1. IC6.3: Using Ensembles in Winter Weather Forecasting

Instructor Notes: Welcome to IC 6 Lesson 3. My name is Richard Grumm and this lesson will focus on using ensemble output in forecasting winter weather.

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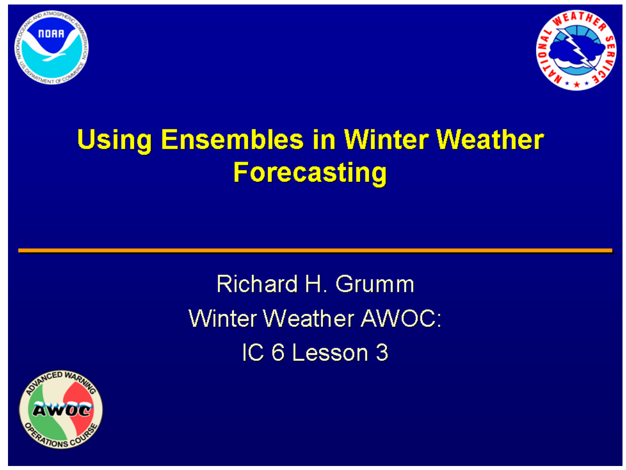

2. What are the Learning and Performance Objectives?

Instructor Notes: These are the 4 primary objectives for this module: The learning objectives are the basis for post-test items. The performance objectives (the ones that start with "demonstrate", #1, 3-4, are evaluated via WES simulations and/or a post-training instrument (questionnaire, survey, etc.). The objectives are: 1.Demonstrate why you should use ensemble forecast information during winter storms in the outlook, watch, and warning phases. 2.Identify the strengths and limitations of EPS products such as mean, spaghetti, spread, plume charts, and probability of exceedance. 3.Demonstrate how to recognize high uncertainty/high probability outcomes in EPS data. 4.Demonstrate how probabilistic forecasting duties in winter weather are related to ensemble forecasting.

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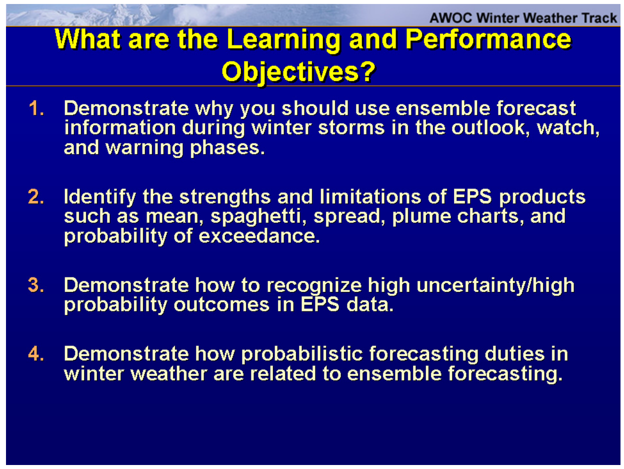
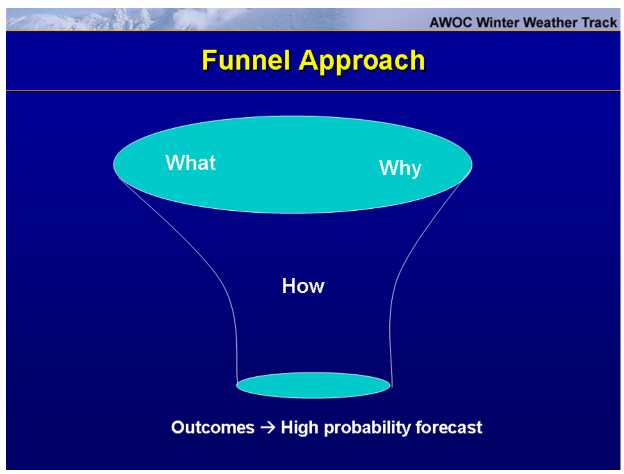


3. Funnel Approach

Instructor Notes: What we will be talking about is ENSEMBLES. Why? To help improve forecasts of significant winter weather events. How? We will review ensemble products which can be used to forecast winter weather. The desired outcome is higher probability forecasts of winter weather.

Student Notes:



4. What? Ensembles. Why? Uncertainty.

Instructor Notes: We need ensembles to deal with the UNCERTAINY in forecasting. An ensemble is a collection of the output numerical weather prediction models (NWP). The individual members of the ensemble may have been initialized with different Initial Conditions (ICs) or use different mathematical formulations and physics packages in their Model Core (MC). The more diverse the Ensemble Prediction System (EPS) the better your forecast will become. We also need to deal with the chaotic nature of the atmosphere which we will most likely never be overcome. Why do we want ensembles? Due to the uncertainty in initial conditions and the calculations in our models which in and of themselves can change the outcome of a forecast.

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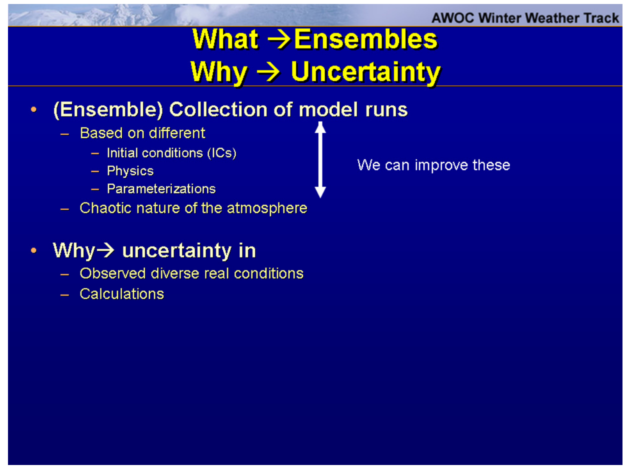

5. Forecast Impacts and Time: Initial Conditions Big Where Winter Storms Forecast

Instructor Notes: This table summarizes the impact of ICs and model errors on forecasts from the short-range to the range of climatic models. For the operational forecaster note the BIG impact ICs can have at both the short- and medium-range. In addition to the big impacts of ICs on the forecast note that model errors too can be quite significant. There is an excellent paper by Zhang, Snyder, and Rotunno about the effects of moist convection on predictability in the Journal of Atmospheric Sciences published in 2003. In this study they showed how changing the convective parameterization scheme significantly impacted the forecasts. After 30-hours time the convective scheme caused each version of the MM5 to produce markedly different forecasts; thus the big effect on the Model Core and the model's ability to introduce errors in the forecasts.

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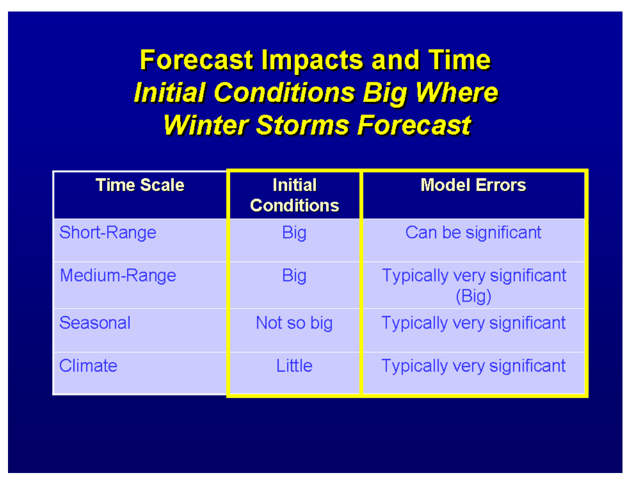

Time Scale	Initial Conditions	Model Errors
Short-Range	Big	Can be significant
Medium-Range	Big	Typically very significant (Big)
Seasonal	Not so big	Typically very significant
Climate	Little	Typically very significant

6. Basic Ensemble Diagram

Instructor Notes: So, why do we need ensembles? First, we need to overcome the uncertainty in initial conditions. Each X is a potential set of initial conditions. The circle around them represents what conditions we might expect based on climatology and our sensors. Once we have these sets of initial conditions we can run our model or models to make a forecast. Each line represents a set of forecasts. At some time X they make a forecast. The range of these forecasts is represented by the cyan area in the figure. The outer area represents the potential range of solutions we might expect which might be the normal spread of climatology. In this case, our ensemble spread is shown to be SMALLER than the SPREAD we might expect from climatology. Thus, we have an example where our ensembles have skill over climatology. Some confidence measures, which we will not discuss, leverage this information about ensemble spread and the expected spread to develop confidence measures of the ensemble forecast system.

