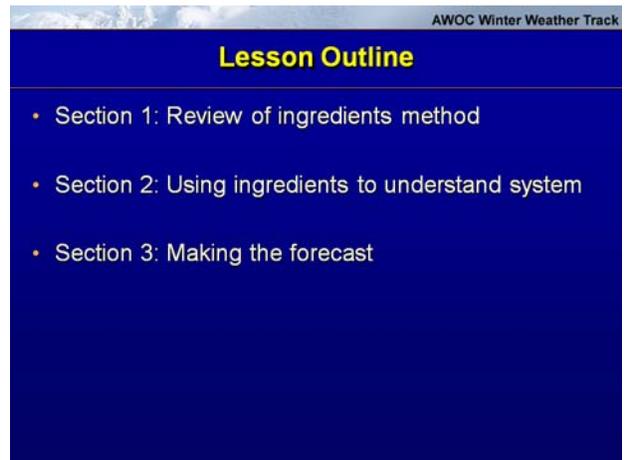
The Ingredients Method

- Lesson 4 of IC 6, Synoptic/Mesoscale
- Uses science from IC 5, Precipitation Mechanisms
- Benefits of using the Ingredients Method
 - Better understanding of winter events
 - Better location of heavy precipitation (snow)
 - Better products and services

3. Lesson Outline

Instructor Notes: In this lesson, I'll provide a frame work for applying the ingredients method in forecasting heavy precipitation. After a review of the ingredients, I will use the ingredients to understand the overall synoptic/mesoscale weather systems. While I won't specifically concentrate on heavy snow, the emphasis is on winter precipitation.

Student Notes:



AWOC Winter Weather Track

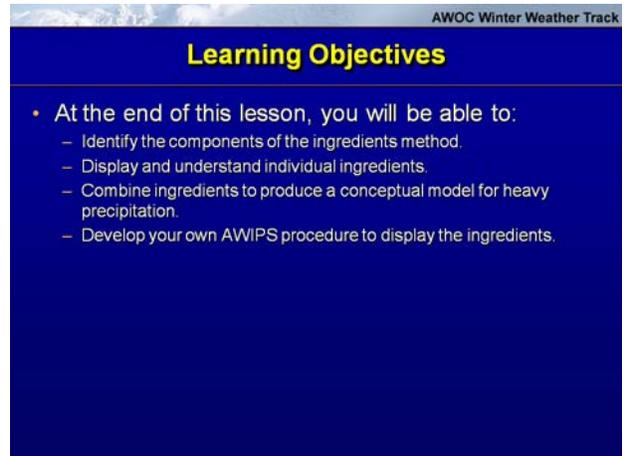
Lesson Outline

- Section 1: Review of ingredients method
- Section 2: Using ingredients to understand system
- Section 3: Making the forecast

4. Learning Objectives

Instructor Notes: The learning objectives for this lesson are straight forward. Being able to identify and understand the main ingredients that are responsible for the production of heavy snow, and combining these ingredients into a conceptual model of the snow event. An example AWIPS procedure based on this method will be provided to your SOO with the WES scenario for Winter AWOC.

Student Notes:



AWOC Winter Weather Track

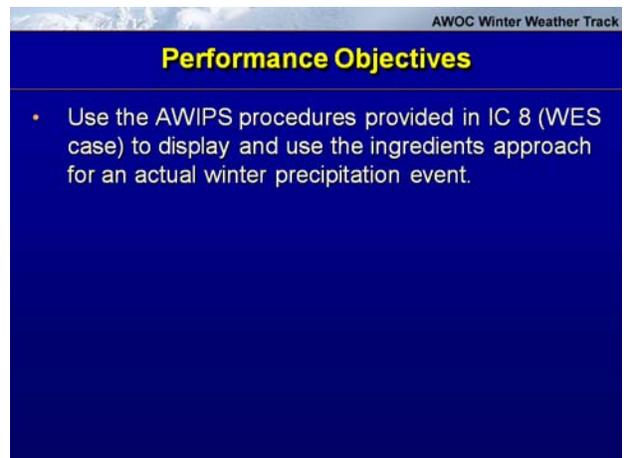
Learning Objectives

- At the end of this lesson, you will be able to:
 - Identify the components of the ingredients method.
 - Display and understand individual ingredients.
 - Combine ingredients to produce a conceptual model for heavy precipitation.
 - Develop your own AWIPS procedure to display the ingredients.

