1. IC4.2 Part 1: Building a Climatology

Instructor Notes: Welcome IC 4 lesson 2 part 1…My name is Richard Grumm and in this module we will cover …The Climatological degree of rarity of hazardous weather—building a climatology.

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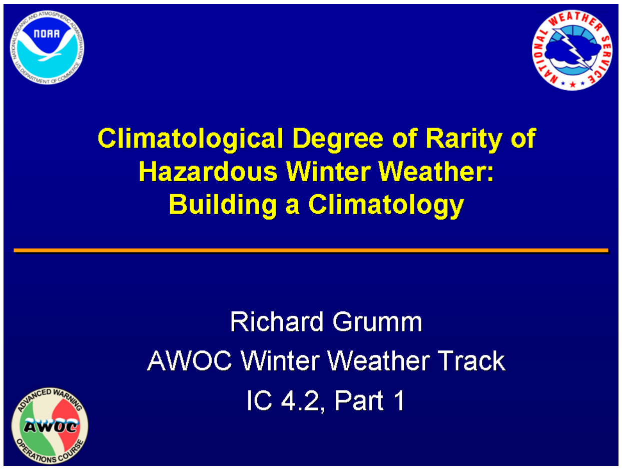

2. Objectives

Instructor Notes: Our objectives are to help understand how to create a useful climatology using the NCEP/NCAR global re-analysis (GR) data. We will talk a little about the newer, high resolution North American Regional Re-analysis (NARR) data too. We will attempt to quantify if an anomaly is significant and its potential impact on the weather situation at hand. The direct applications will vary around the United States based on which features affect winter storms the most in your area. Several examples will be presented to help you understand how to apply Standardized anomalies to determine if an event may be significant or not. Finally, we will apply the climatic means and standard deviations to model data. This will allow you to gage your system against the climatology. However, it is important to understand the limitations of using the low resolution global re-analysis (GR) data when examining forecasts from higher resolution NWP output.

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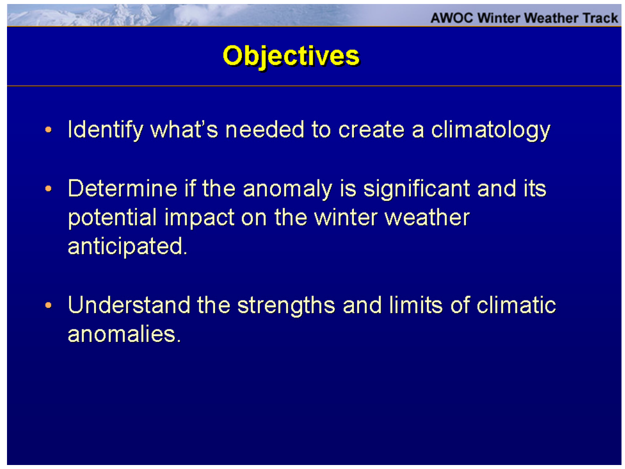

3. Funnel Approach

Instructor Notes: We will take a funnel approach to this process. First, we will cover the key aspects of developing a climatology. We will then show how this climatology can help define the features associated with significant storms. Then we can determine the known ranges and parameters to examine. Then, using a forecast approach, we can compare the NWP output from deterministic models and ensembles to see how a forecast storm compares to the climatology. This should provide us a measure of how normal or abnormal the event may be so we can gage its potential impact. Our goal is to be able to discriminate between an ordinary winter storm and a potentially significant winter storm.

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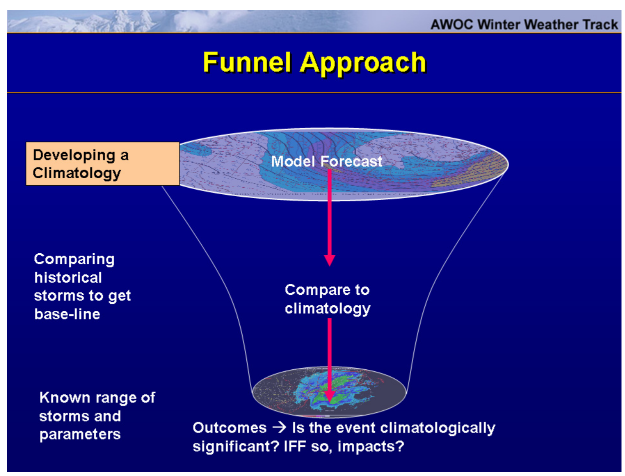

4. Creating a Climatology

Instructor Notes: Most standards for climatological data sets require a recent 30-year period of record, simply called POR. This is covered in two papers in the references including the MWR paper by Hart and Grumm (2001). A good POR is critical for using climatic data. Most of the data presented here will be from the NCEP/NCAR re-analysis project and will be referred to as the Global Re-analysis. This is a global data set at 2.5 X

2.5 degree resolution. The data is quite coarse. However, a new data set, the North American Regional Re-analysis data set is now available. The GR data has a temporal resolution of 6-hourly data. Means and standard deviations were compute by each 6-hour time period using a 21-day centered mean calculation. This smoothes the data, avoids choppy transitions, and ensures the data sample is large enough. The GR data extends from 1948 to about 5 days from the current day. This provides good case study capabilities. The means and standard deviations are available and well documented.

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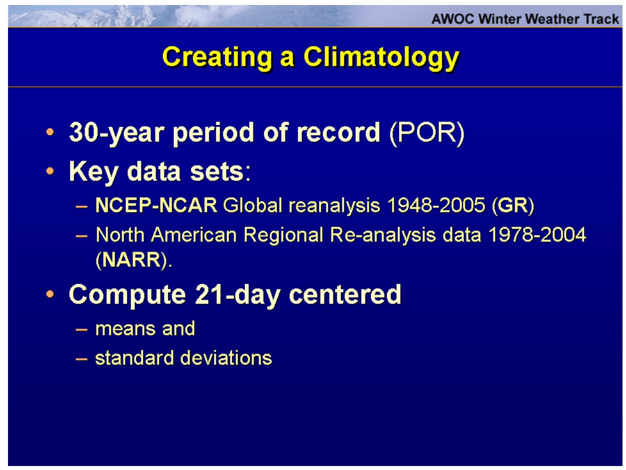

5. The Data is Not Normally Distributed at any Grid Point Over any Domain

Instructor Notes: The figure above shows the 850 hPa temperatures at a point in central Pennsylvania. These data show that the absolute temperatures are skewed. Data rules about a normal distribution do not fully apply. The mode skewed well to the warm side. Using the counts we can arrive at a frequency of occurrence. Based on the number of months or years of data we can assign return periods as we have done in the lower image (blue arrow). The lower image shows the departures from normal of the 850 hPa temperatures at this point and the return period. These data are also skewed. Note that most of the time the 850 hPa temperature anomalies lie between 2 and -2 SDs from normal. With the current data, there is a long return time between -4 and +4 SD events. There have been more -3 to -4SD events than +3 to +4SD events, a part of the skewed nature of these data.