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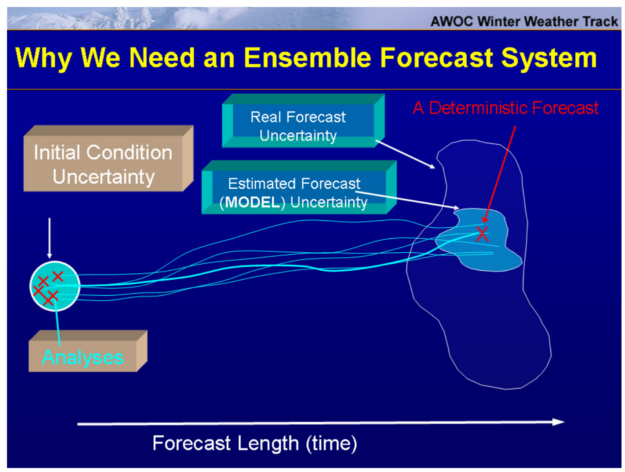

7. How Products to View the Ensemble Forecast

Instructor Notes: Understanding what an ensemble is important. It is also important to know how to interpret the output of the ensemble prediction system (EPS). We will discuss some of these output products. The concept of a spaghetti diagram is most obvious from the lines that represent each forecast in the picture. But we can also compute the mean and the spread about the mean to show uncertainty. We will now examine the strength and weaknesses of several ensemble display strategies.

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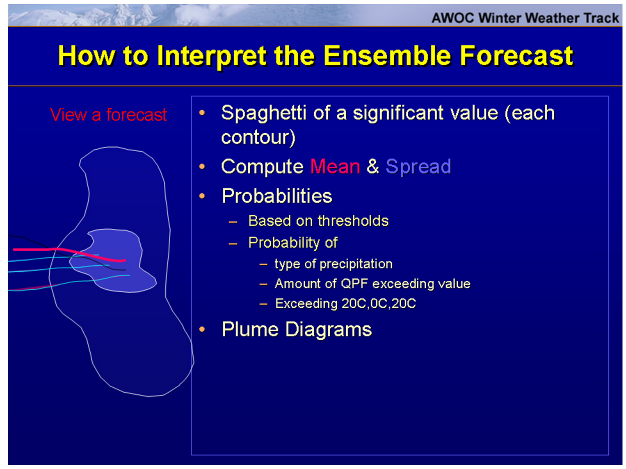
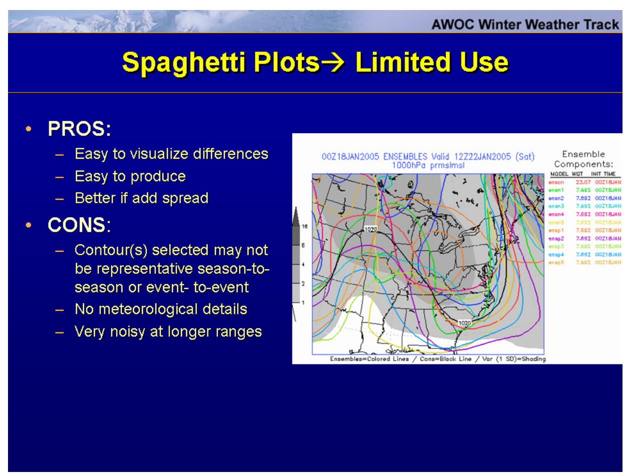


8. Spaghetti Plots --> Limited Use

Instructor Notes: Spaghetti plots are probably the most widely known. We will not discuss the thumbnails of each member. The upside a spaghetti plots include the fact that they are easy to produce and readily allow the user to visualize differences. They are enhanced when shown with the spread. Some of the limits include that fact that the select contours may not be valid season-to-season and location to location, they lack meteorological details, and can become noisy at longer ranges. Actually, this latter point is also useful forecast information. The noisier, the more uncertain the forecast!

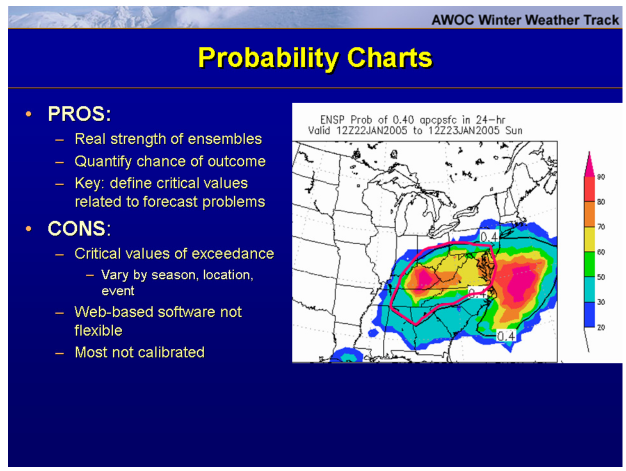
Student Notes:



9. Probability Charts

Instructor Notes: Probability charts represent one of the main strengths of ensemble data. They allow the user to quantify a probability to an outcome. The key is often defining the probability for the parameter or parameters that meet your needs. Some of the CONS include the fact that the critical threshold value YOU require may not be available. These thresholds may vary from season to season, location, and for the event. For example, the probability of 850 hPa and 2m temperatures below 0 degrees C may have little value to you in July. Or if your criteria is 3 inches for advisory snow, at a first guess you might want to see the probability of meeting or exceeding 0.30 inches of QPF in 12 hours. However...If you expect a 20:1 ratio during that event, you might want to see the 0.15 QPF exceedance probabilities. Web based probabilities are normally fixed and are not flexible. Additionally, there are few calibrated probabilities available. Calibrated ensemble probabilities will likely evolve over the next 2-6 years. In our example here, we can see very high probabilities that the QPF will exceed 0.4" across the Mid Atlantic region. The big thick contour (line) represents the ensemble mean of the 0.4" value. The highest probabilities of receiving at least 0.4" of liquid are located in Tennessee and Kentucky.

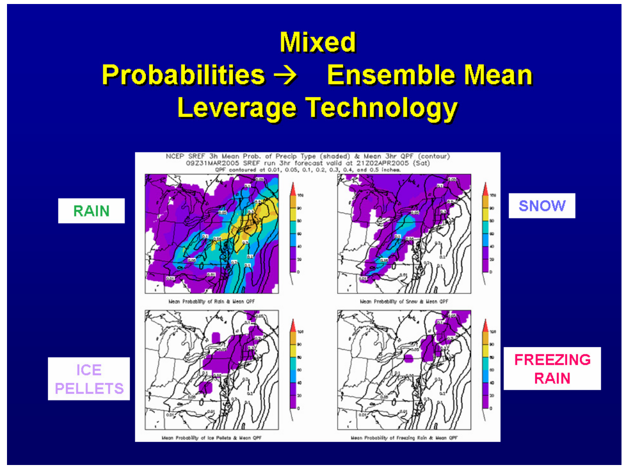
Student Notes:



10. Mixed Probabilities --> Ensemble Mean Leverage Technology

Instructor Notes: Mixed mode products are also quite valuable. This example shows the probability of precipitation type (PTYPE) as forecast by the SREF for each of the four types in the model. In addition to the PTYPE, the ensemble mean 3-hour precipitation is overlaid. These data allow the forecaster to see potential accumulation of precipitation by type. They also could be used to get conditional probabilities of rain, snow, ice, and ice pellet amounts.