5. Performance Objectives

Instructor Notes: During your WES case, you will be provided a procedure based on this presentation of the ingredients method.

Student Notes:



AWOC Winter Weather Track

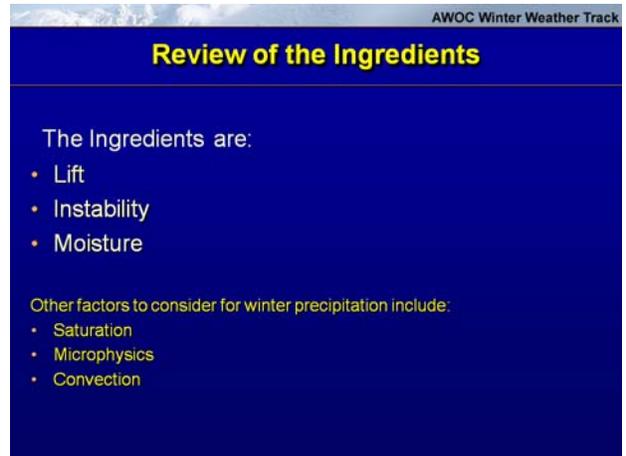
Performance Objectives

- Use the AWIPS procedures provided in IC 8 (WES case) to display and use the ingredients approach for an actual winter precipitation event.

6. Review of the Ingredients

Instructor Notes: Specifically, heavy precipitation is the result of sustained high precipitation rates. To achieve these rates, you need sufficient deep lift, an atmosphere that is unstable to vertical forcing, and sufficient moisture for both precipitation production and replenishment of lost moisture. Precipitation efficiency is also related to several items covered in other lessons including degree of saturation, microphysics of snowfall production and release of convective instabilities, either slanted or upright. The top-down approach should be used to determine precipitation type and whether dendritic crystal growth will be prevalent.

Student Notes:



AWOC Winter Weather Track

Review of the Ingredients

The Ingredients are:

- Lift
- Instability
- Moisture

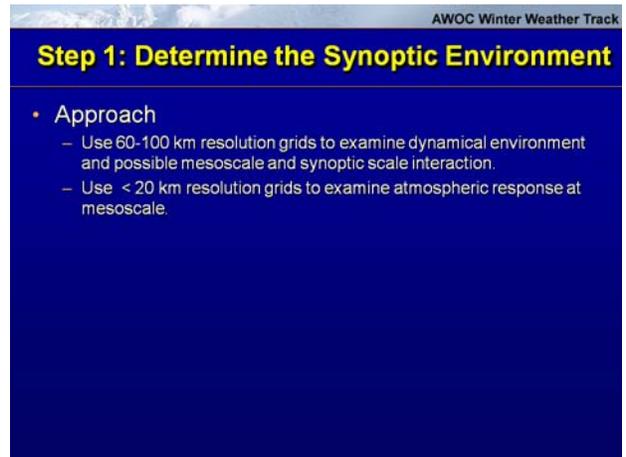
Other factors to consider for winter precipitation include:

- Saturation
- Microphysics
- Convection

7. Step 1: Determine the Synoptic Environment

Instructor Notes: The ingredients method really starts with a forecast funnel mentality. First, we are going to determine the synoptic potential for sustained lift. In this step, I'll be using Q vectors. In order to use Q vectors, I need to make the quasi-geostrophic approximation. Thus, I will look at model output at a fairly coarse scale, around 80 kilometers, so the QG approximation remains valid. When querying the mesoscale for sustained lift, we should look at much higher resolution model output to determine areas and times. A word of caution: moisture is one of the poorest variables forecast in the numerical weather prediction models. Errors in location and timing of mesoscale forcing and response may be a result of a poor moisture forecast by the models.