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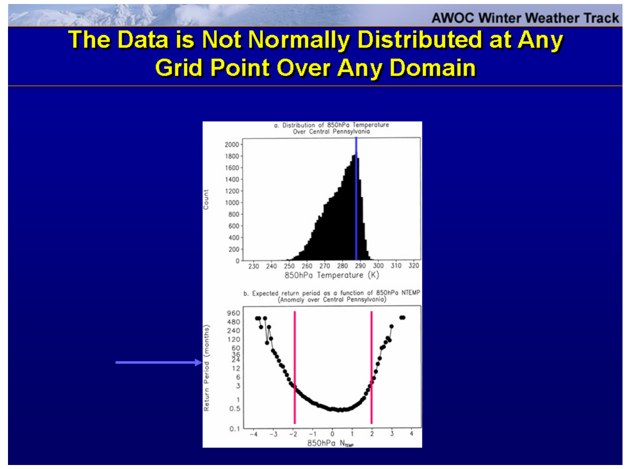

6. GR Has Critical Fields for Winter Weather Forecasting

Instructor Notes: The GR data has many fields including singular fields such as MSLP, 2m temperatures, accumulated precipitation, and PWAT. Multi-level fields such has heights, temperatures, U-wind, V-wind, and specific humidity are available at mandatory levels. All these fields have climatologies which can be used to accomplish case studies and to compare to operational model forecasts.

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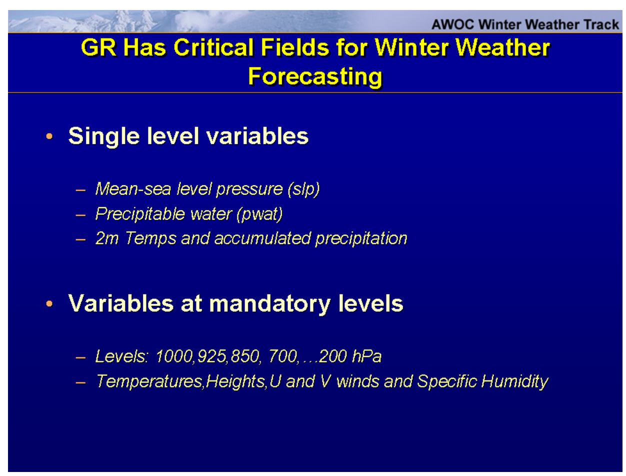

7. Current GR Climate 30-Year POR 1970-2000

Instructor Notes: The Current GR climatology has means and standard deviations for all fields. They are for each 6-hourly time period and represent a 21 day mean centered on that date. This eliminates noise using daily values and sharp transitions from month-to-month if monthly values were used. The NARR data has more fields and higher spatial and temporal resolution. However, a robust set of 21-day centered means and standard deviations is not available and a 30-year POR is still a few years off.

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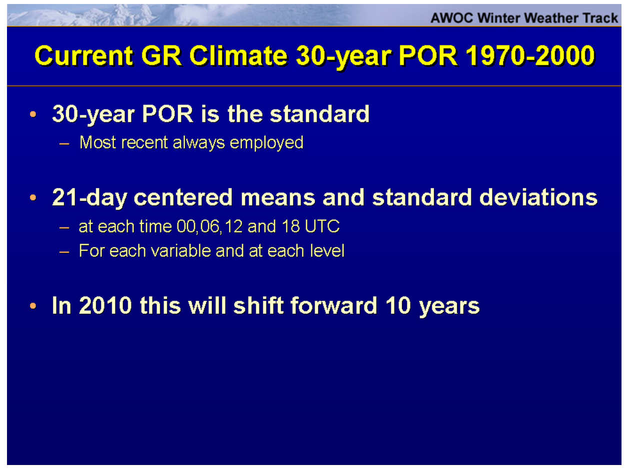

8. North American Regional Re-Analysis Data (NARR)

Instructor Notes: In the near future, we will do case studies and examine model forecast compared to NARR fields. This high resolution data set has far more fields, more vertical levels, and is available in 3-hour time increments. The higher spatial and temporal resolution of these data will allow for more mesoscale diagnosis of past cases and capture focused anomalies better than the GR data. This data also will allow local mesoscale modeling studies. This data set has several disadvantages including a limited area focused over North America and the data only goes back to 1979. Thus, pre 1979 case studies cannot be conducted and there is not a good 30-year POR yet in the data set to build reliable means and standard deviations.

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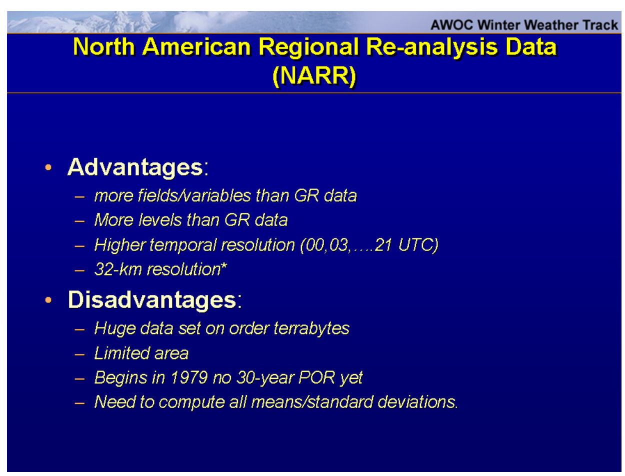

9. Climatic Anomalies

Instructor Notes: Most forecasters are used to the more traditional anomaly where a simple departure from the mean is shown. As a rule, bigger values will occur at higher latitudes. Thus a 200 m below normal 500 hPa low center in the Gulf of Alaska may be quite ordinary while a 90 m below normal 500 hPa low center over the Golan Heights might be climatically significant. Standardized anomalies allow us to probe into the significance of an anomaly quickly eliminating seasonal and latitudinal influences. Lets look at this closer…

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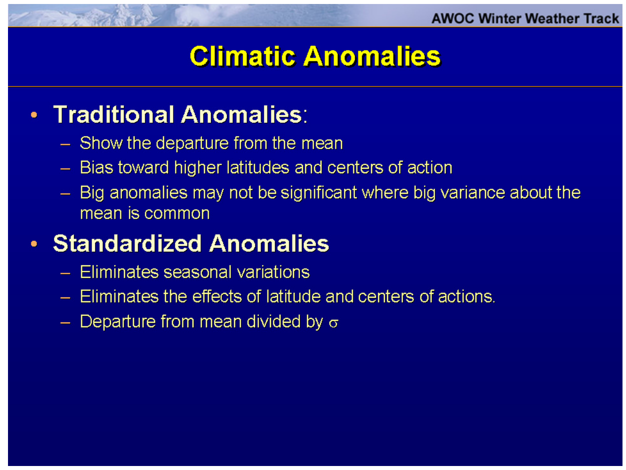

10. GR Means and Standard Deviations for Mid-January

Instructor Notes: This image shows the 500 mb mean heights and the value of 1 standard deviation (meters) on 15 January. The 1900 date is just a place holder these are 21-day centered mean values. Generally, the 500 mb height decrease poleward and the value of 1 SD increase poleward. The latter also appears to have some longitudinal effects. Lets look an example. Over the Gulf coast…the mean height is about 5760 m and 1 SD is about 40 m. So, plus or minus 1 SD is a range of 5720 to 5800. Near James Bay…the mean height is about 5220 m and 1 SD is a whopping 140 m. Our +/- SD range would be 5080 to 5360 m. -----This is the kind of information we want to leverage with standardized anomalies. The 500 and 850 charts show us the centers of action…note the mean low is associated with large values of 1 SD and the baroclinic zone over the western plains is another "center of action". We have two effects…latitudinal and "centers of action".