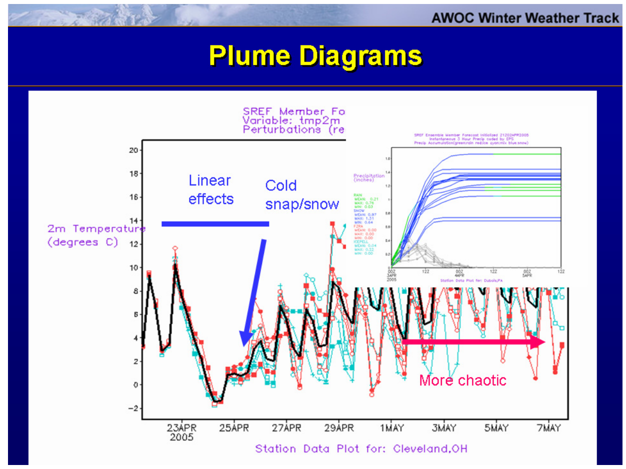
Student Notes:



11. Plume Diagrams

Instructor Notes: Plume diagrams have not been well exploited in the United States. They are basically point diagrams that are very similar to a spaghetti plot. The advantages of plumes include that they are good at a single point over time. The user can visually assess the probability distribution function (PDF), see clustering, and estimate the mode and mean visually. The cons include the fact that these products are geographically specialized, there are many parameters to display and they may not meet YOUR needs. Plume generation requires specialized application software. As an example, we can see that a plume can help refine the timing and the onset of precipitation. They can help the forecaster focus on times of heavy precipitation, and in this example, when it is mostly likely to be snow as the plume is color coded by precipitation type. This is another example of a plume from April 2005. It shows 2m temperatures. Note how the initial forecasts were in good agreement. However, over time the forecasts agree less. Toward the end, many of the forecasts are out of phase with each other. Like a spaghetti plot, plumes show us where the linear effects dominate and we have high confidence in the forecast, when the non-linear effects begin to impact the forecast, and finally, where the non-linear effects dominate. As the non-linear affects become larger, we need to account for the uncertainty and move toward more probabilistic tools. BTW: Cleveland and Detroit had record snowfall on the cold day forecast by the MREF!

Student Notes:



12. EPS

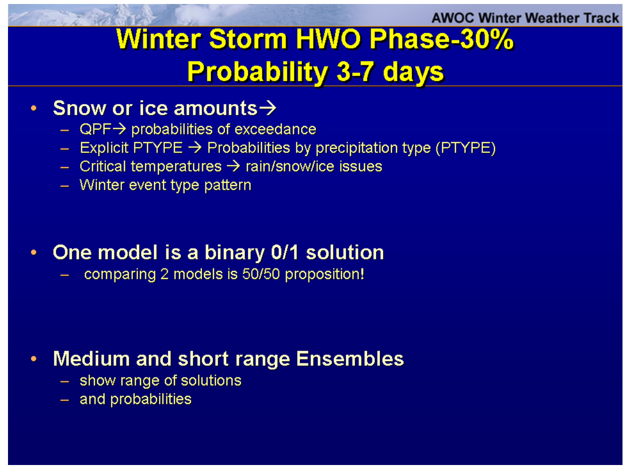
Instructor Notes: Here is a quiz based on what you've learned so far.

Student Notes:

13. Winter Storm HWO Phase-30% Probability 3-7 Days

Instructor Notes: We will now discuss using ensemble prediction products to help with the NWS winter weather program related to forecasting winter storms. We will move from the Hazardous Weather Outlook (HWO) phase of a potential event to the Warning phase. Critical questions we need to extract from EPS data include: The amounts and timing of precipitation, Precipitation type explicitly forecast by the EPS, and Critical temperatures for rain/snow/ice considerations. We also want to identify a known event pattern from the data. Is it an ice storm or snow storm? Is it a typical or an atypical event? If we use 1 model this it is pretty much hit or miss. Both Medium and short range ensembles may help us arrive at some probabilities we can match to our 30% HWO criteria.

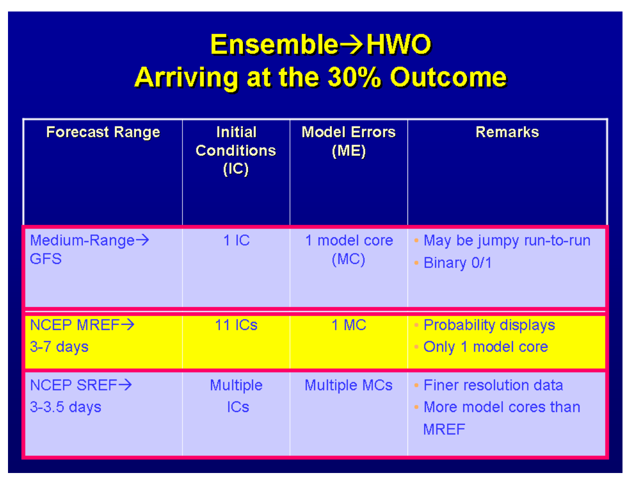
Student Notes:



14. Ensemble HWO: Arriving at the 30% Outcome

Instructor Notes: For the HWO, we rely on the NCEP Medium range ensemble forecast system which we call MREF for the greatest lead time (>3.5 days). In the 3.5 day range we can use the NCEP short range ensemble forecast system which we call the SREF. If we use the output from the Global Forecast System (GFS) alone we get 1 set of initial conditions and 1 model core. We want to avoid the binary solution and we do not want to deal with jumpiness issues. Jumpiness is defined as big changes in model forecasts between consecutive model runs. The MREF gives us 11 sets if IC's. But, a critical weakness to this system is the single model core. A strength of the Canadian EPS is its diverse model cores. But, the MREF does provide use with probabilistic tools. As the forecast length shortens, the SREF comes into play. The SREF gives us multiple IC's like the MREF but it also has diversity in its model cores. At this time the SREF has 5 RSM member, 10 NAM members 5 each with the Kain-Fritsch and Betts-Miller convective schemes, and 6 WRF members. Model diversity is an added strength of the SREF.

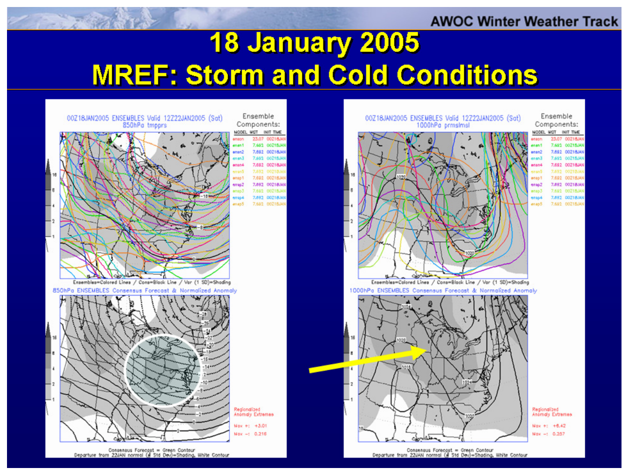
Student Notes:



15. 18 January 2005 MREF: Storm and Cold Conditions

Instructor Notes: We will now do a small case study to show how to use ensemble forecast data during a winter storm. The 22-23 January 2005 winter storm is used. You may recognize the lower panel on the right from our discussion on using the mean and spread. In this example we have MREF data from 18 January showing the EPS mean 850 hPa temperatures and MSLP forecasts. Note the noise in the spaghetti of 850 temperatures and the large spread over the Ohio Valley. Some uncertainty here. Our pattern suggests that from Chicago to Washington it may be cold enough for snow on the north side of our cyclone. Note the large spread in the pressure field north and east of our surface low. There is considerably uncertainty with the location, and depth of our surface low. We will look at the MSLP and some QPF forecasts more in a bit.