Student Notes:



AWOC Winter Weather Track

Step 1: Determine the Synoptic Environment

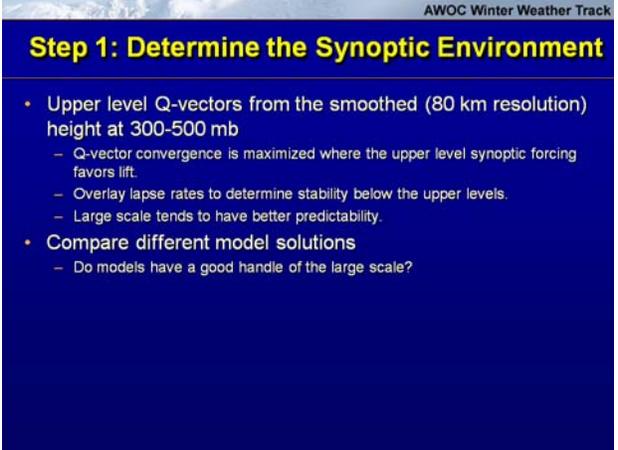
- Approach
 - Use 60-100 km resolution grids to examine dynamical environment and possible mesoscale and synoptic scale interaction.
 - Use < 20 km resolution grids to examine atmospheric response at mesoscale.

8. Step 1: Determine the Synoptic Environment

Instructor Notes: In this example, we'll look at convergence of Q vectors to assess the potential for synoptic lift. We choose a layer in the top half of the troposphere. This fairly deep layer from 500 to 300 mb will show maximum Q vector convergence where upper level forcing is greatest. In order to see how effective this forcing will be in producing lift,

overlay a layer stability product below these forcing layers. The more unstable the layer is, the more lift will occur for a given amount of forcing. It is critical not to use only one model or one cycle to determine synoptic lift. Most of the operational NWP models do a good job with synoptic lift, so run to run and multiple model consistency should be checked

Student Notes:



AWOC Winter Weather Track

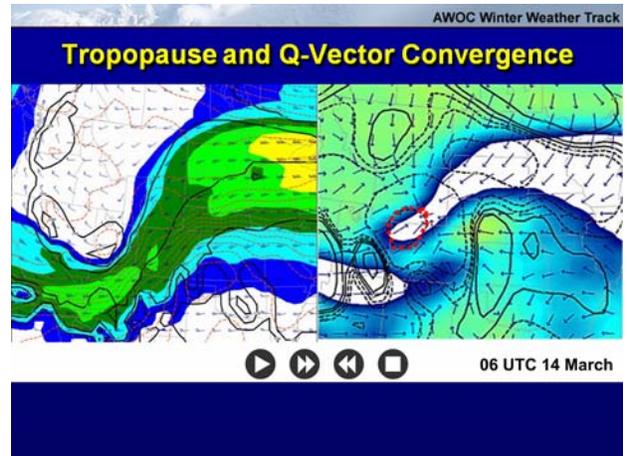
Step 1: Determine the Synoptic Environment

- Upper level Q-vectors from the smoothed (80 km resolution) height at 300-500 mb
 - Q-vector convergence is maximized where the upper level synoptic forcing favors lift.
 - Overlay lapse rates to determine stability below the upper levels.
 - Large scale tends to have better predictability.
- Compare different model solutions
 - Do models have a good handle of the large scale?

9. Tropopause and Q-Vector Convergence

Instructor Notes: This loop shows the tropopause pressure (black lines) and tropopause wind speed (image) on the left along with 500-300 mb Q vector convergence (black lines) and 700-500 mb lapse rates (color image). The warmer colors represent more unstable lapse rates. An area of maximized Q-vector convergence is shown with a dashed red line. This loop, running from 06 UTC 14 March through 00 UTC 15 March shows the evolution of the deepening trof and area of upper level forcing represented by the q-vector graphic. The importance of looking at a dynamic tropopause map can't be overstated. If one looks at standard pressure levels, you can miss many details of the tropopause/jet structure such as coupled jets and tropopause folds. One standard pressure level isn't likely to capture both the sub-tropical and polar jets. Thus jet structure and tropopause information should be evaluated at the model tropopause level instead of just 300 mb (or your favorite upper level). It is also important to look at the effects upper level forcing, represented here by the q-vector graphic, and the underlying stability of the air. Strong upper level forcing that overlies unstable air will allow deeper vertical circulations. Building displays of these combined elements is critical to understanding the ingredients necessary to produce heavy precipitation.

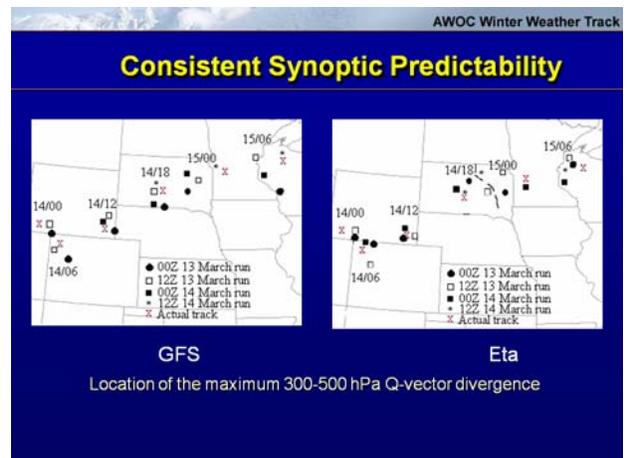
Student Notes:



10. Consistent Synoptic Predictability

Instructor Notes: Shown are the central locations of the max Q vector convergence over 4 model runs with the model analysis indicated with a red X. Even though the 4 previous model runs had very different positions of the surface low and mid level frontogenesis, the location of the synoptic forcing maximum was consistent. If there are large differences in the run to run location of the synoptic forcing, going down to the mesoscale is very difficult at best.

Student Notes:

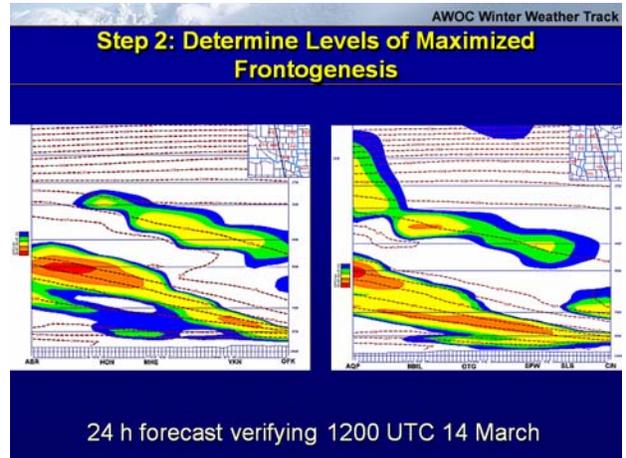


11. Step 2: Determine Levels of Maximized Frontogenesis

Instructor Notes: Now observe cross sections plotted across the area of interest. Make frontogenesis an image and overlay with a plot of equivalent potential temperature. Here we are looking for the vertical distribution of frontogenesis, and the vertical separation between equivalent potential surfaces represents a quick check on stability; the further apart in the vertical the equivalent potential surfaces are, the more vertical motion

occurs for a given amount of forcing. Note the levels where frontogenesis is strong in the area of interest, and how these levels change with time. In this case, on the left graphic, we see strong frontogenesis centered around 500 mb to the north, sloping to around 850 mb in the south.

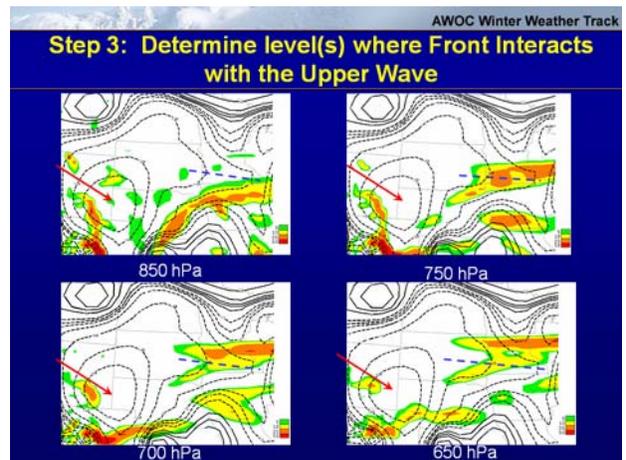
Student Notes:



12. Step 3: Determine level where front interacts with upper wave

Instructor Notes: This slide depicts a 4 level analysis of 500-300 mb Q-vector convergence, shown as dotted black lines, and frontogenesis at a specific level. The red arrow points to the maximum area of Q-vector convergence. The dashed blue line shows a relative high area of Q-vector convergence. Just by looking at the depicted levels, you can see the frontogenesis at 750 mb (and to a slightly lesser extent, 700 mb) is best aligned with the upper level forcing. When lower level frontogenesis aligns with upper level forcing, deep vertical responses are possible, given enough instability. We'll examine the affects of instability in the next slide.

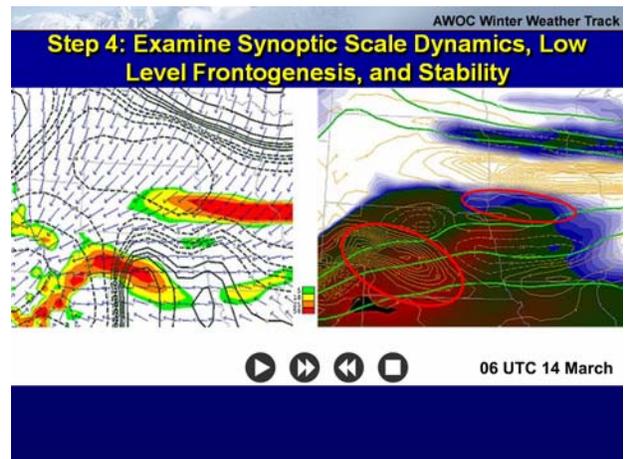
Student Notes:



13. Step 4: Examine Synoptic Scale Dynamics, Low Level Frontogenesis, and Stability

Instructor Notes: In this loop, the left graphic represents 500-300 mb Q-vectors (black arrows), convergence of Q (black lines), and 700 mb frontogenesis (color image). The right graphic depicts relative 600-500 mb relative humidity (green lines), equivalent potential vorticity of less than 0.25 PV units (color image), and 700 mb frontogenesis (orange lines). We are looking for areas where low level frontogenesis and upper level forcing (left graphic) line up with unstable air (EPV image on the right) in a saturated environment. On the right graphic, I have indicated areas where this occurs with a red oval. The affects of stability can not be stressed enough. Vertical motions resulting from strong low level frontogenesis forcing will only produce a deep vertical response if the air above the forcing is unstable. Technically, we should be looking for saturated areas where $EPV < 0$, but due to model smoothing and errors, I suggest looking at areas where $EPV < 0.25$. The layer chosen to evaluate negative EPV can be located using cross sections and time sections of EPV and frontogenesis. Choose an appropriate layer above the level of maximum frontogenesis to evaluate the vertical depth and time continuity of the negative EPV layer and the frontogenesis. At 06 UTC 14 March, 2 areas of interest are indicated, one in west central Nebraska and one near the Iowa/South Dakota/Minnesota border. The tri-state area of interest is characterized by frontogenesis, saturation indicated by $RH > 90\%$, and $EPV < 0.25$, co-located with an area of q-vector convergence. As we step forward, notice how these parameters remain relatively persistent over this area. This is an area that one would need to pay close attention to for heavy precipitation.

Student Notes:

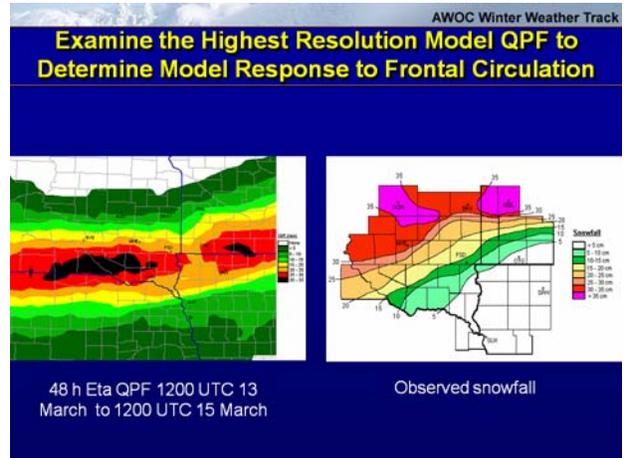


14. Examine the Highest Resolution Model QPF to Determine Model Response to Frontal Circulation

Instructor Notes: In this case, the highest resolution QPF output from the Eta model produced nearly 1.4 inches of liquid. The largest values are located along a line roughly

corresponding to the intersection of the maximum mesoscale forcing and most unstable air. However, when the verification snow amounts are plotted, the heaviest snow amounts were measured north of the model depiction. In this case, the heaviest snow amounts, while produced by mesoscale lift, were more closely located in the area coupled by the upper level synoptic scale forcing and the lower level mesoscale forcing. As stated before, moisture is one of the poorest forecast variables in the numerical models. Poor moisture representation and convective parameterization errors can lead to low QPF forecasts and often miss the highest values. Use the model QPF output very carefully, and don't use the values literally; instead, look for trends over several model cycles.

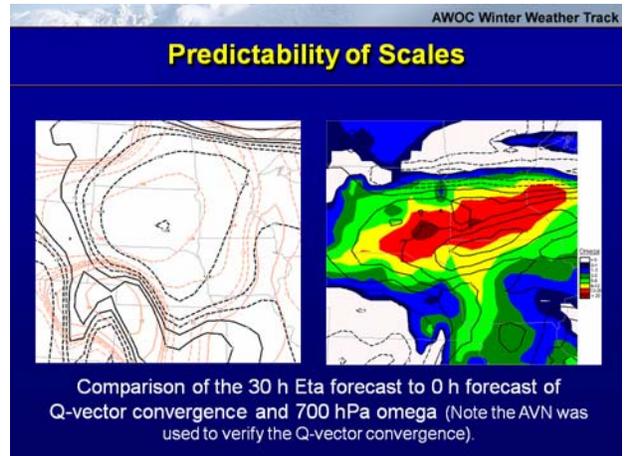
Student Notes:



15. Predictability of Scales

Instructor Notes: Even with higher resolution mesoscale models available to forecasters, there is still a need for lower resolution model output. If we want to use QG theory and visualize q-vectors, we must use a data resolution that supports the QG approximation. Generally, model grids in the 70 km resolution and above are good to use for your QG diagnosis. On the left, notice how consistent the synoptic scale forecast of Q-vector divergence (black lines) was with the verifying model analysis (orange lines). On the right side of the slide is the 700-mb vertical velocity forecast and verifying model analysis. Notice how far the maximum upward motion shifted from the 30 hour forecast (black lines) to the analysis time (color image). Even with a very consistent synoptic scale, mesoscale details often shift dramatically from run to run. The key here is to adjust forecast areas of strong mesoscale forcing towards the consistent synoptic scale forcing. If you see consistency in the synoptic scale forecast, you can examine the mesoscale more closely. However, if the synoptic scale has high run to run and model to model variability, use caution when transitioning to the mesoscale.

Student Notes:



16. Making the Forecast

Instructor Notes: When making the forecast, we are looking for areas where upper level synoptic forcing and lower level frontal forcing align the best in the most unstable air. It is here that deep mesoscale responses are possible. The more unstable the environment, the more narrow the resulting band will be. Once you have identified an area of mesoscale concern, use the highest resolution QPF grids available. This helps preserve the tight gradients and results in less smoothing of high amounts. Use caution with the placement of the model QPF as often the precipitation processes in the NWP models are not tied directly to the dynamics of the model. You may need to adjust the placement of the precipitation towards the best superposition of moisture, lift and instability.

Student Notes:

AWOC Winter Weather Track

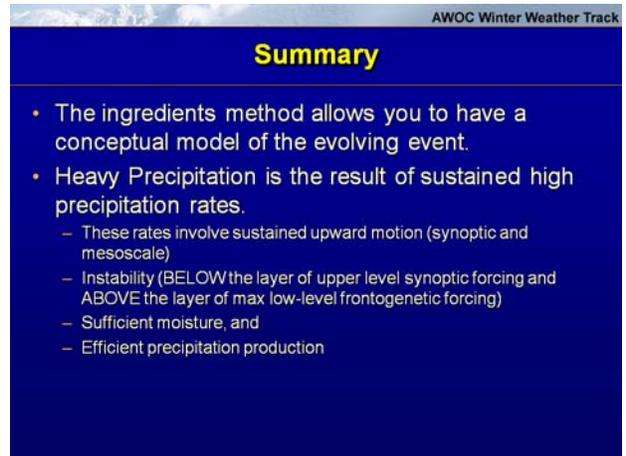
Making the Forecast

- Examine areas where upper-level synoptic forcing align with lower-level frontal forcing.
- Examine the stability of the lifted layer.
 - Generally, higher instability leads to narrower bands.
- Examine high resolution QPF grids to examine the model response.
 - Location of model response may differ from your analysis.
 - Remember moisture is poorly forecast and may need to be adjusted.

17. Summary

Instructor Notes: If we understand the ingredients that produce heavy precipitation (or snow), we can directly analyze each and understand when one or more of them changes and becomes more or less favorable. This leads to an orderly forecast approach to the necessary conditions for heavy precipitation.

Student Notes:



The slide is titled "AWOC Winter Weather Track" in the top right corner. Below the title, the word "Summary" is written in yellow on a dark blue background. The main content is a bulleted list of points:

- The ingredients method allows you to have a conceptual model of the evolving event.
- Heavy Precipitation is the result of sustained high precipitation rates.
 - These rates involve sustained upward motion (synoptic and mesoscale)
 - Instability (BELOW the layer of upper level synoptic forcing and ABOVE the layer of max low-level frontogenetic forcing)
 - Sufficient moisture, and
 - Efficient precipitation production

18. ingredients quiz

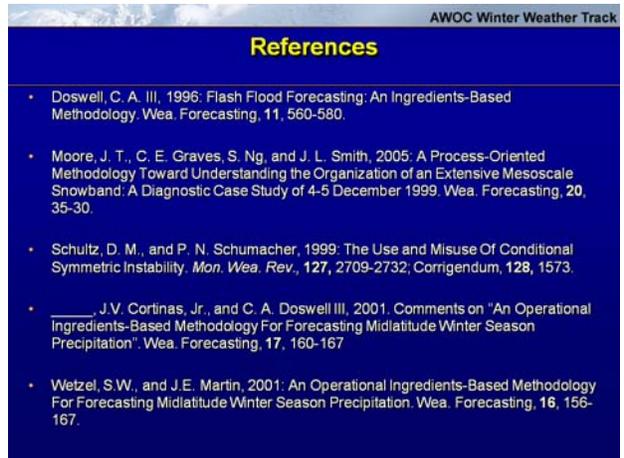
Instructor Notes: Take a few moments to complete this interactive quiz.

Student Notes:

19. References

Instructor Notes: Here are some useful papers with references to ingredient-based forecasting.

Student Notes:



AWOC Winter Weather Track

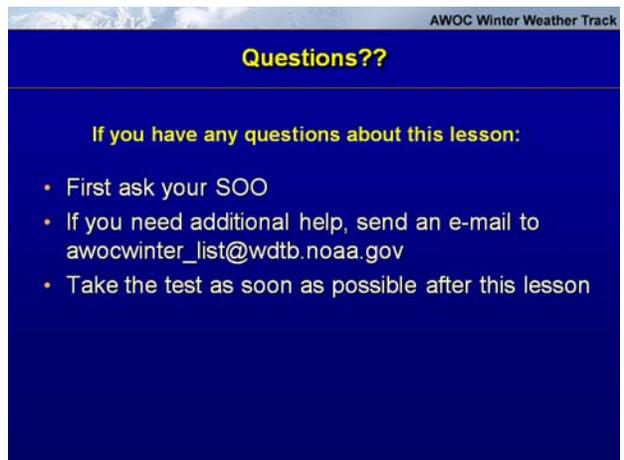
References

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- Moore, J. T., C. E. Graves, S. Ng, and J. L. Smith, 2005: A Process-Oriented Methodology Toward Understanding the Organization of an Extensive Mesoscale Snowband: A Diagnostic Case Study of 4-5 December 1999. *Wea. Forecasting*, **20**, 35-30.
- Schultz, D. M., and P. N. Schumacher, 1999: The Use and Misuse Of Conditional Symmetric Instability. *Mon. Wea. Rev.*, **127**, 2709-2732, Corrigendum, **128**, 1573.
- _____, J.V. Cortinas, Jr., and C. A. Doswell III, 2001. Comments on "An Operational Ingredients-Based Methodology For Forecasting Midlatitude Winter Season Precipitation". *Wea. Forecasting*, **17**, 160-167
- Wetzel, S.W., and J.E. Martin, 2001: An Operational Ingredients-Based Methodology For Forecasting Midlatitude Winter Season Precipitation. *Wea. Forecasting*, **16**, 156-167.

20. Questions??

Instructor Notes: If you have questions, your first stop is your SOO. For additional help, contact the WDTB using the email above. There are also help resources located on the main Winter AWOC web page. Good luck with the test!

Student Notes:



AWOC Winter Weather Track

Questions??

If you have any questions about this lesson:

- First ask your SOO
- If you need additional help, send an e-mail to awocwinter_list@wdtb.noaa.gov
- Take the test as soon as possible after this lesson