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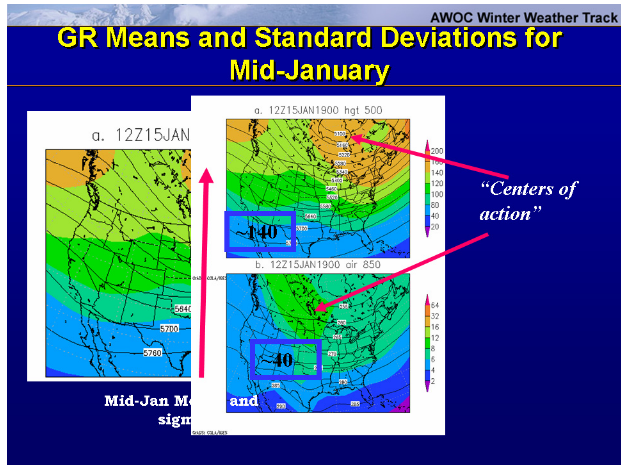
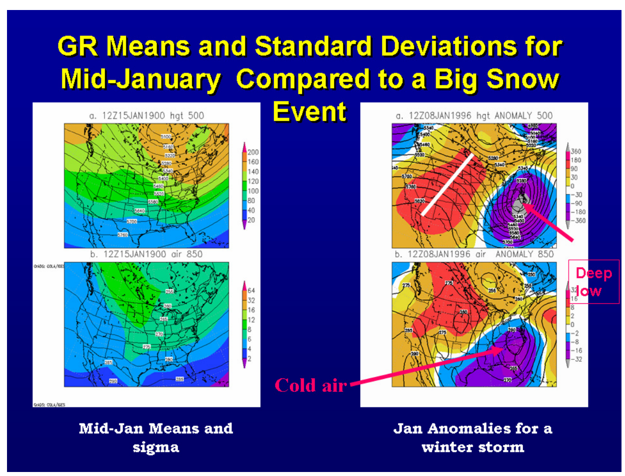


11. GR Means and Standard Deviations for Mid-January Compared to a Big Snow Event

Instructor Notes: Now we will compare the data for a single day relative to the climatology (on the right). This was a major snow storm along the East Coast in 7-8 January 1996 and this particular image is from 1200 UTC 8 January 1996. Note that we have some big anomalies at 500 mb. We have the deep trough in the east (purple and gray colors) and a large ridge in the west. Both appear to be "anomalous". At 850 mb we see a cold surge in the southeastern United States and warm air over the western US. Our goal now is to assign some meaning to these data by dividing out what 1 standard deviation is from the data on the right hand side.

Student Notes:



12. Traditional Verse Standardized Anomalies-Focus on What's Significant

Instructor Notes: Here we see the traditional anomalies on the left and the standardized anomalies on the right. They are for the same time, a big East Coast winter storm from January 1996. Note how the traditional anomalies show lots of areas of concern. The largest anomalies appear in the trough and ridge. When these anomalies are standardized, by dividing by the value of 1 standard deviation, a more coherent pattern begins to emerge. On the standardized anomaly chart, we can clearly see the areas where the anomalies depart the greatest from normal and gauge how significant the values on the left are. They key is to determine significant areas where the atmosphere is showing big departures. Then we can quickly identify the significant weather events. Standardized anomalies allow us to do this quickly.

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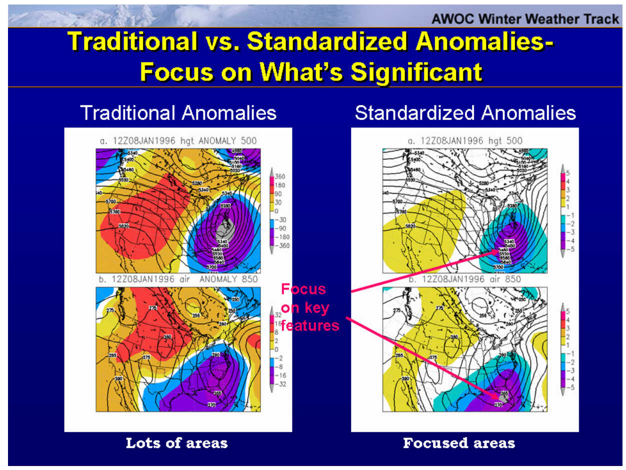
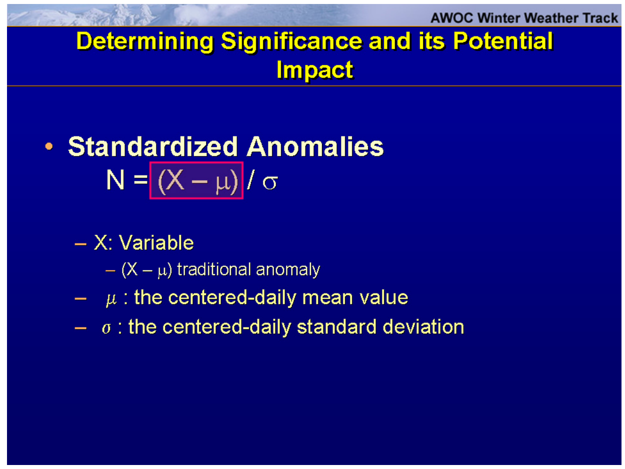


13. Determining Significance and its Potential Impact

Instructor Notes: The equation above shows how we compute standardized anomalies (N). Note that the traditional anomaly is buried in the equation. It contains useful information. They key difference between the traditional and standardized anomaly is that we divide the former by 1 standard deviation to arrive at the latter. We can compute standardized anomalies for variables, such as sea level pressure, temperatures, heights, u and v winds, and other fields. We can compute these quantities over the various vertical levels arriving at a value for N at each level for each variable. N can be computed at a point over a domain.

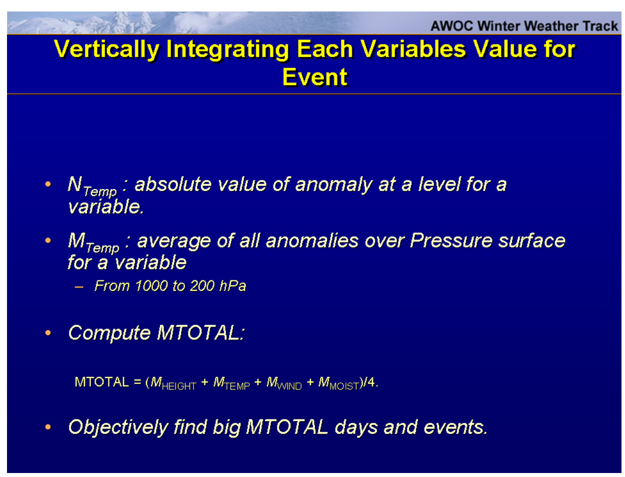
Student Notes:



14. Vertically Integrating Each Variables Value for Event

Instructor Notes: Research has shown that big events, such as the super storm of March 1993, are synoptically significant, and anomalies occur in many fields. One way to measure this is to compute anomalies for variable and at each level and come up with a Mean (M) value for that variable integrated over all levels. The integration is pressure weighted. We can get M for each variable and then equally weight them and arrive at an MTOTAL. We do this for temperatures, heights, moisture, and wind. The wind has two components including the U and V winds, but their average is equally weighted to the other fields. It turns out Big MTOTALS are associated with most historic events in the literature. We will show some examples. There is some value to M and N values for more mesoscale weather events.

Student Notes:



15. Interactive Quiz #1

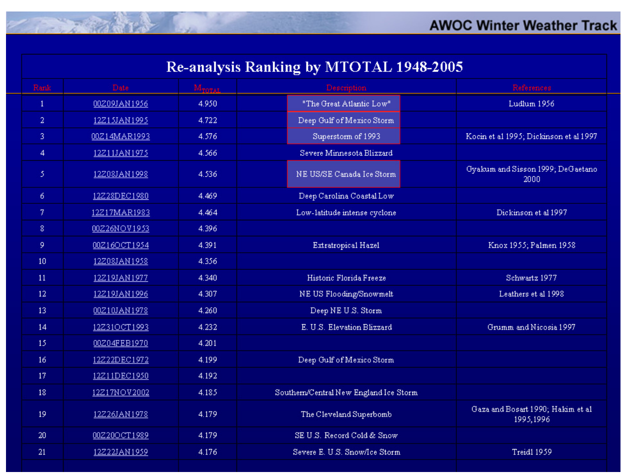
Instructor Notes: Take a moment to complete this quiz.

Student Notes:

16. Re-Analysis Ranking by MTOTAL, 1948-2005

Instructor Notes: This is table showing the top 20 MTOTAL events from 1948-2005. It is interesting to note that most of the big storms were found in the published literature, pointing out how these larger events tend to be significant. Read data and convey information as an example for the 1st 5 events through the big 1998 ice storm.

Student Notes:



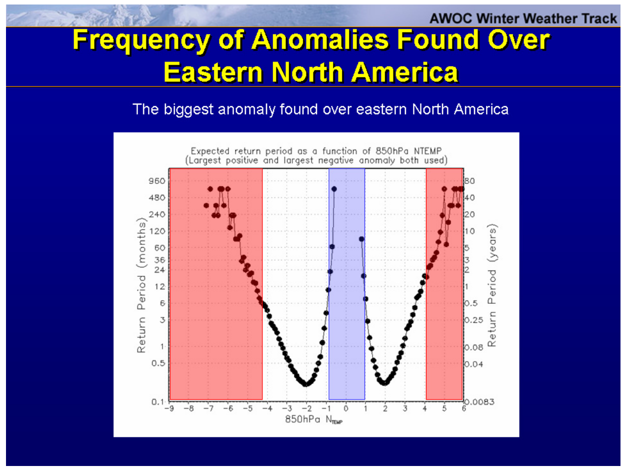
Re-analysis Ranking by MTOTAL 1948-2005

Rank	Date	M_{TOTAL}	Description	References
1	00Z09JAN1956	4.950	"The Great Atlantic Low"	Ludlum 1956
2	12Z15JAN1995	4.722	Deep Gulf of Mexico Storm	
3	00Z14MAR1993	4.576	Superstorm of 1993	Kocin et al 1995; Dickinson et al 1997
4	12Z11JAN1975	4.566	Severe Minnesota Blizzard	
5	12Z08JAN1998	4.536	NE US/SE Canada Ice Storm	Gyakum and Sisson 1999; DeGaetano 2000
6	12Z28DEC1980	4.469	Deep Carolina Coastal Low	
7	12Z17MAR1983	4.464	Low-latitude intense cyclone	Dickinson et al 1997
8	00Z26NOV1953	4.396		
9	00Z16OCT1954	4.391	Extratropical Hazel	Knox 1955; Palmen 1958
10	12Z08JAN1958	4.356		
11	12Z19JAN1977	4.340	Historic Florida Freeze	Schwartz 1977
12	12Z19JAN1996	4.307	NE US Flooding/Snowmelt	Leathers et al 1998
13	00Z10JAN1978	4.260	Deep NE U.S. Storm	
14	12Z31OCT1993	4.232	E. U.S. Elevation Blizzard	Grumm and Nicosia 1997
15	00Z04FEB1970	4.201		
16	12Z22DEC1972	4.199	Deep Gulf of Mexico Storm	
17	12Z11DEC1950	4.192		
18	12Z17NOV2002	4.185	Southern/Central New England Ice Storm	
19	12Z26JAN1978	4.179	The Cleveland Superbomb	Gaza and Bosart 1990; Hakim et al 1995,1996
20	00Z20OCT1989	4.179	SE U.S. Record Cold & Snow	
21	12Z22JAN1959	4.176	Severe E. U.S. Snow/Ice Storm	Treidl 1959

17. Frequency of Anomalies Found over the Eastern North America

Instructor Notes: This is the distribution over eastern North America of 850 hPa temperature anomalies. Large positive and negative anomalies are rare events as are values close to 0. This implies there is some type of anomaly over the region most of the time. The data shows both the POSITIVE and NEGATIVE VALUES. Taken over a large domain, finding values near 0 is RARE! This is not true for a single point. Both cold and warm anomalies peak at around -2 and +2 standard deviations respectively. Note both the warm and cold anomalies are skewed.

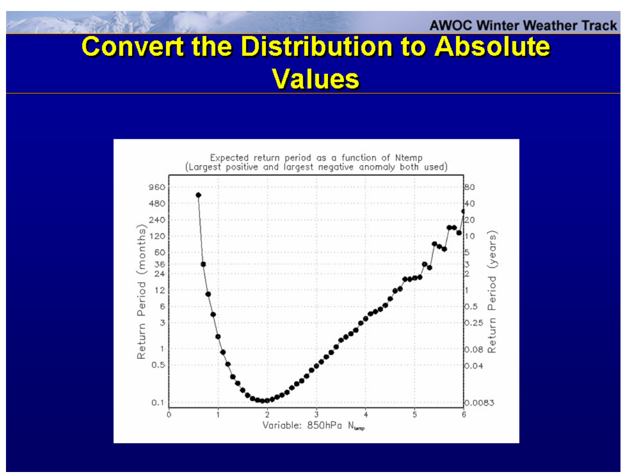
Student Notes:



18. Convert the Distribution to Absolute Values

Instructor Notes: These data are the same as in the previous figure except taking only the absolute values. Like M-VALUES, this case is at 1 level (850mb). In this case, the distribution shows that around 2 standard deviations departures from normal typically are observed over the eastern United States. Large events, NTOTAL over 5 are quite rare as are values much below 1. These data imply there should be some area of anomalies near +/-2 over the eastern US on any given day. Similar values are found for western North America. But getting these values into your CWA or over a point is not as frequent an event. This is an area still to be exploited.

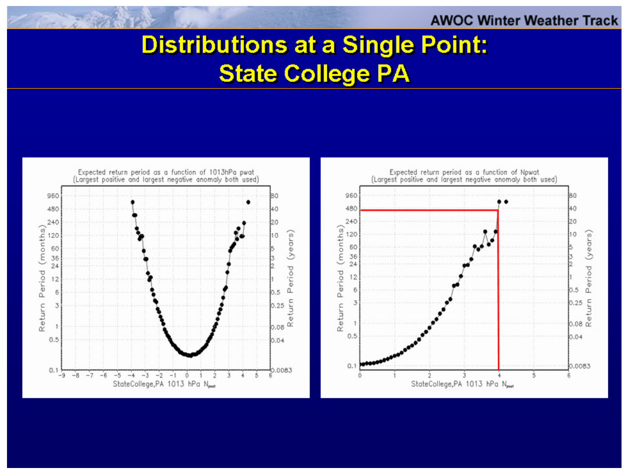
Student Notes:



19. Distributions at a Single Point: State College, PA

Instructor Notes: This data is at a point showing precipitable water values. The data is for 1948-2005. Unlike over an area, the distribution shows values at or near zero occur quite typically. The NTOTAL for this variable looks similar to what one would expect over a region though fewer extreme values have occurred at this point than might be found over a regional domain. Note that a 4SD event has a return period of around 40 years at State College, but it has a 3-month return period over the eastern United States! There have been no 5SD events yet which are observed every 2 years over the eastern United States. This data have applications at points and could be used at a local office. When a big anomaly is over your forecast region may be when these values are significant.

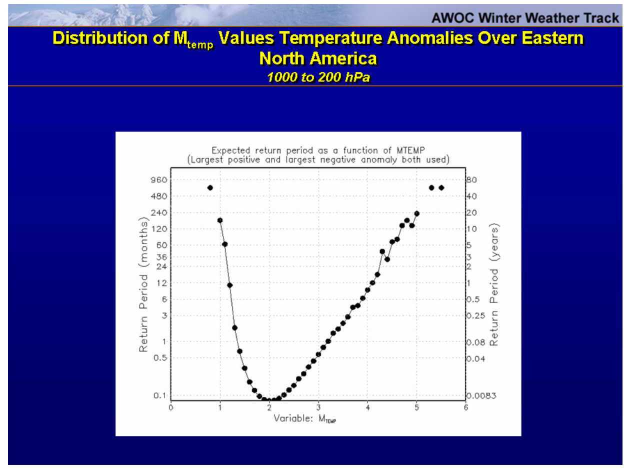
Student Notes:



20. Distribution of M_{temp} Values Temperature Anomalies Over Eastern North America: 1000 to 200 hPa

Instructor Notes: MTOTAL for temperatures is the sum of each level's NTOTAL values. The sum in the GR data is 1000 to 200 hPa and includes 925 hPa values. M can be computed for all variables, and a mean MTOTAL is derived. This allows cases to be rated. All tropical cases need to be removed!

Student Notes:



21. Interactive Quiz #2

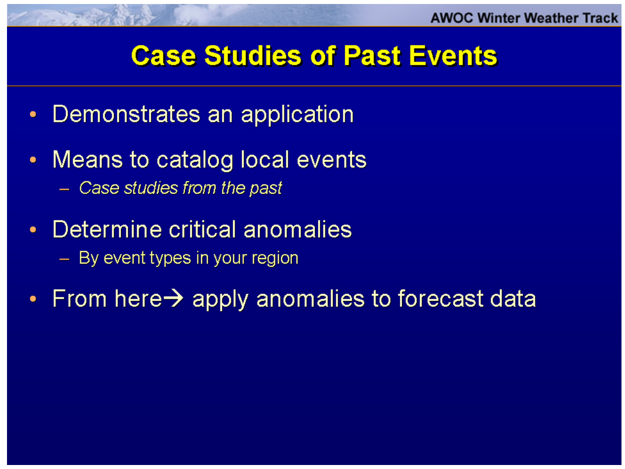
Instructor Notes: Take a moment to complete this interactive quiz.

Student Notes:

22. Case Studies of Past Events

Instructor Notes: We will now look at a quick case study using the superstorm of 1993. It will demonstrate how to use these data. I will show you that you have the means to catalog local events and do case studies to find which anomaly fields are significant to your forecast problems. You can determine critical anomalies by event types and seasons in your region. From here lets look at the #3 case.

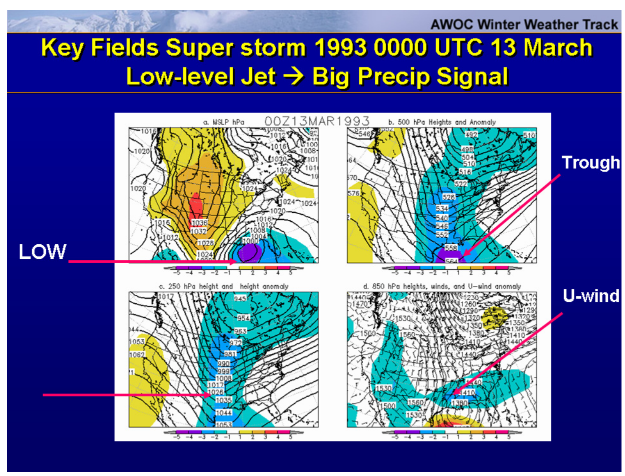
Student Notes:



23. Key Fields Super Storm 1993 0000 UTC 13 March: Low-Level Jet --> Big Precip Signal

Instructor Notes: We have select fields from the GR and the standardized anomalies for 0000 UTC 13 March 1993…the superstorm. Note the deep and anomalous low in the Gulf of Mexico. -3SD anomalies are pretty impressive and the deep 500 and 250 hPa trough. And at 850 mb note the anomalous U-wind anomalies…Many snow and heavy rain storms have this anomalous easterly wind in them at 850 hPa.