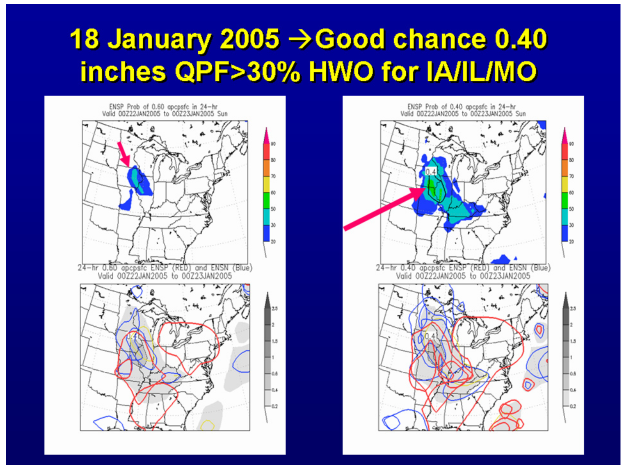
Student Notes:



16. 18 January 2005 --> Good Chance 0.40 Inches QPF > 30% HWO for IA/IL/MO

Instructor Notes: These 24-hour precipitation probability forecast are valid at 0000 UTC 23 January 2005. Upper panels show the probabilities and the lower panels show the ensemble mean QPF with spaghetti of the specified amount overlaid. In this time period there is a high probability of exceeding 0.40 inches of QPF from IA to eastern Kentucky. Note that the mean 0.40 inch contour is over IL-IA and MO. The probability of exceeding 0.60 inches is less and covers a smaller area. To a first guess we can see that storm has potential to produce a 4 inch or greater snowfall over the Mid-west. Though not shown, this precipitation shield was forecast to move over the Mid-Atlantic region over the following 12-24 hours. The next slide will show the forecast track of our storm.

Student Notes:



17. MSLP-Loop with Mean and Spaghetti

Instructor Notes: We will now look at the MREF forecasts initialized at 0000 UTC 19 January 2005. These forecasts show the MSLP forecasts. The upper panels show the spaghetti plots and dispersion about the mean and the lower panels show the ensemble mean and the dispersion about the mean. The mean and dispersion charts allow us to put the event in a meteorological context. Watching the loop go by, we can clearly see a clipper like low in the mean with the potential for secondary re-development along the coast. Note how the spaghetti plots show us where there is big disagreement. This plot has each member's 1012 and 1020 contour plotted along with the mean position (thick black). Few members have a 1012 contour initially so there is no contour in some of the early images. Note how the spread is largest, initially north and east of the cyclone. As the surface low reaches the coast, the area of largest uncertainty shifts north of the cyclone. Timing, position, and intensity issues all impact the location of the cyclone in each member contributing to the uncertainty. Since the MREF uses 1 model core, we are seeing the impact of initial conditions on the forecast.

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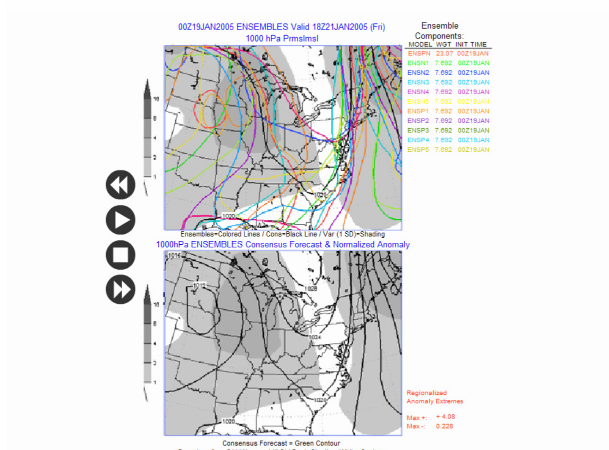
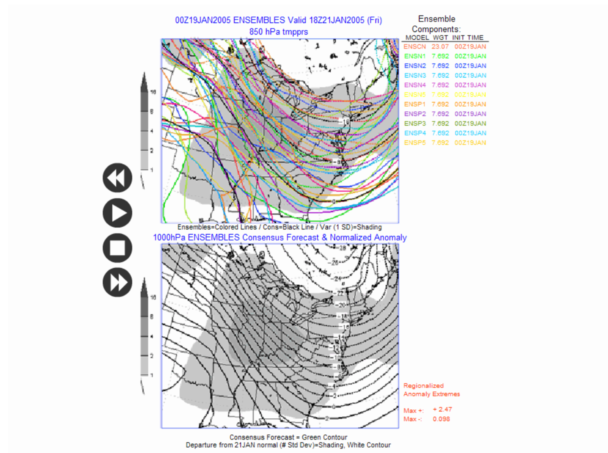


18. 850 hPa Temperature Loop

Instructor Notes: This loop shows the evolution of our 850 hPa mean and spread. Later we will look at some probabilities. There are some areas along the southern edge where precipitation type issues may arise. We will now examine the QPF forecasts.

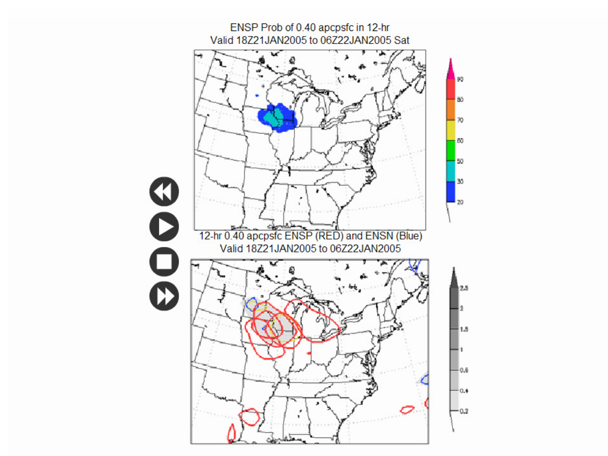
Student Notes:



19. Probability QPF Loop

Instructor Notes: This slide shows the evolution of the MREF QPF fields over time. The forecast is for 0.40 or more QPF in a 12-hour period. We have a confidence in SNOW with 0.40 inches or greater QPF from Illinois to Maryland based on these images. For 4 inch warning criteria the confidence is in the 30 or greater range…good enough for a 30% HWO. Later we will look deeper into precipitation type issues.

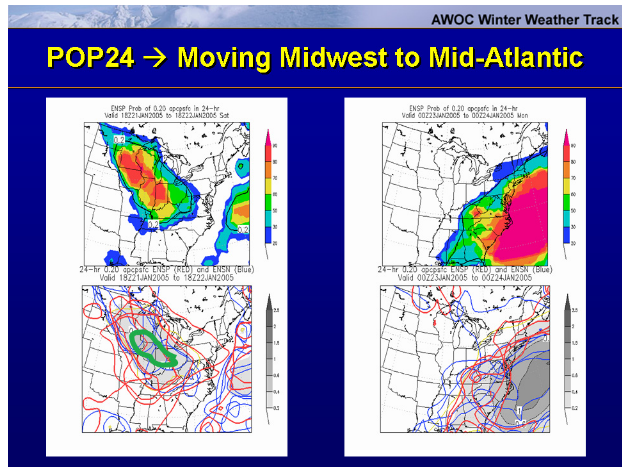
Student Notes:



20. POP24 Moving Midwest to Mid-Atlantic

Instructor Notes: These images show the probability of 0.20 inches or more of PRECIPITATION for the 24 hour periods ending at 18Z Saturday 22 January 2005 and 00Z Monday 24 January 2005. These images show a stripe of high probability in the Midwest on Saturday and along the coast on Sunday. We will see a loop of the evolution of the precipitation shield shortly. Note that the ensemble mean in the lower panels shows a broad area of 0.40 inches or more QPF over the Midwest on Saturday.

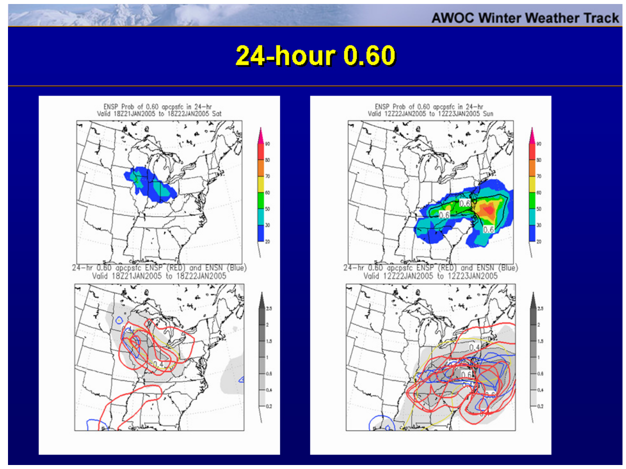
Student Notes:



21. 24-Hour 0.60

Instructor Notes: These two charts show the 24-hour exceedance of 0.60 inches of QPF...or the potential for 6 or more inches of snow along the path of our storm. The times selected are to illustrate a few points...lets look at the Midwest panel on the left. First, in the mean there is no 0.60 contour. Our probabilities show a broad 20% area in the blue color and two smaller 30-50% areas in the cyan color. There is a small area of 50-60% over IL and IA. Once the storm gets to the coast note that there is more QPF and the ensemble mean does produce a 0.60 contour. The probabilities are much higher, 50% or higher with some areas exceeding 70%. Unfortunately, as we will see later on the precipitation type in the Mid-Atlantic region was not certain to be snow.

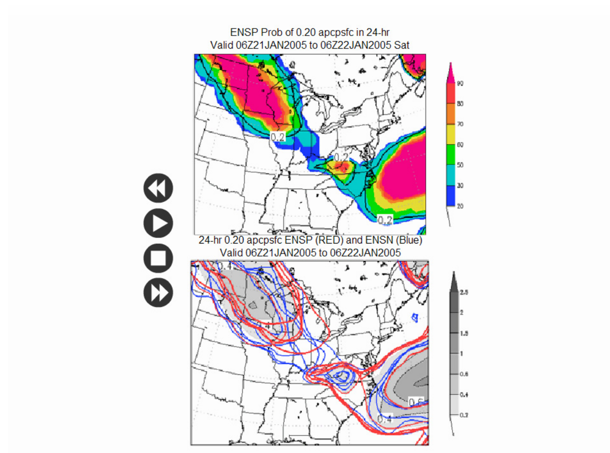
Student Notes:



22. Loop of 0.20 Inch Probability

Instructor Notes: This is a loop of the 0.20 inch probabilities in 24 hour periods. They illustrate how the precipitation shield moves along with our cyclone. The lower panels show the ensemble mean QPF for each time period and each members forecast location of the 0.20 contour if it was present. We want to exploit the information available in both the mean forecasts and the probability forecasts.

Student Notes:



23. Forecast Implications

Instructor Notes: These forecasts show us the high probability based on the 30% threshold for 0.4 and 0.60 inches of QPF and conditions cold enough for snow. Thus we might have some quantifiable confidence in an HWO for a winter storm along the path of this potential snow swath. We did not look to closely at mixed precipitation implications though they exist and we will examine these problems later.

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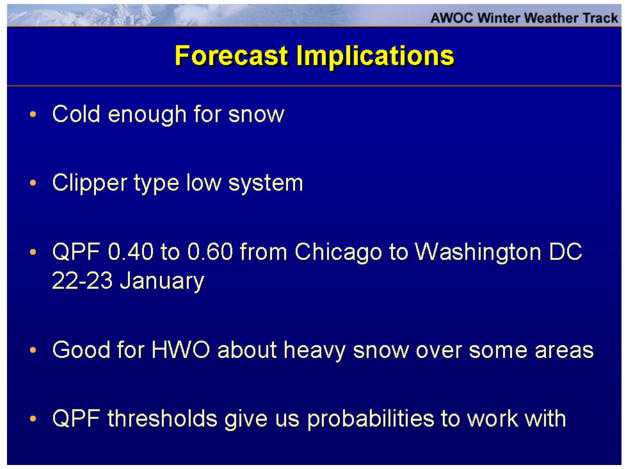

24. Watch Phase-50% Probability 12-48 Hours

Instructor Notes: Now we move into the watch phase...the 50% percent outcome solution. The problems are still the same, we just need to attach more confidence to these forecasts as we are now looking at the 50% probability outcome. At this time frame, the SREF will encompass the entire forecast. But, we will still use some MREF forecasts for demonstration purposes. Additionally, the MREF shows some skill and should be used in forecast from about 18 hours on out. It offers different ICs and a different model core.

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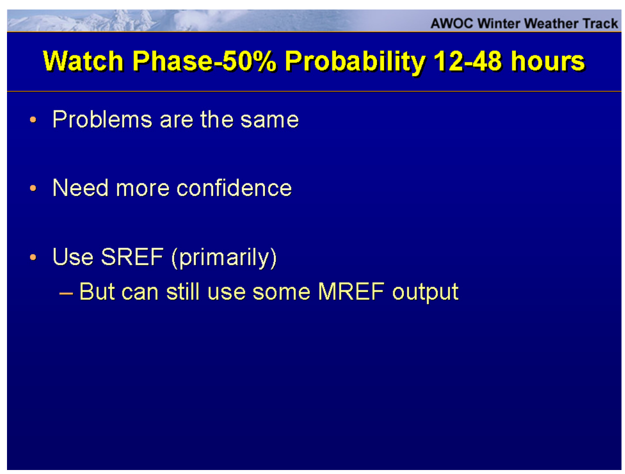
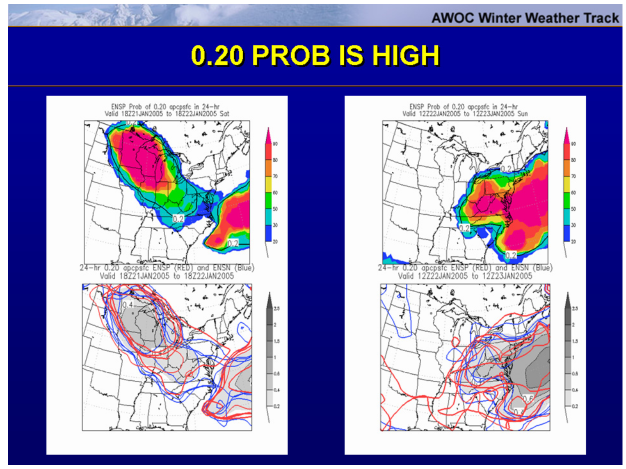


25. 0.20 Prob is High

Instructor Notes: For brevity we do not show the PTYPE or 850 hPa temperatures, but for the most part, snow is the primary type and the mixed precipitation issues are only along the southern 1/3 of the shield. At this threshold we see a high probability of precipitation. Many locations should see at least 2 inches of snow.

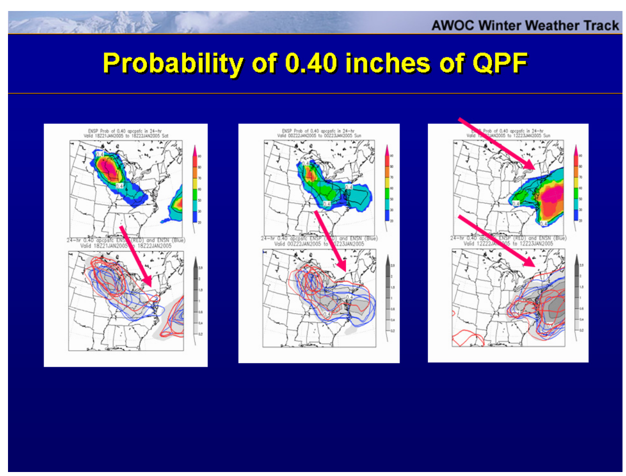
Student Notes:



26. Probability of 0.40 Inches of QPF

Instructor Notes: The probabilities of 0.40 inches of QPF are a bit lower but they still show an area of concern similar to the 0.20 forecasts. A Band of at least 4 inches of snow is forecast from Minnesota to Maryland. Note the few outliers with some precipitation faster and farther east. Next time period we still see some faster and farther north outliers. In the panel on the far right, note that a few members forecast the precipitation shield to extent farther to the north. These outliers would prove to be quite prescient as the heaviest snow in this case was observed in southeastern New England. There were so few that the probabilities based on our contour intervals did not register.

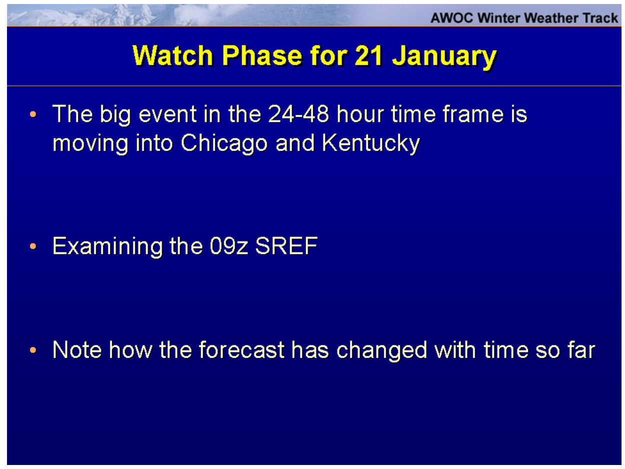
Student Notes:



27. Watch Phase for 21 January

Instructor Notes: At this point we could still use MREF data. But for brevity, we shift to SREF imagery. Experience has shown that there is value in the MREFs in the 18-48 hour range. The data from the MREFs should be considered and an ensemble that mixes the two data sets would have some unique applications in the near future. Recall the SREF has several advantages: It has at least 3 model cores. It has finer resolution.

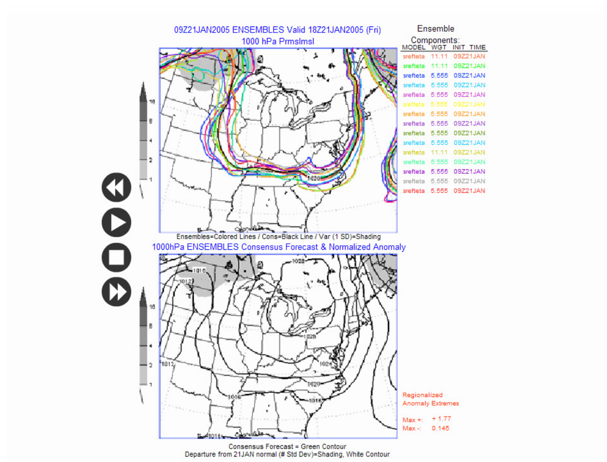
Student Notes:



28. Loop of SREF MSLP Forecast

Instructor Notes: This loop shows the SREF MSLP forecasts from forecasts initialized at 09Z 21 January. In the interest of time, we start the loop deeper into the forecast. Just watching the loop we can clearly see how uncertainty grows with time and we can see that most uncertainty is focused where the weather is going to be significant. The spaghetti plots quickly get quite noisy! A few things to note, compared to our earlier MREF loop, these forecasts are initialized 2 days later so they should be more accurate. Show more detail because the SREF is of higher resolution thus it captures the secondary development better. Stop the loop at 21Z on the 22nd and move to 00Z on the 23rd. Note that in the mean by 00Z there is a secondary low along the coast over the Delmarva. But there is big spread showing lots of uncertainty in the timing, location, and intensity of the secondary cyclone. By 03Z all members have a low over the western Atlantic with big spread to the north due to timing, intensity, and location issues. The noisy spaghetti is telling us the same thing. Uncertainty is a significant issue!

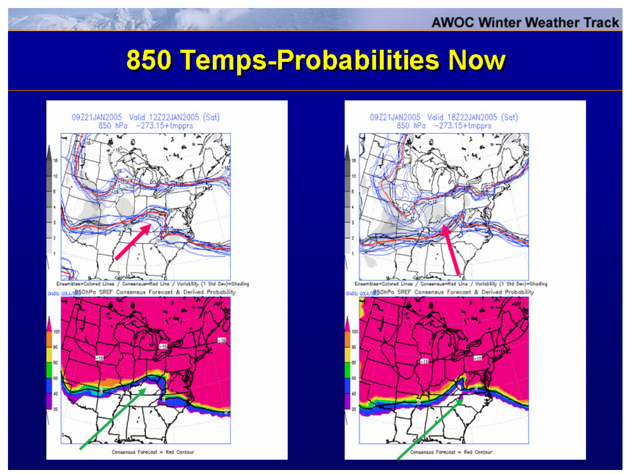
Student Notes:



29. 850 Temps-Probabilities Now

Instructor Notes: The probabilities of the 850 hPa temperature being 0 degrees C or less are shown in these two images. The red area is clearly cold enough for snow. Based on the cyclone track in the previous loop, it was clear that some warm air could work into the precipitation shield ahead of the primary cyclone. We can see that from southern Illinois to Ohio there is a chance of the 850 hPa temperatures being at or above 0 degrees C. The red arrows highlight the areas where each SREFs 0 degrees C contour appear to show considerable variation. In the right hand panel, the spread is quite large in this region. The GREEN arrows in the lower panels show the same areas of uncertainty put in a quantifiable context...a percentage. On the left hand side, we can see that mixed precipitation was a concern over northern Ohio and Kentucky at this time. Observations revealed that mixed precipitation did occur over Ohio (not shown). 2 m temperature probabilities would help define further refine areas of potential freezing rain.

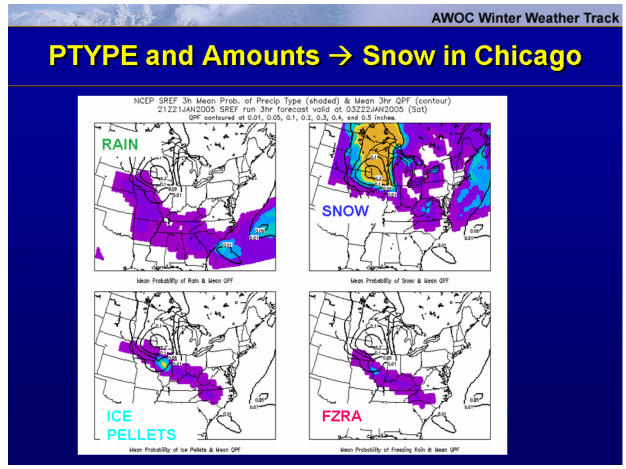
Student Notes:



30. PTYPE and Amounts: Snow in Chicago

Instructor Notes: These forecasts show the probability of precipitation by type. They also show the instantaneous 3-hour ensemble mean QPF. As our previous 850 mb temperatures suggested, we can see the risk of freezing rain and ice pellets along the southern edge of our baroclinic zone. The cold areas, like the Chicago area, are pretty much forecast to be snow. On the next slide, we will look at a plume diagram for Chicago in the cold air. Comparing critical temperature probabilities to model PTYPES can help reinforce conceptual models and reinforce confidence in snow and mixed precipitation areas. We could compare PTYPE, 850 hPa and 2m temperatures during an event to help with the forecast process.

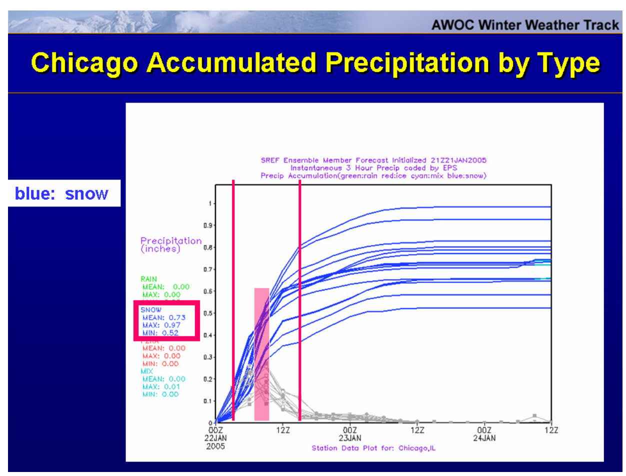
Student Notes:



31. Chicago Accumulated Precipitation by Type

Instructor Notes: This plume diagram is for Chicago. It is color coded by PTYPE. Blue is snow. The smaller contours show the 3-hour precipitation forecasts for each SREF member. We do not know which member any forecast is from. These data tell us that Chicago will get all the precipitation as snow. Most of the snow will accumulate between about 03Z and 15Z on the 22 of January. If your warning criteria was for 6 inches of snow, using a first guess 10:1 ratio, you might expect a high probability of meeting the warning criteria around 09Z on the 22nd. For impacts, clearly TAFS would need snow in them at the time indicated. Road crews would probably be busy just trying to keep up with the snow accumulations between 06 and 15 UTC on 22 January. It would appear that around 0.70 inches of QPF is close to the median.

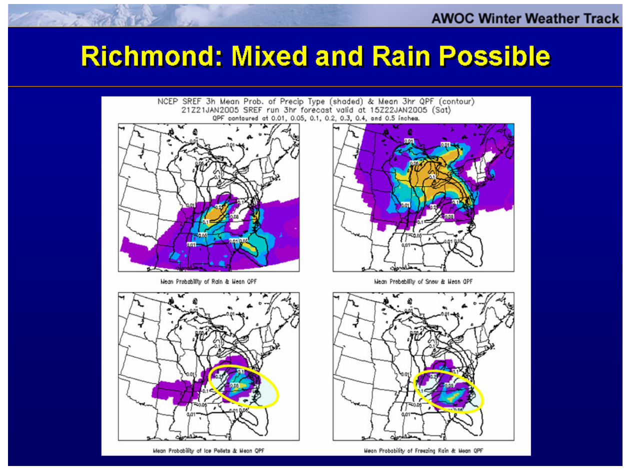
Student Notes:



32. Richmond: Mixed and Rain Possible

Instructor Notes: This is another PTYPE diagram from the same SREF run just valid later in time. Base on our previous 850 hPa temperature forecasts we can see that the areas of concern (yellow circles) based on our knowledge of 850 hPa temperatures are being identified by the PTYPE forecasts in the members too. In this time period, freezing rain and ice pellets are a concern in Virginia and North Carolina. We could use a plume diagram to delve deeper into this issue.

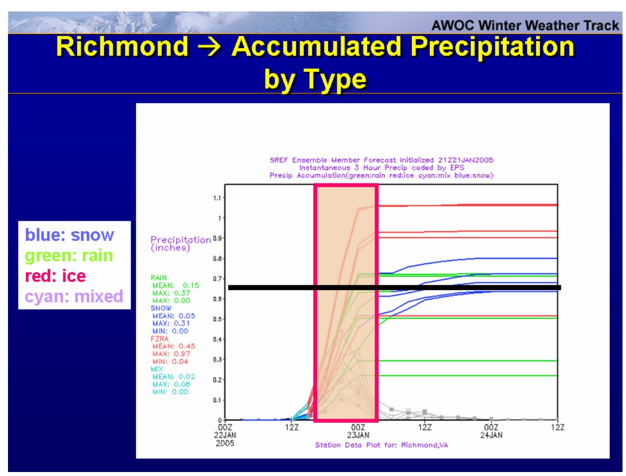
Student Notes:



33. Richmond: Accumulated Precipitation by Type

Instructor Notes: This is a plume diagram for Richmond, VA. The red and cyan lines show freezing rain and ice pellet potential. A few members also show the chance of rain (GREEN) and snow (Blue). The time of maximum QPF and potential ice accretion appears to be from 15 UTC on the 22 to about 03UTC on the 23rd. Big snow is a low probability outcome here. Note the large range of potential QPF and a clustering around 0.65. This diagram has PDF that shows lots of uncertainty in total QPF and lots of uncertainty in precipitation type.

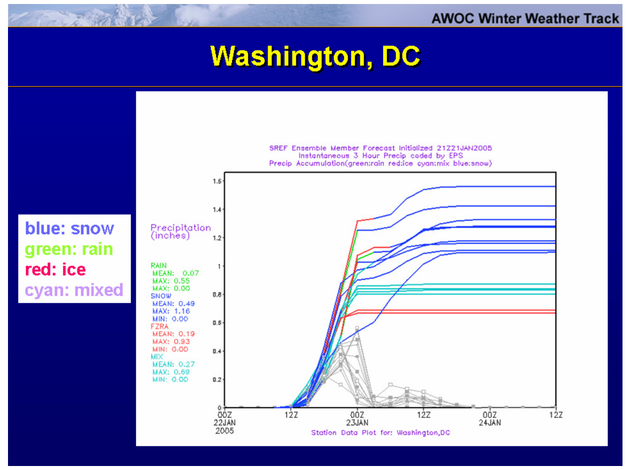
Student Notes:



34. Washington, DC

Instructor Notes: This plume is for Washington, DC. Unlike Richmond, less freezing rain and more ice pellets are forecast. There are only a few members that show any time of rain. Snow is the dominant precipitation type. But ice pellets and freezing rain were still a forecast concern.

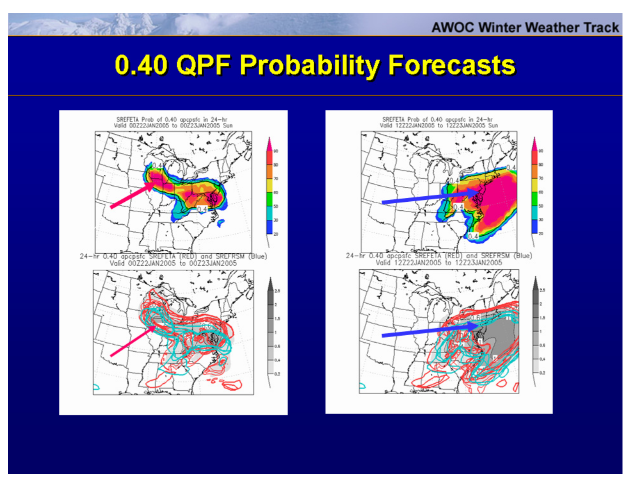
Student Notes:



35. 0.40 QPF Probability Forecasts

Instructor Notes: These two images show the probability of exceeding 0.40 inches of QPF in a 24 hour period and the ensemble mean and spaghetti plots in the lower panels. The red arrows show us the high potential for 0.40 inches or more QPF in Chicago. We already know this region is cold enough for snow and the PTYPE in the SREF is 100% snow. As the storm moves to the east, the blue arrows show a higher probability of 0.40 inches of snow. These forecasts significantly underestimated the observed snowfall in southern New England. Note, however, that there is a 0.60 contour in the ensemble mean. With a 10:1 ratio we have confidence in a 4 inch or greater snowfall in Chicago in along the East Coast from this storm. If our warning criterion was 4 inches we would be good to go for a watch or warning depending if you were forecasting in Chicago or New York. But if we had a 6 inch criterion you might want to see the 0.60 probabilities OR if you expected a 20:1 ratio you might want to see another threshold QPF.

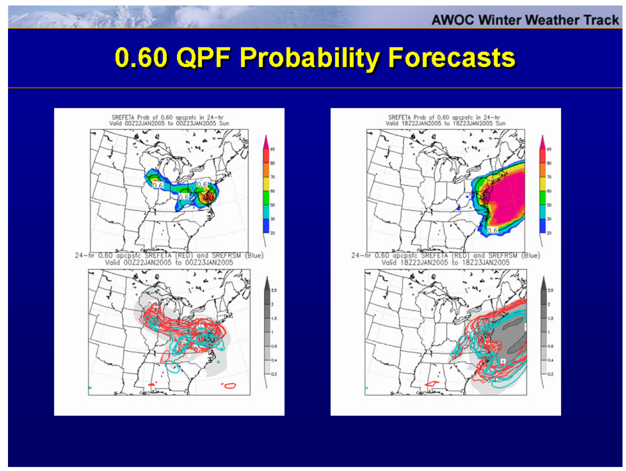
Student Notes:



36. 0.60 QPF Probability Forecasts

Instructor Notes: As luck would have it, the ensemble gods provided us these two images showing the probability of exceeding 0.60 inches of QPF in a 24 hour period and the ensemble mean and spaghetti plots in the lower panels. Our confidence is high for some 6 inch snows in and south of Chicago land on Saturday (left) and along the East Coast on Sunday. Other time periods, though not shown, provided more details of areas in between.

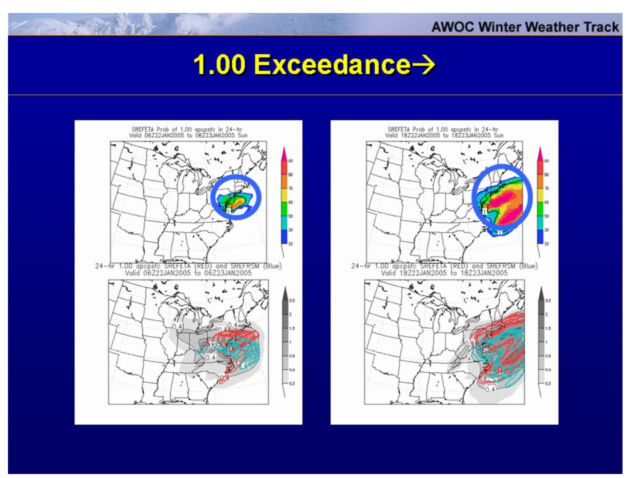
Student Notes:



37. 1.00 Exceedance

Instructor Notes: Ah, and for the really big snows...we have the 1.0 inch exceedance. We can see our confidence goes down as the areas get smaller. One could see the value of various potential thresholds in winter storms of snow amounts and in rain events depending on your flash flood thresholds. Thus illustrating both the strength and limits of these charts. We need to get better at developing thresholds for various needs!

Student Notes:



38. Ensemble Watch 12-48 Hours and 50%

Instructor Notes: This table summarizes the watch process models and the ensemble forecast products. Other than we are now looking for the 50% probability outcome, not much has changed. Our two single models are quite deterministic when used by themselves. But they too can be mixed into the ensemble. Due to the finer resolution these “deterministic” models deserve a big weight in a blended ensemble. They are valuable forecast tools and should not be overlooked. However, our SREF and MREF offer us the best set of tools. The SREF having the added advantage of multiple ICs and multiple MCs.

Student Notes:

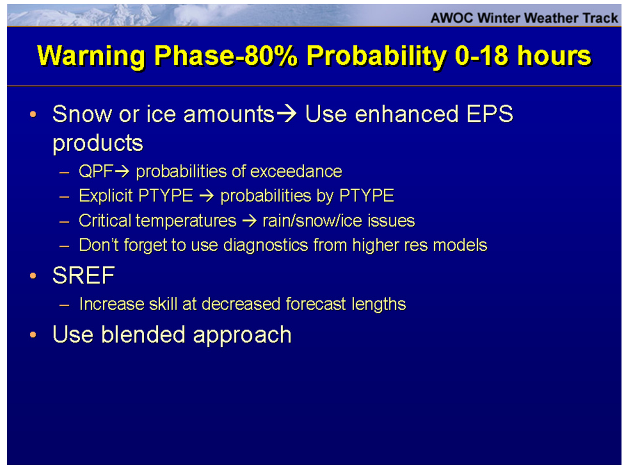
Ensemble → Watch
12-48 hours and 50%

Forecast Range	Initial Conditions (IC)	Model Errors (ME)	Remarks
Short-Range→ NAM	1 IC	1 Model Core (MC)	• May be jumpy run-to-run • Binary 0/1 • High resolution makes it valuable ensemble member
Short-Range→ GFS	1 IC	1 MC	• May be jumpy run-to-run • Binary 0/1 • Valuable ensemble member
NCEP MREF→ 12-48 hours	11 ICs	1 MC	• Probability displays • Only 1 Model core
NCEP SREF→ 12-48 hours	Multiple ICs	Multiple MCs	• Finer resolution data • More model cores than MREF

39. Warning Phase-80%, Probability 0-18 Hours

Instructor Notes: The warning phase is a shorter term forecast but with it comes increased expectations. The NWS would like warnings to be the 80% likely outcome event. The forecast issues change little and EPS tools change very little, unless the event takes you by surprise and is an extremely short-term event. Due to uncertainty in forecasting it is clear why such short lead times are in order. Longer fused warnings will more than likely be lower probability outcomes. Ideally would have local scale ensembles for this time period. We could use enhanced ensemble products and blend ensembles with climatic anomalies. The tools are the same. At very short-ranges 0-12 hours, diagnostics from the higher resolution model may be in order. It should be noted that experiences and case studies show increased skill at decreased forecast length in the SREFs. A blended ensemble with the SREF and deterministic models may have added value here for updating the forecasts.

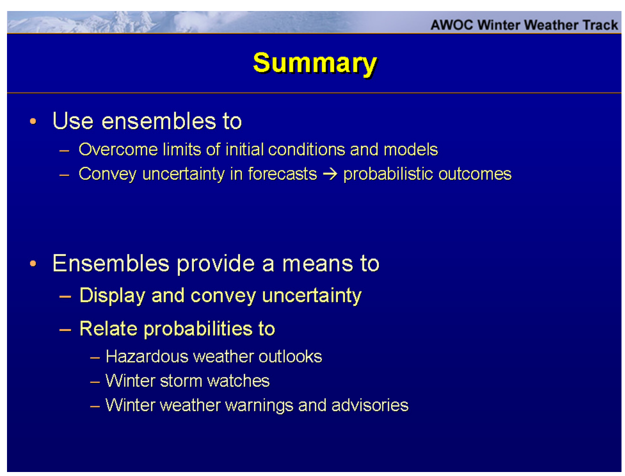
Student Notes:



40. Summary

Instructor Notes: We discussed why you need to use ensembles in the forecast process. Our goal is to overcome uncertainty in the initial conditions and the errors introduced by the models themselves. There is no perfect model. Chaos in weather forecasting and increased uncertainty with forecast length is an issue we will never overcome. Output from ensembles help us visualize and quantify uncertainty in weather forecasts. The probabilistic displays attach a quantitative measure to the forecast process. With these probabilities, we can make better decisions and provide users better decision making capabilities. Ensembles will help us improve at designing the decision. We worked through a brief case study showing ensemble products that may be of value in forecasting a winter storm. These products, such as the QPF where it was forecast to be snow, help us assign probabilities which we can than match to our HWO, and WSW products. Not quite a perfect match but one that is getting incrementally better.

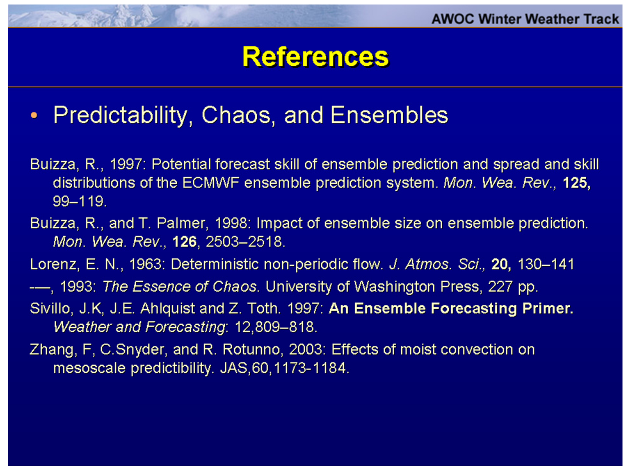
Student Notes:



41. References

Instructor Notes: I have included a few references on predictability, chaos, and ensembles here. There are many other good papers. I strongly recommend the Zhang paper for those interest in just how sensitive our models can be based on physics packages.

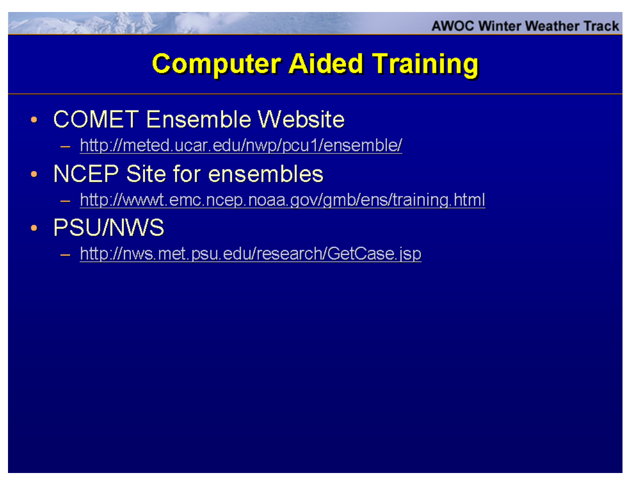
Student Notes:



42. Computer Aided Training

Instructor Notes: There is a plethora of information available on the web to facilitate ensemble training. I have shown just 3 sites. I highly recommend the COMET web site for those just starting out learning about ensembles. I also find the NCEP site quite valuable. Our local site in State College also has useful information and cases studies related to ensembles and winter storms.

Student Notes:



43. Questions???

Student Notes: After going through this lesson if you have any questions, first ask your SOO or your local AWOC Winter facilitator. Your AWOC facilitator should be able to help answer most questions. If you need additional info from what your SOO provided, please send an e-mail to the address on the slide. This address sends the message to the instructors who developed this IC. Our answer will be CC'd to your SOO so that they can answer any similar questions that come up in the future. We may also consider the question and answer for our FAQ page. Thanks for your time and good luck on the exam!

Student Notes: