It's been mild and almost snow-free this December. Why? And where do we go from here?
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Although the astronomical winter is just beginning, the meteorological season (December through February) is well underway. For the first couple of weeks temperatures and rainfall have been above average, while snowfall has been nearly nonexistent. This has been a very sharp departure from what was experienced across the area in December 2010, as well as a few Decembers prior to that, when the area experienced below to well below normal temperatures and above normal snowfall. To highlight just how different this winter has been thus far, Figure 1 and 2 below portray departure from average temperatures and snowfall across the Midwest from December 1st through December 20th 2010 (Figure 1) and 2011 (Figure 2). Having established the dramatically different weather pattern observed thus far this winter, what are some explanations as to why it has been so mild and almost snowless? Furthermore, what may the rest of the winter season bring us here in northern Illinois and northwestern Indiana?

Figure 1: Departure from Normal Temperatures and Percent of Normal Snowfall, Dec. 1-20, 2010 (MRCC)
Well below normal temperatures (9-14 deg. below normal) and well above normal snowfall (150%-400% of normal)

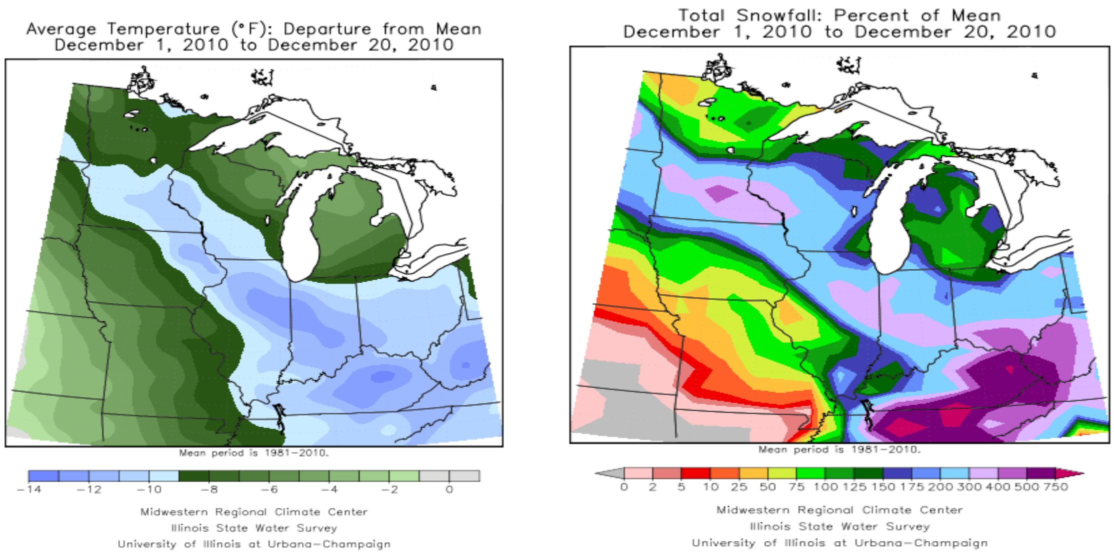
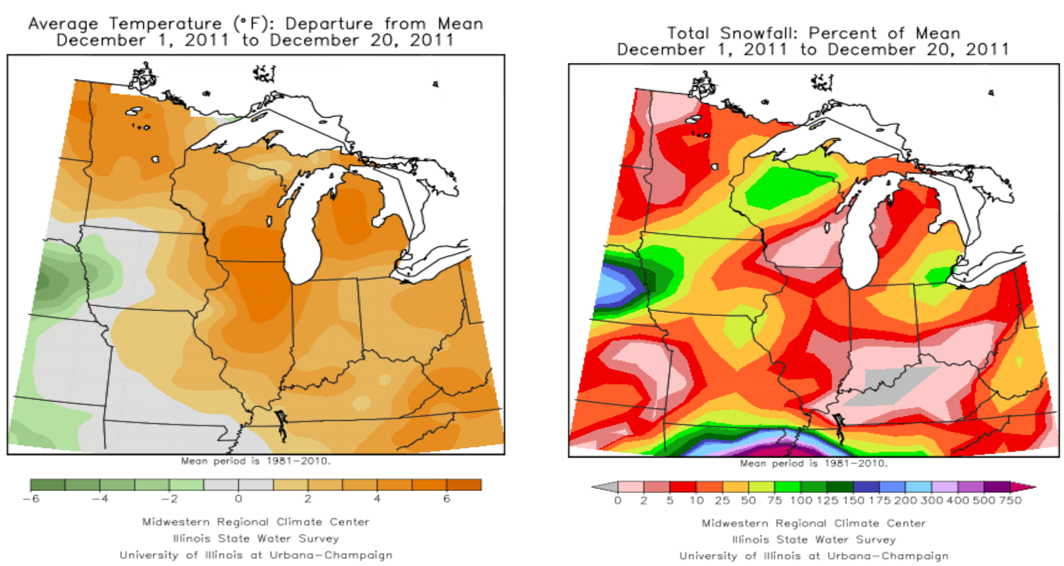


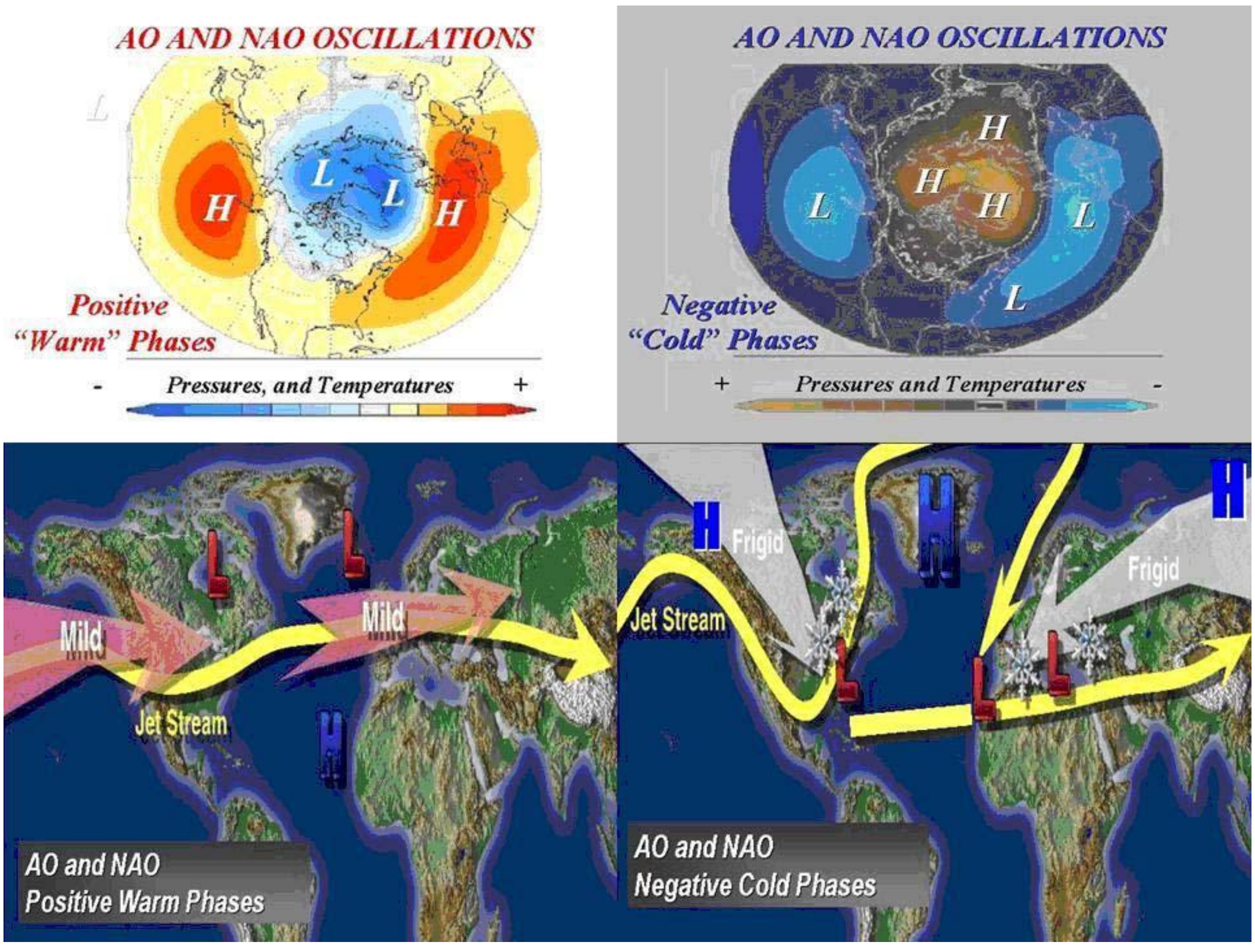
Figure 2: Departure from Normal Temperatures and Percent of Normal Snowfall, Dec. 1-20, 2011 (MRCC)
Well above normal temperatures (4-7 deg. above normal) and well below normal snowfall(2%-25% of normal)



La Nina conditions continue across the equatorial Pacific similar to last year at this time. So the question that arises is why are the conditions this year nearly opposite of what we experienced last year? To answer this we have to consider the behavior of some other large scale phenomenon such as the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO). The NAO and the AO are both naturally occurring oscillations that represent flip flops in atmospheric pressure between the high latitudes and the mid latitudes of the Northern Hemisphere. The main difference is that the NAO is just localized to the North Atlantic Ocean.

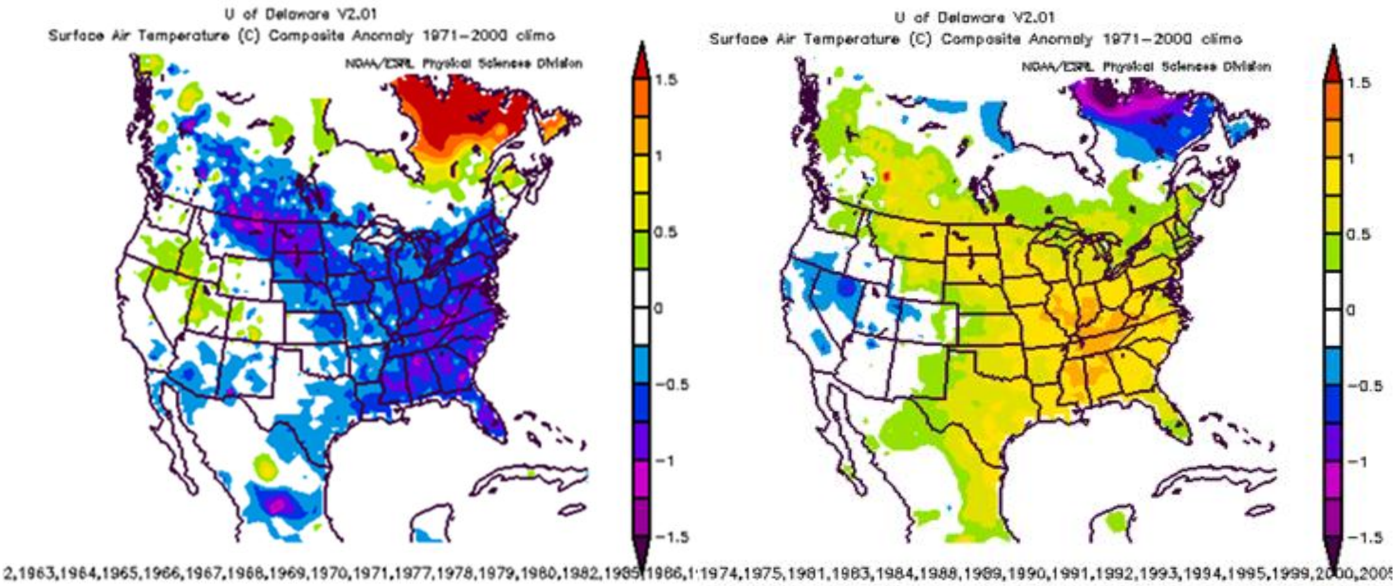
There are two phases that make up the NAO and the AO; a positive and a negative phase. The negative phase of the AO features relatively high atmospheric pressure across the high latitudes of the arctic, with lower pressure across the mid-latitudes. Similarly the negative phase of the NAO features above average pressure across the high latitudes of the North Atlantic near Greenland and Iceland, and lower pressure across the mid-latitudes of the Atlantic (top right of figure 1). The positive phases of the AO and NAO are the opposite of the negative phase (top left of figure 3).

Figure 3: The Positive and Negative Phases of the AO and NAO (icecap.us)



These pressure anomalies have a profound impact on the strength and geographical location of the storm track across the Northern Hemisphere. The negative phases produce a weaker jet across the higher latitudes of Canada and the North Pacific (bottom right figure 3). This allows the storm track and the cold arctic temperatures to drop southward across the central and eastern United States. The higher pressures over the Arctic and Greenland areas also serve as a bottle neck, or blocking in the atmosphere at the higher latitudes. This high latitude blocking also prevents cold air masses from quickly exiting the central and eastern United States. As a result, winters tend to be colder during prolonged periods of the negative phase of the AO and NAO (left side of figure 4). In contrast, the anomalous pressure patterns associated with the positive phases of the NAO and AO induce a stronger westerly upper level jet across the northern latitudes of Canada and the North Atlantic and reflect a lack of high latitude blocking (bottom left figure 3). This makes it very difficult to get cold air to spill southward across the central and eastern United States, and any cold air that does move into the region is not blocked from exiting quickly off to the east with the fast jet stream flow. As a consequence, winters tend to be warmer during prolonged periods of the positive phase of the AO and NAO (right side of figure 4).

Figure 4: Winter season surface temperature anomalies during a negative NAO (left) and during the positive NAO (right)



What has the phase of the AO/NAO been this December relative to the last couple of winters? The tables below display the monthly AO and NAO indices observed over the past two winter seasons. We have been primarily in the negative phases of both the AO and NAO for the past two winter seasons. This has helped lead to fairly cold and snowy winters across much of the United States. However, this is not the case thus far this year. Instead, this year these indices have been predominately positive, indicating that we are experiencing the positive NAO and AO phase. As a result, temperatures have been warmer than average, and much warmer than the conditions we experienced last year at this time.

Arctic Oscillation (AO) index			
	December	***January***	***February***
2009/2010	***-3.4***	***-2.6***	***-4.2***
2010/2011	**-2.6**	**-1.7**	**+1.6**
2011/2012	**>0**	**???**	**???**

North Atlantic Oscillation (NAO) index			
	December	***January***	***February***
2009/2010	***-1.9***	***-1.1***	***-2.0***
2010/2011	**-1.9**	**-0.9**	**+0.7**
2011/2012	**>0**	**???**	**???**

So, what about La Nina? Below average Sea Surface Temperatures (SST) continue across the eastern equatorial Pacific. These cooler waters have major impacts on the placement of thunderstorms across the equatorial Pacific, which in turn affects the mean winter season storm track across North America. Figure 5 below displays the typical winter season storm track during La Niña events. The main characteristic of the flow pattern is the presence of a large area of high pressure across the North Pacific. This area of high pressure acts as a "block" to the upper level flow which causes the storm track to buckle northward around the high and then southward across western North America. Dynamics associated with this atmospheric flow pattern also tends to favor high pressure across the southeastern United States, which in turn buckles the storm track back northward across the mid-Mississippi valley and the Great Lakes region. The main highlights with this highly meridional (north to south) flow pattern are:

1. Tendency for more persistent arctic outbreaks across the Northern Plains and upper Midwest (figure 6).
2. Warmth across the south and southeastern states (figure 6).
3. Above average precipitation in the form of rain and snow across portions of the mid-Mississippi valley eastward through the Ohio Valley.
4. Dry conditions in the south.

Figure 5: The typical upper level jet stream/storm track during La Niña winters.

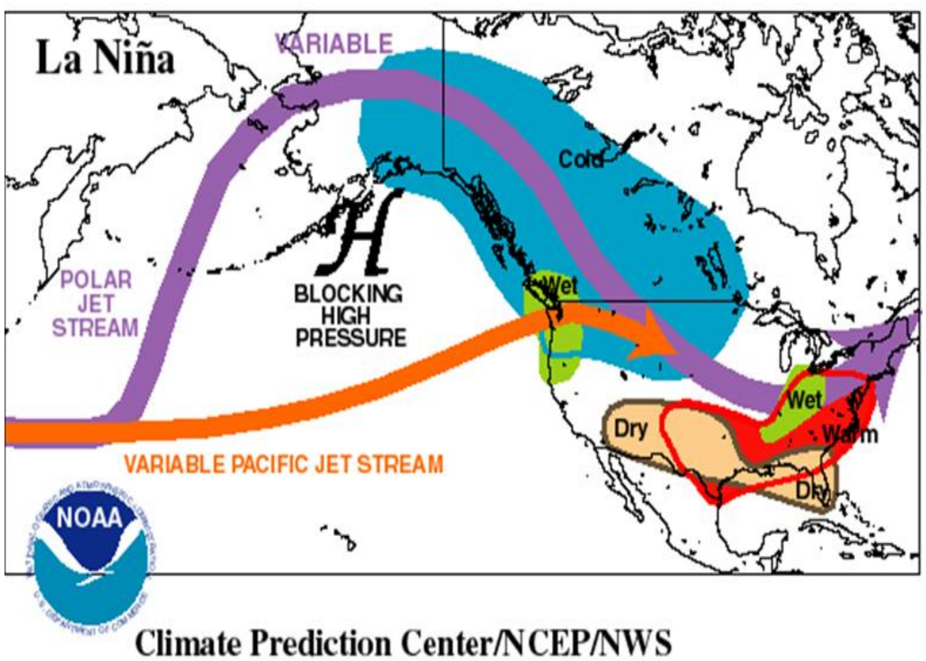
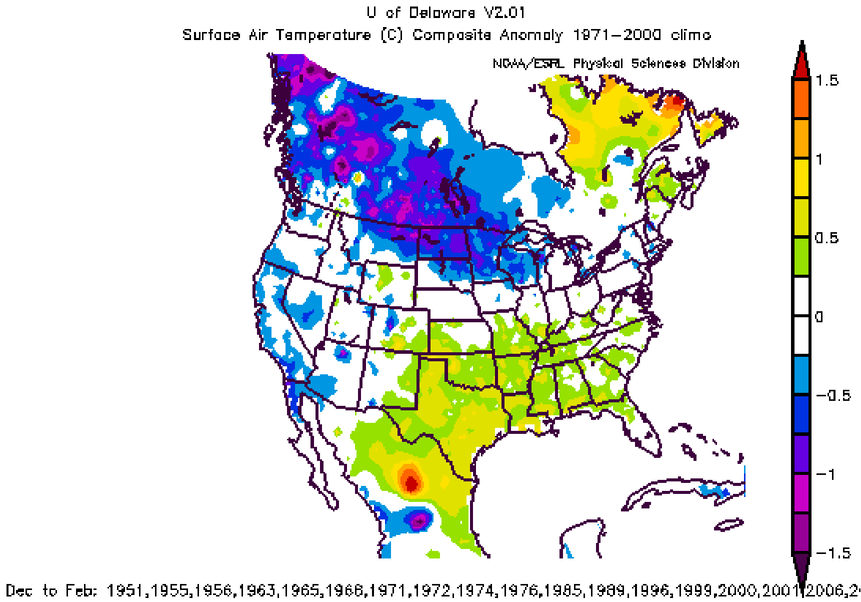


Figure 6: Winter season surface temperature anomalies during La Nina events



Considering that the phases of the AO/NAO have significant impacts on the winter season conditions, it is good practice to consider how the behavior of the AO/NAO will modulate the effects of La Nina across the country. It is apparent from figures 7 and 8 below that the phase of the AO/NAO has profound impacts on the type of winter season conditions La Nina events produces across the central and eastern United States. Notice that the cooler conditions are enhanced across much of the northern United States during a negative AO/NAO during La Nina events (figure 7). Similarly, the cool conditions normally associated with the negative phase of the AO/NAO significantly reduce the warm La Nina signal across the Southern U.S. Therefore during these particular events, a large and expansive area of cooler than normal conditions is favored across much of the northern and eastern United States. This is exactly what was experienced during last year's La Nina event, and is the main reason why such cold conditions were experienced across much of the eastern half of the country. However, we have not experienced this same behavior thus far this winter. Figure 6 below shows that during positive AO/NAO La Nina events the warm La Nina signal across the southern U.S. tends to be significantly enhanced and more expansive. The warm signal associated with the positive AO/NAO can act to wipe out much of the cold signal across the northern states typical associated with La Nina events.

Similar to temperatures, precipitation also shows significant differences based on the behavior of the AO/NAO (right side of figures 7 and 8 below). This is especially the case for areas from the central Mississippi valley eastward across much of the Ohio Valley and lower Great Lakes region. The bottom of figures 7 and 8 display pressure anomalies in the mid-levels of the atmosphere during these events. The above normal pressure across the northern Pacific are displaced farther southeast during positive AO/NAO La Nina events (bottom of figure 8). In addition, there is higher than average atmospheric pressure across the southeastern states associated with the positive phase of the AO/NAO. The lower than average pressure across Canada and the northern United States helps to drive a stronger upper level jet (storm track) across the northeastern Pacific and also a strong southwesterly jet across the Ohio valley. This southwesterly jet helps bring warmer and wetter storm systems up across the Mid-Mississippi and Ohio Valleys, resulting in above average winter season precipitation. In contrast, during the negative AO/NAO La Nina winters, lower than average pressure extends across much of the Continental United States. This flow pattern tends to produce colder and drier storms systems that originate across western Canada. These drastically different regimes experienced during La Nina events indicate the importance of being able to forecast the behavior of the AO/NAO.

Figure 7: Winter season surface temperature anomalies (top left) and precipitation anomalies (top right) and atmospheric pressure anomalies (bottom) during La Nina events with a negative AO/NAO

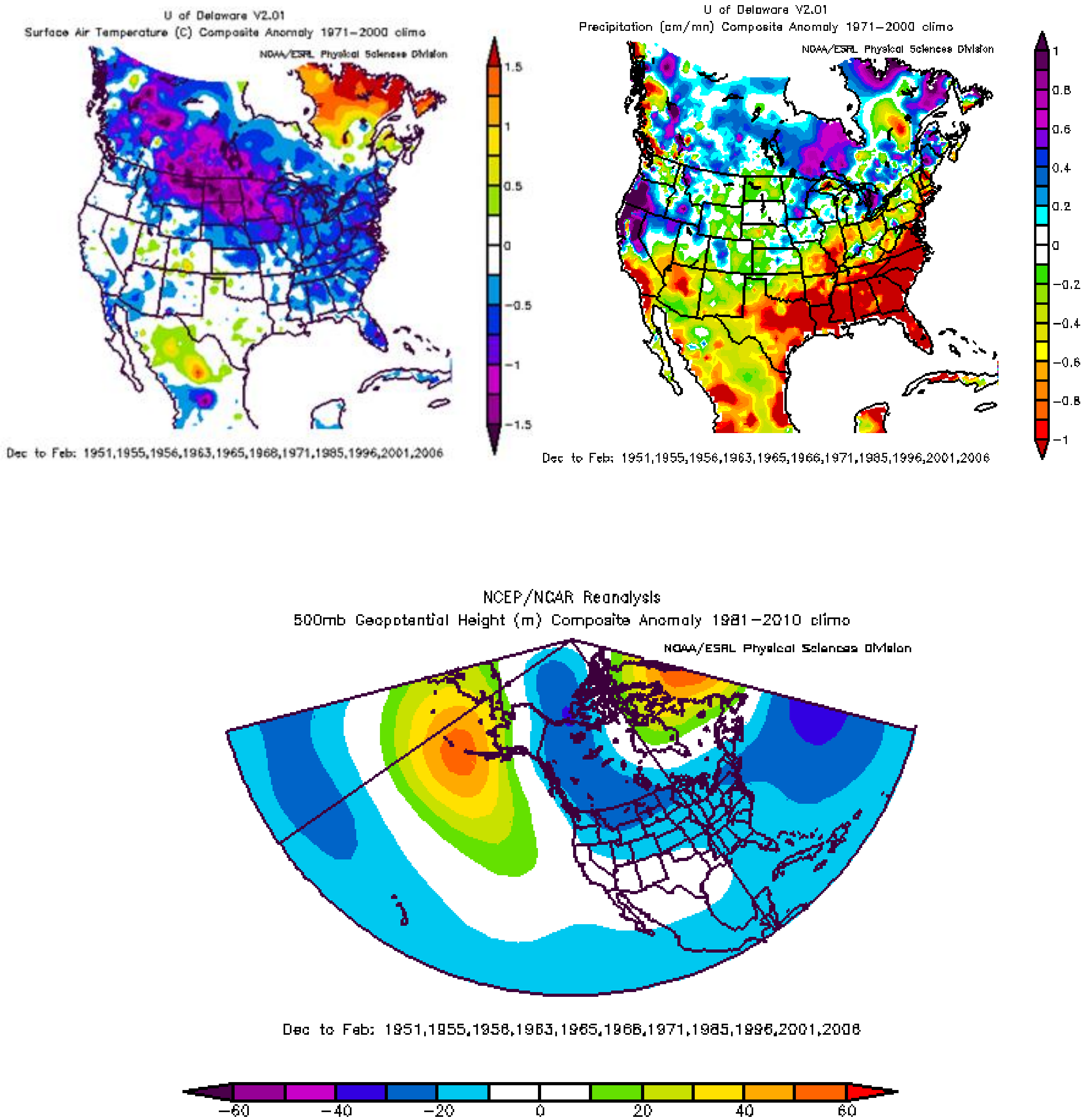
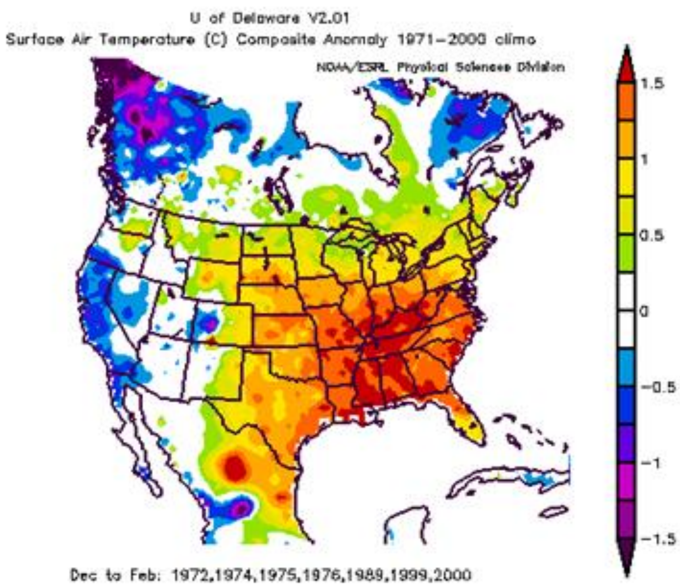
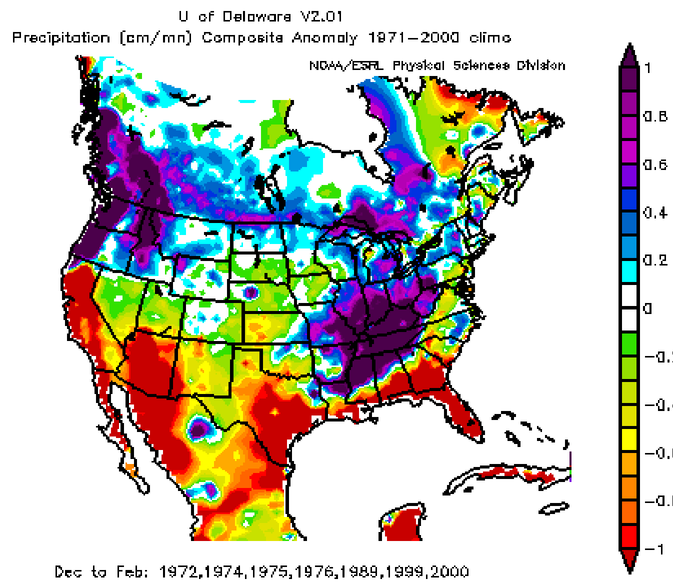
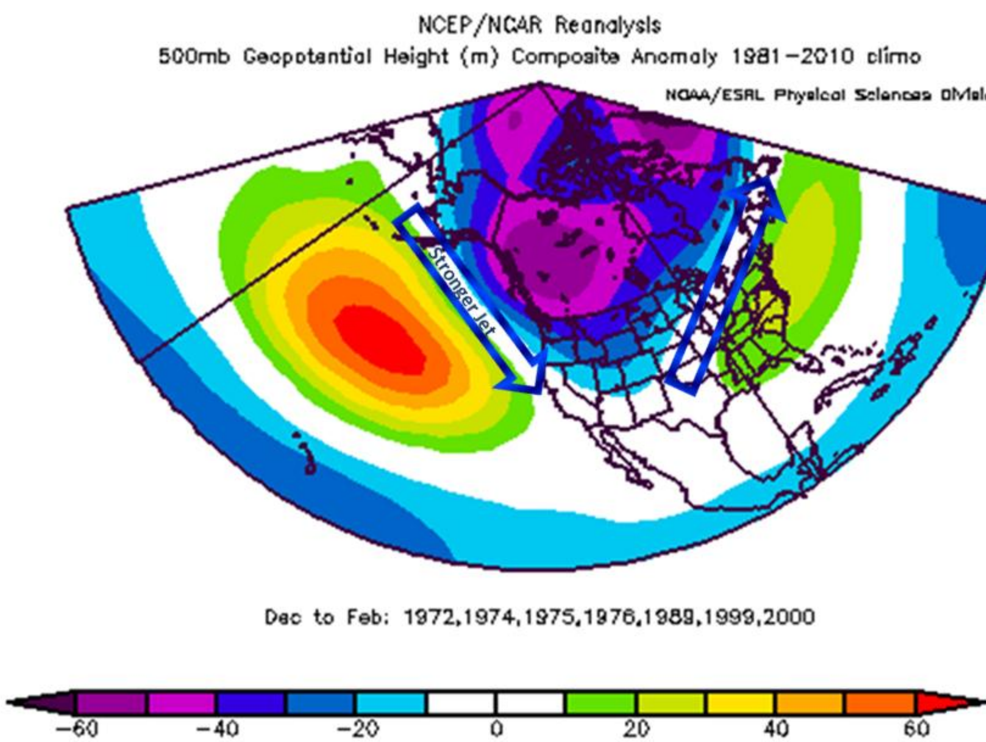


Figure 8: Winter season surface temperature anomalies (top left) and precipitation anomalies (top right) and atmospheric pressure anomalies (bottom) during La Nina events with a positive AO/NAO

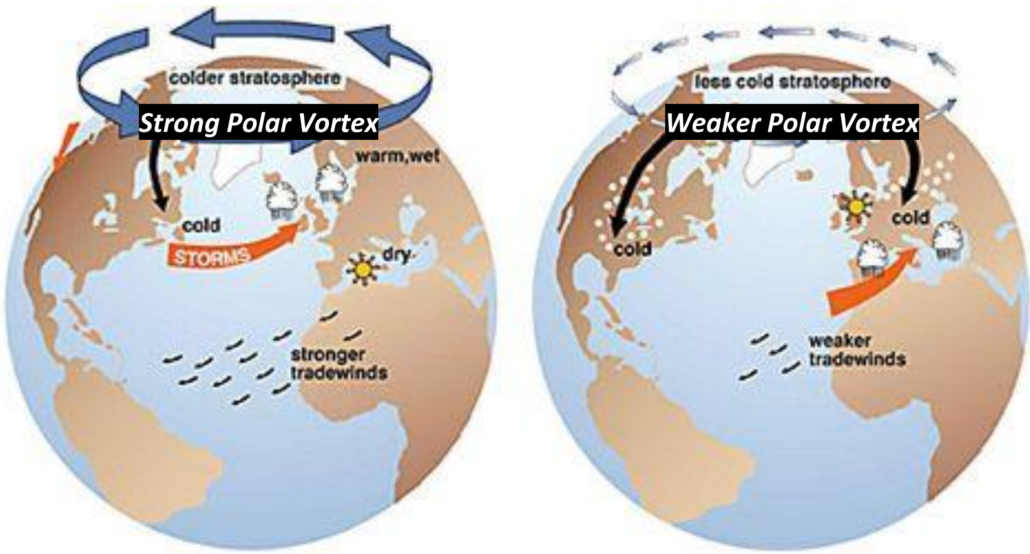






The Linkage of Stratospheric Temperatures to the Phase of the Arctic Oscillation

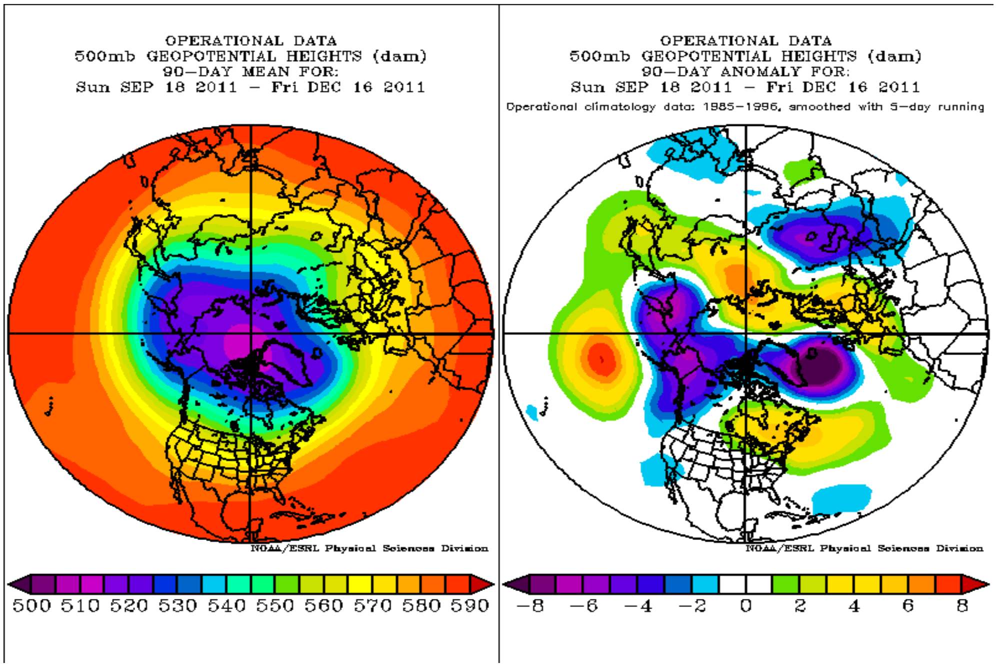
Figure 9: The Stratosphere and the AO (National Snow and Ice Data Center)



Positive phase of AO **Negative Phase of AO**

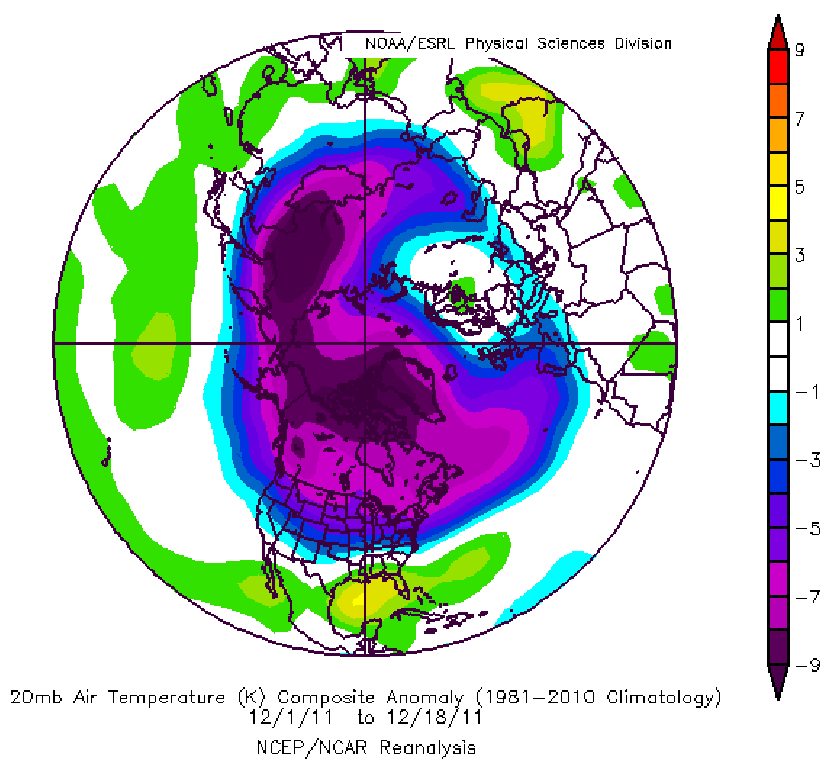
Unfortunately, the phase of the AO, and concurrently, the NAO, have limited predictability beyond a couple weeks in advance, which is the range at which ensemble models forecast their expected phases . In contrast, the ENSO phase can be reasonably well predicted several months in advance by various ensemble forecast models, allowing for the Climate Prediction Center to issue ENSO outlooks, watches and advisories in advance of the official onset of ENSO conditions. Recent research into the stratosphere (the zone of the atmosphere above the troposphere, where our weather takes place), however, may point the way toward better predictability of the phase of the AO. As shown in figure 9 above, without getting too much into the mechanics of why, a colder stratosphere above the North Pole region favors the positive phase of the AO, while a less cold stratosphere above the North Pole region favors the negative phase of the AO. The colder stratosphere is thought to translate to a strong polar vortex (very low pressures aloft above the North Pole), favoring the positive phase of the AO, while a less cold stratosphere allows for a weaker polar vortex and a better chance for a negative AO. Figure 10 below shows that from mid September through mid December this year, there has been a very strong polar vortex over the North Pole. The cool colors on the left hand graphic in the figure show that there has consistently been very low pressures aloft at the mid levels of the troposphere over the North Pole, while the cool colors in the right hand graphic shows that these low pressures have indeed been below normal and indicative of the positive phase of the AO.

Figure 10: 90 Day Mean (left) and Anomalies (right) for Pressure Aloft Over the Northern Hemisphere (CPC)



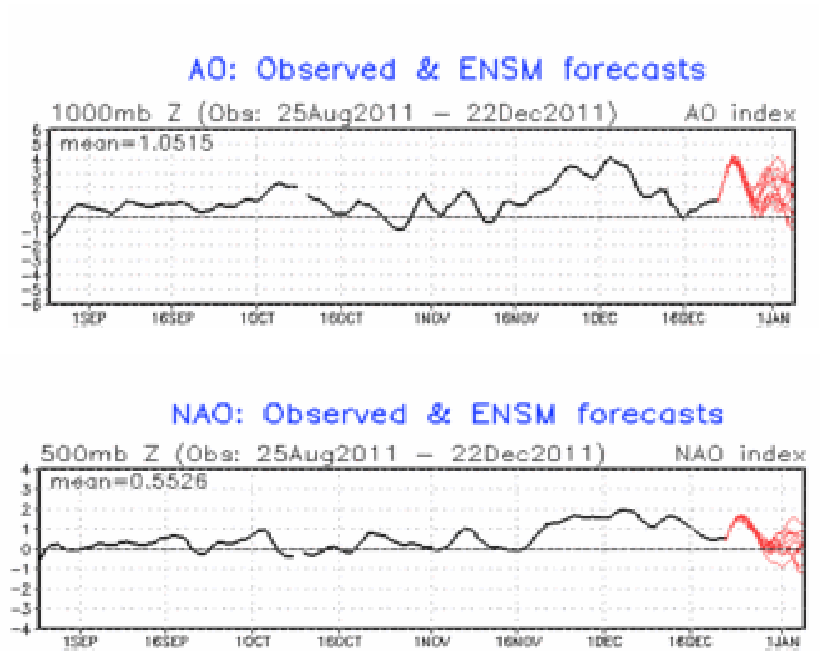
Looking up at the stratospheric level, it becomes clear that the stratospheric signal for the strong polar vortex noted in Figure 10 has certainly been in place this December. Figure 11 below portrays stratospheric temperature anomalies at the 20 mb pressure level in Kelvin (1K = 1 deg. C) from December 1st through December 18th.

Figure 11: Northern Hemisphere Stratospheric Temperature Anomalies December 1-December 18 2011



We can see that temperatures have not been just slightly below the 1981-2010 normal in the stratosphere above the polar region, they have been substantially below normal. These anomalies fit in well with the diagram in Figure 9, so that the anomalously strong polar vortex noted in Figure 10 make sense. This is important because it will take significant stratospheric warming to result in a weakening of the vortex and an atmospheric pattern more favorable for a negative AO/NAO. Additionally, any major warming in the stratosphere would have a lag time of at least a few weeks to work down through the stratosphere until a coincident tropospheric response in terms of the AO/NAO phase. Some of the global forecast models utilized by weather forecasters do predict stratospheric temperatures out to 240 hours to as much as 384 hours in advance, but thus far there has been no strong evidence of a major breakdown of the unusually cold stratospheric temperatures that have been locked over the polar region. Considering the linkage of this feature to the phase of the AO/NAO that has been discussed here, it is very likely that the polar vortex will remain anomalously strong at least through the beginning of January, keeping the truly cold air locked over far northern Canada and Alaska. Therefore, the AO and NAO can both be expected to remain in their positive phases for the foreseeable future. This is borne out by the ensemble of the Global Forecast System (GFS) model, which indeed show no end in sight to the positive AO/NAO, anti-blocking regime, in Figure 12 below. With the La Nina positive NAO composites of above normal temperatures in mind, it stands to reason that a turn to a sharply colder weather pattern is unlikely for the remainder of December and at least through the beginning of January. We would like to see the ensemble members clustering on the negative side of the scale to foretell a major change in the weather pattern that has been observed thus far. Even a return of the AO/NAO to more neutral conditions may at least allow for a less mild weather pattern than has been observed.

Figure 12: Observed and Ensemble Forecasts of the AO (top) and NAO (bottom) as of December 22nd (CPC)
***Most ensemble members show increasing positive AO/NAO in the short term and a tendency for a continued positive phase at the beginning of 2012**



In conclusion, until we are able to transition to a prolonged negative AO/NAO, we can expect to have near to above average temperatures and above average precipitation. It appears this will be the case for most of this winter season, as a prolonged positive AO/NAO looks to continue into January. Although uncertainty increases with the behavior of the AO/NAO later this winter season, the latest trends indicate the winter season as a whole will be marked by the positive phase. Therefore, in spite of the fact that La Nina conditions are in place again this winter, it does not appear that winter season will replicate last year's cold and snowy winter. Instead odds favor this winter to continue to be on the warm and wetter side of average. This of course does not mean there will be no cold or snowy periods this winter. We will be tracking the phase of the AO/NAO closely to help us have a better idea of when we may be entering a period featuring the cold and snow residents have become accustomed to the last several winters. Should the stratosphere show signs of becoming less cold, favoring a flip to at least a period of negative AO/NAO and high latitude blocking, then the chances will increase for a much colder pattern conducive to snow.

A great example of an otherwise warm winter marked by a predominantly positive AO/NAO coupled with a moderate La Nina was the 1998-1999 winter. December was quite mild and almost snow free (only 1” in Chicago and 0.4”! at Rockford), much like this December (only 1.7” at each site through 12/22), but the first few weeks of January saw a dramatic change to snow and arctic cold during a brief flip to a negative AO/NAO. Notably for residents of northern Illinois and northwest Indiana, the New Year was ushered in by the 2nd largest snowstorm on record for Chicago, the January 1st-3rd blizzard. Two weeks later, the snow was gone, in the midst of weeks on end of mild weather through February. Winter weather did not make much of an appearance again until March 1999 when the AO/NAO became strongly negative and a well above average 18.2 inches of snow fell that month at Chicago-O’Hare. So the 1998-1999 meteorological winter was warm overall, averaging around 30 degrees, when the normal average is in the lower and middle 20s, but featured a historic blizzard and then a sharp return to winter weather with the onset of spring. Largely as a result of the 21.6 inches of snow recorded at Chicago-O’Hare during the blizzard, winter season snow totaled slightly above normal for Chicago at 32.5 inches. Only 10.9 inches fell the other 87 days of the winter season! Even in the mild weather pattern we are in and expect to be in for the next couple of weeks at least, a minor to moderate snowstorm is not precluded, although the pattern does favor a storm track more conducive to rain events in our region. And finally, as always, large day to day variability is typical across northern Illinois and northwestern Indiana during the winter season.

The official outlooks from the Climate Prediction Center for temperature and precipitation for the period January through March are posted below, which are line with local expectations of the mild but wetter than average weather pattern continuing deeper into meteorological winter.