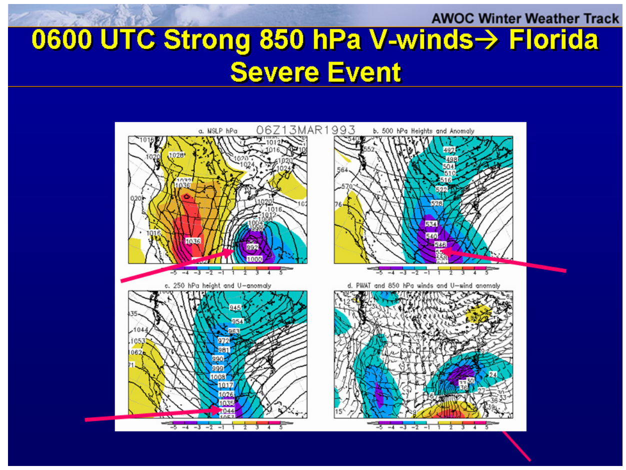
Student Notes:



24. 0600 UTC Strong 850 hPa V-Winds: Florida Severe Event

Instructor Notes: We now move 6-hours into the future. The low is much deeper now as is the 500 mb height anomalies. The easterly wind anomalies are in the -4 SD below normal range. We say -4 SD because there is an EASTERLY not a WESTERLY anomaly in the U winds. Now if we switch images…we can see the 850 hPa V-wind anomalies. These data show the strong southerly jet in the warm moist air. We now have precipitable water shown too. A strong southerly jet has been shown as another heavy rain feature and in the warm season with unstable air…a severe weather signature…Florida had severe weather with this event.

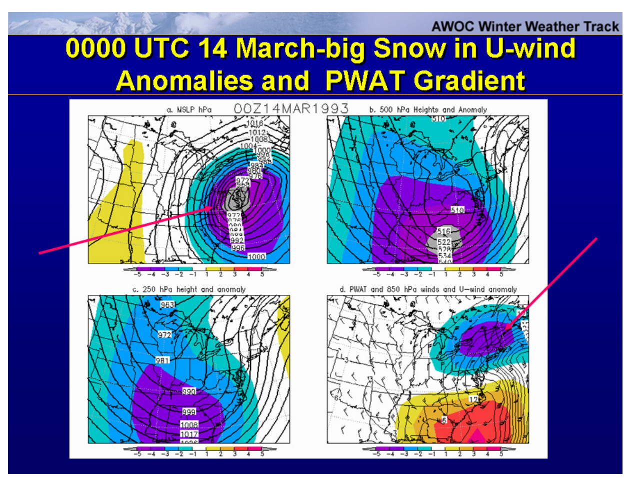
Student Notes:



25. 0000 UTC 14 March-Big Snow in U-Wind Anomalies and PWAT Gradient

Instructor Notes: We move up the coast to see the storm over the Northeast. Note the more than -5 SD anomalous low over the Mid-Atlantic region and the large swath of above normal easterlies north of the surface cyclone at 850 mb. This anomalous U-winds are a good signature in nearly all northeastern United States heavy snow cases. Recently, we have noted some heavy snow storms, such as October 2005 in the northern plains associated with strong easterly wind anomalies. Similarly, a major snow storm in Colorado in March 2003 also had some anomalous low-level 850 mb winds. Lets see how this looked in the NARR data.

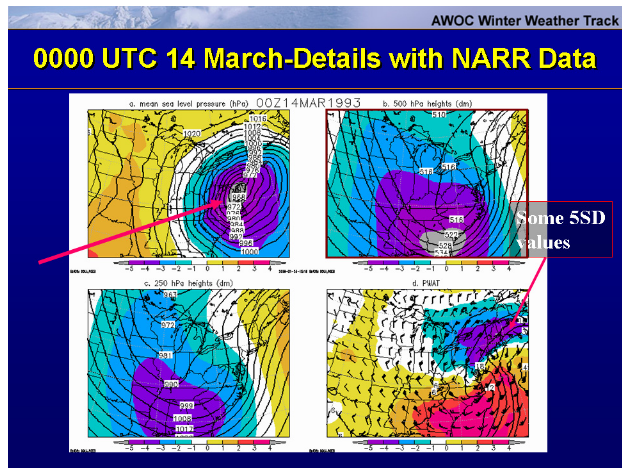
Student Notes:



26. 0000 UTC 14 March-Details with NARR Data

Instructor Notes: This image is really the same as the previous image except all the contours are from the 32km NARR data. We computed the departures from normal using the GR data. I do not have good means and standard deviations of all the fields yet. Note the stronger low and better area of the low center. Note the cut-off 500 hPa low that was really not as defined in the GR data. Some observations: NARR fields are more sensitive and provide more detail at lower levels. As the 500 and 250 hPa charts show…changes are less aloft. Wind field details can and do emerge. Look close and see the -5SD anomaly area over NH. Some time soon we will have standardized anomalies at this scale too. This looks like what NAM data might look compared to GR anomalies.

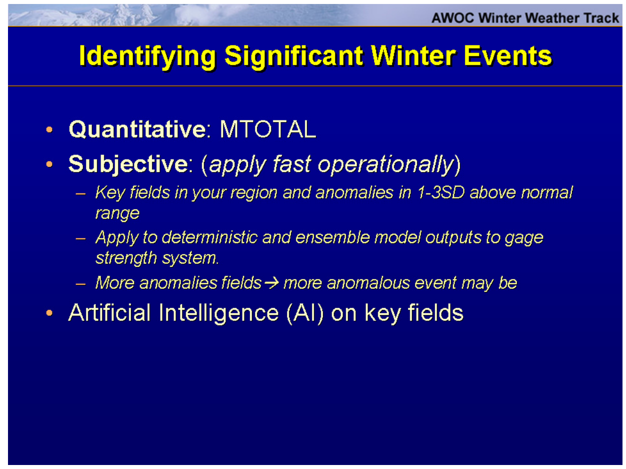
Student Notes:



27. Identifying Significant Winter Events

Instructor Notes: To identify significant events we could apply the MTOTAL method. It’s quantitative but who will do it for you? So, do it subjectively: know the key fields in your region, relate these to key forecast fields, display these relative to ensemble or model output, and get a grasp on the significance of an event. In the future, artificial intelligence programs will help us out here too.

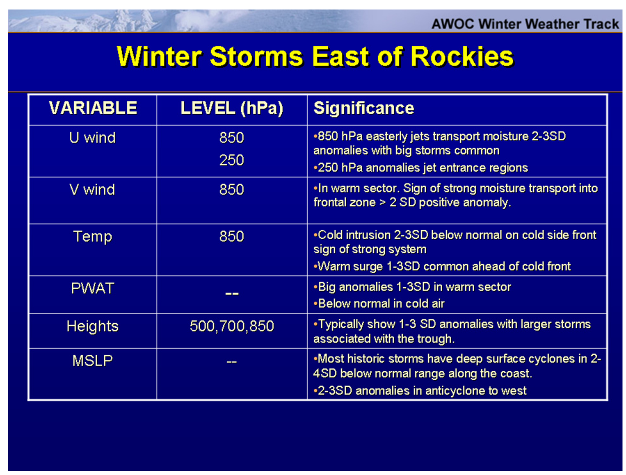
Student Notes:



28. Winter Storms East of Rockies

Instructor Notes: Here are some observations. Many of these were published in WAF back in 2001 and a paper…just on snow storms is in review for East Coast storms.

Student Notes:

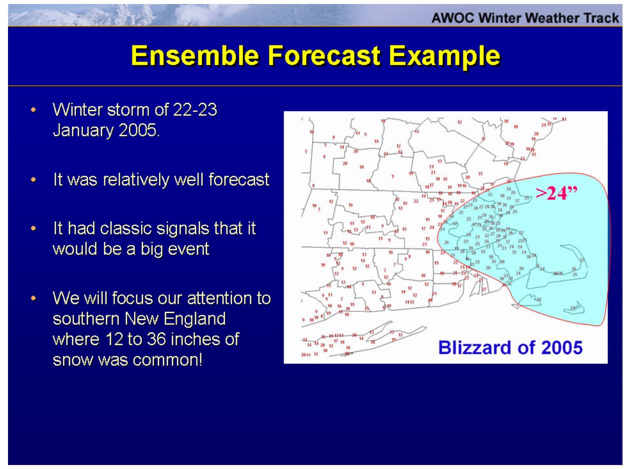


VARIABLE	LEVEL (hPa)	Significance
U wind	850 250	•850 hPa easterly jets transport moisture 2-3SD anomalies with big storms common •250 hPa anomalies jet entrance regions
V wind	850	•In warm sector. Sign of strong moisture transport into frontal zone > 2 SD positive anomaly.
Temp	850	•Cold intrusion 2-3SD below normal on cold side front sign of strong system •Warm surge 1-3SD common ahead of cold front
PWAT	--	•Big anomalies 1-3SD in warm sector •Below normal in cold air
Heights	500,700,850	•Typically show 1-3 SD anomalies with larger storms associated with the trough.
MSLP	--	•Most historic storms have deep surface cyclones in 2-4SD below normal range along the coast. •2-3SD anomalies in anticyclone to west

29. Ensemble Forecast Example

Instructor Notes: Lets look at a forecast example using NCEP short range ensemble data…we might get more impressive results from one model. We will use the winter storm of 22-23 January 2005. This event was well forecast though early forecasts tracked the low and snow threat too far south. It had classic signals of a big snow, a large and anomalous low-level easterly jet north of the cyclone center. We will focus on New England where 12 to 36 inches of snow, quite impressive, was common.

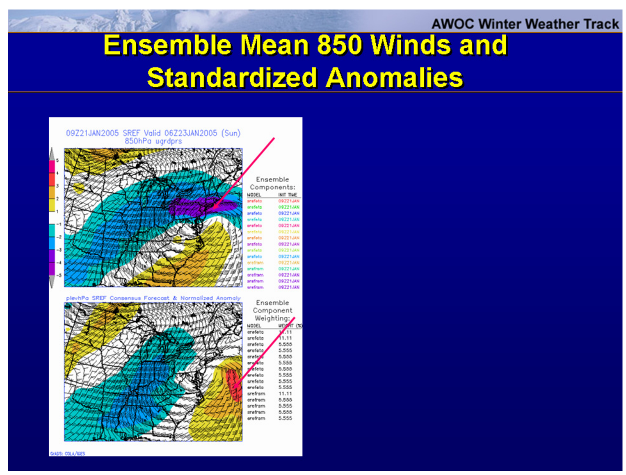
Student Notes:



30. Ensemble Mean 850 Winds and Standardized Anomalies

Instructor Notes: Here are some forecasts compared to the GR data. Focus on the upper charts which show the 850 mb U wind anomalies and the ensemble mean winds. The lower panels show the V-winds anomalies. You can see the above normal southerly winds over the Atlantic in the lower left panel. But we want to focus on the highly anomalous 850 mb easterly winds, and in an ensemble mean forecast at that! These are 45 hour forecasts. The ensemble mean had a -4 to -5 SD wind anomaly over NY and NJ. This was too far north and not strong enough!

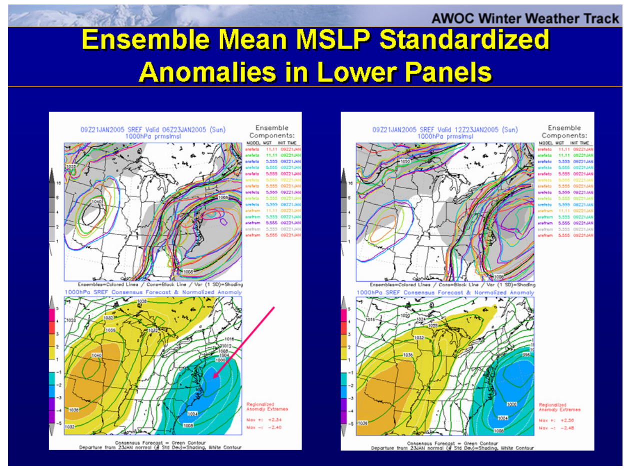
Student Notes:



31. Ensemble Mean MSLP Standardized Anomalies in Lower Panels

Instructor Notes: Same times here but mean-sea level pressure forecasts and anomalies. The upper panels show the plots of all the models used to get the mean, and until you take lesson 6, just let this tell you that there was not total agreement by all the models used here on the low intensity and position. But in the mean the low was forecast to be -2 to -3 SDs below normal. That strong U-wind anomaly was in the gradient north of our low. The old cold conveyer was forecast well. Lets look at forecasts initialized 12 hours later in the next page.

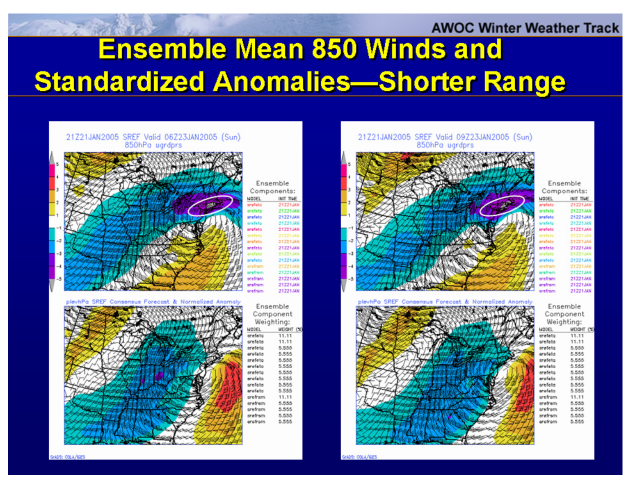
Student Notes:



32. Ensemble Mean 850 Winds and Standardized Anomalies—Shorter Range

Instructor Notes: What a difference 12 hours can make! These forecasts were initialized at 21 UTC on 21 January. Our 850 mb jet is strong now and farther north. We see some -5SD anomalies in the forecast valid at 06Z on the 23 over CT. 3 hours later the -5SD area expands over RI and SE MA too. In early 2005, NCEP did not produce PWAT fields with the trimmed SREF files used to produce these images. But they do now, and it would have helped here to see these fields. The key point here is a key field associated with BIG PRECIPITATION and BIG snow events had an incredibly large anomaly value where it snowed big amounts! The screaming message in these terse images is that this event had the potential to be bit more than your normal January snow fall. We could gage this on just how anomalous a key field in the 850 mb U winds were from normal.

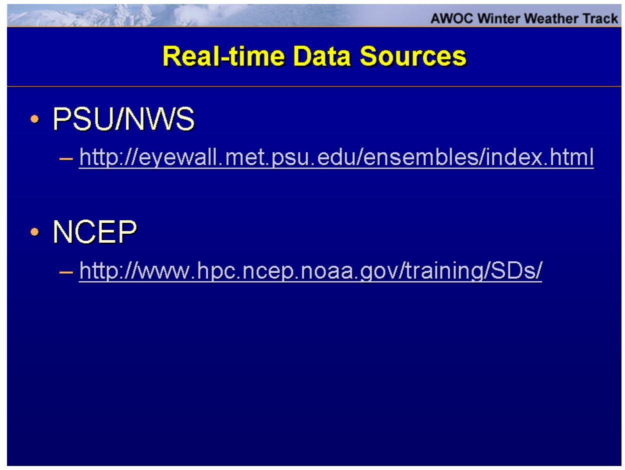
Student Notes:



33. Real-Time Data Sources

Instructor Notes: Links to real-time data.

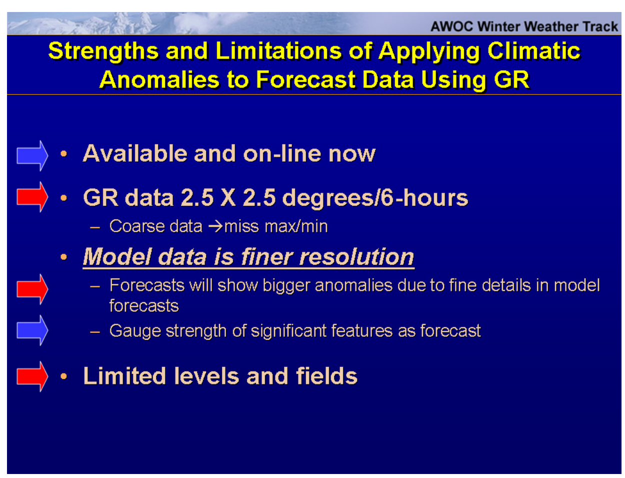
Student Notes:



34. Strengths and Limitations of Applying Climatic Anomalies to Forecast Data Using GR

Instructor Notes: Some strengths and weaknesses of applying climatic anomalies using the GR data should be noted. Strengths: The data is available now! The data goes back to 1948 so you can do lots of case studies We can use it now to gage the strength synoptic scale systems. Weaknesses: Data is only on a 2.5x2.5 degree grid…coarse model data we use is of much finer We could miss the details and local max/min. Limited levels.

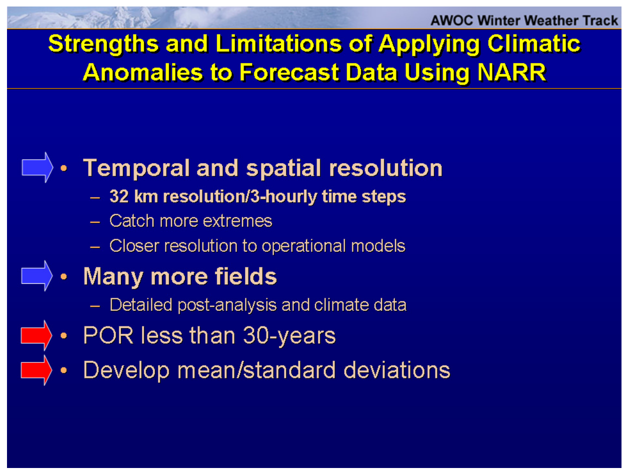
Student Notes:



35. Strengths and Limitations of Applying Climatic Anomalies to Forecast Data Using NARR

Instructor Notes: Some strengths and weaknesses of applying climatic anomalies using the NARR data should be noted. Strengths: The data, for case studies and meso model re-runs is available now! 32km grid higher temporal resolution at 3-hourly intervals! Scale closer to our operational models. Has many more fields and levels than the GR data It should catch more of the local/regional extremes. Weaknesses POR is still not 30 years long. Means are available, but you need to make your own standard deviations. These data sets can be enormous requiring over 6 GB of space to store all the data. Limits most users to case study archives.

Student Notes:



36. Interactive Quiz #3

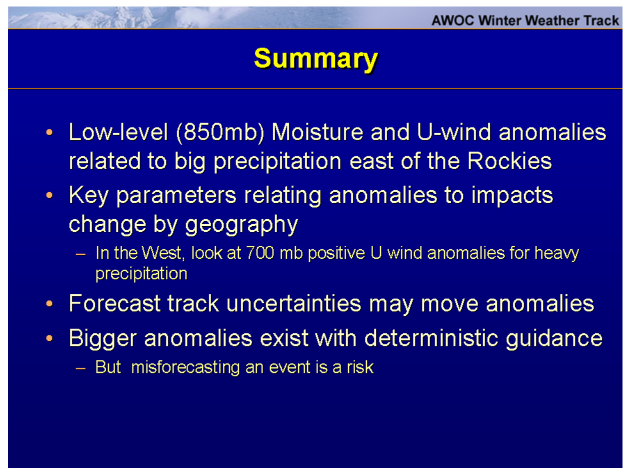
Instructor Notes: Take a moment to complete this quiz.

Student Notes:

37. Summary

Instructor Notes: Low-level (850mb) moisture and U-wind anomalies related to big precipitation east of the Rockies when you're north of the low. Key parameters relating anomalies to impacts change by geography. For example, in the West, look at positive 700 mb U wind anomalies. Forecast track uncertainties may move anomalies. Bigger anomalies exist with deterministic guidance, but misforecasting an event is a risk. Go with probabilistic forecasting to reduce your risk of large forecast errors. You can leverage the anomaly data and know parameters to gage if a storm or winter weather event will be in the range of ordinary or extraordinary.

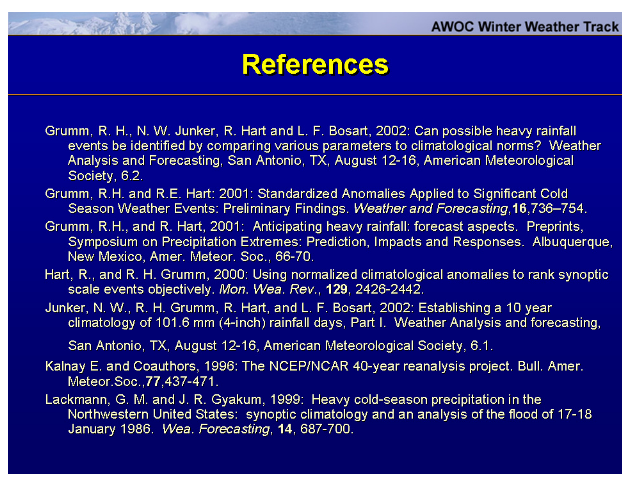
Student Notes:



38. References

Instructor Notes: Here are a few references you may want to check out.

Student Notes:



39. Questions???

Instructor Notes: Current E-mail: icwinter4@wdtb.noaa.gov

Student Notes: