Winter Outlook 2012-2013

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What are some of the factors that will play a role in determining what kind of winter we will have?

So what will this winter be like across Northern Illinois and Northwest Indiana?

To forecast what the winter season will be like requires studying large scale weather patterns (storm tracks) across the Northern Hemisphere, and trying to determine how these weather patterns may behave over the coming months. Ultimately, the mean position and strength of the storm track across North America has a large influence on the type of winter season the area experiences. Unfortunately, there are several phenomena that have low predictability, which can have profound influences on the strength and placement of the winter season storm track. Therefore, compared to a forecast for the next few days, there is much greater uncertainty in the type of conditions that will be experienced a couple of months in the future.

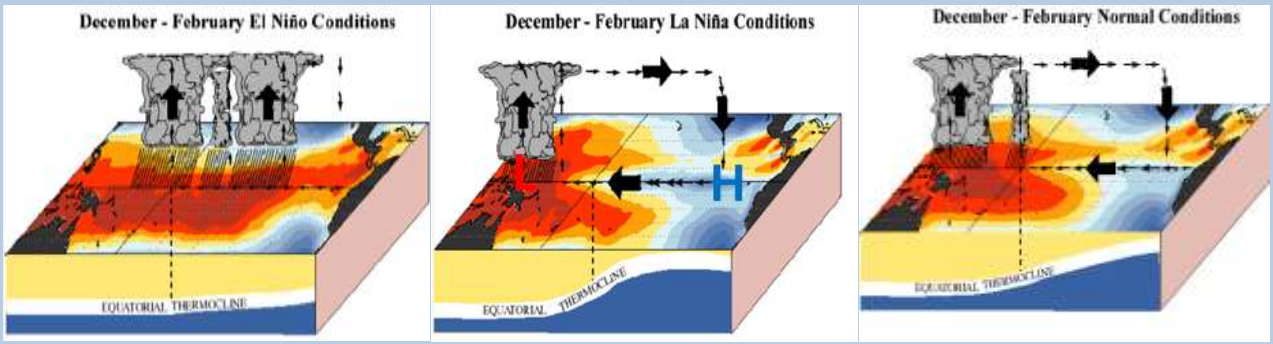


Figure 1: The typical winter season conditions across the equatorial Pacific observed during El Niño (left) and La Niña (center) and Neutral (right).

One of the phenomena that can affect the winter season storm track across the country is the El Nino Southern Oscillation (ENSO). The ENSO is a naturally occurring oscillation that occurs across the equatorial Pacific. An oscillation is a motion that repeats itself over a period of time. For ENSO that period is between about 3 to 7 years.

There are three phases that make up the ENSO. They are: El Nino, La Nina and Neutral. The defining characteristics of these three phases of ENSO are Sea Surface Temperature (SSTs) anomalies (departures from average) across the central and eastern equatorial Pacific. During La Niña conditions, cooler than average SSTs are found along the equator in the central and eastern Pacific region (center of figure 1 above). Just the opposite occurs during El Niño events (left-hand of figure 1). However, during ENSO Neutral events SST's are near normal across the equatorial Pacific (right-hand of figure 1).

The importance of these SST anomalies lies in the fact that they largely dictate where tropical thunderstorms will develop and be the most persistent. Thunderstorms thrive over warm ocean waters in the same way tropical storms and hurricanes do in the Atlantic. During La Niña events, the warmest ocean waters are confined to the western equatorial Pacific region. Therefore, this is the preferred placement for tropical thunderstorms during the Northern Hemisphere cold season. These thunderstorms can be considered as a "bridge" between the ocean and the atmosphere. As these thunderstorms develop, they induce atmospheric low pressure across the western Pacific region, while atmospheric high pressure sets up across the eastern equatorial Pacific where thunderstorms are less favorable (center of figure 1 above). This leads to stronger easterly trade winds (flow from high to low pressure). In return, these stronger trade winds help reinforce the SST pattern by pushing the warm water west and enhancing the strength of the cool eastern Pacific water. Just the opposite occurs during El Niño events. It is this process that produces significant changes to the atmospheric circulation in the tropics and also throughout much of the Northern Hemisphere.

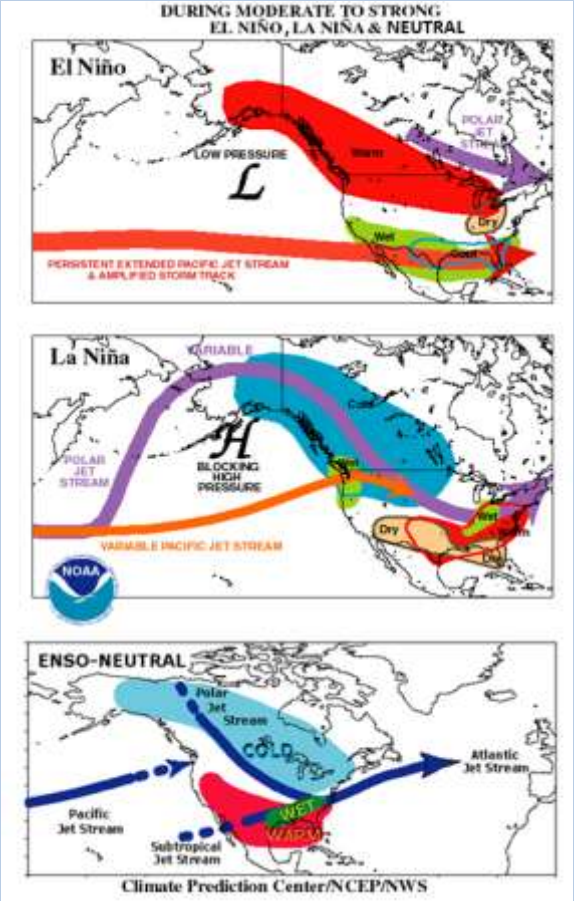


Figure 2: The typical upper level jet stream/storm track during El Niño (top), La Niña (middle) and Neutral (bottom) winters. Courtesy of NOAA, Climate Prediction Center

Usually the stronger an event is, the greater the impact it will have on the placement and strength of the cold season storm track across the Northern Hemisphere. Figure 2 displays the typical winter season storm track during each ENSO phase.

The main characteristic of the flow pattern for La Nina 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 tend 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. This tends to support colder and snowier conditions across the north central CONUS during a La Nina phase of the ENSO.

In contrast, during El Nino events, the main storm track extends from the Pacific eastward across the southern portion of the country, which supports drier and warmer winters across much of the Great Lakes region. During ENSO Neutral winters, the overall storm track can mimic those of La Nina events, with cold conditions favored, especially across the northern CONUS. However, not every event is the same and although the figure above indicates that cold conditions may be favored during La Nina and ENSO neutral events, there are other factors that can modulate the effects of ENSO events.

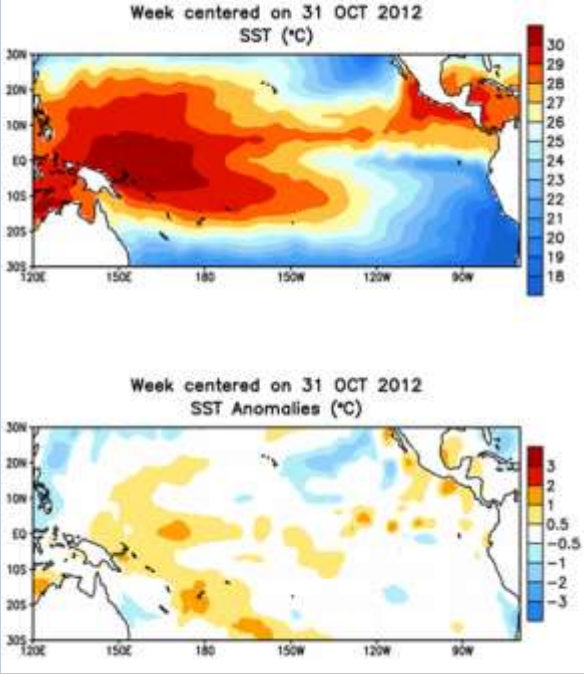


Figure 3: Observed sea surface temperatures across the equatorial Pacific (top) and their departures from average (bottom). Courtesy of NOAA, Climate Prediction Center

So what phase of ENSO are we in now? A couple of months ago it was thought that El Nino conditions would be in place this winter season. However, conditions across the equatorial Pacific now resemble ENSO Neutral conditions. Notice that the SST departures from average across the equatorial Pacific are relatively small (bottom of figure 2). The latest forecasts now indicate a high likelihood that ENSO Neutral conditions will continue through the winter season.

The Pacific Decadal Oscillation

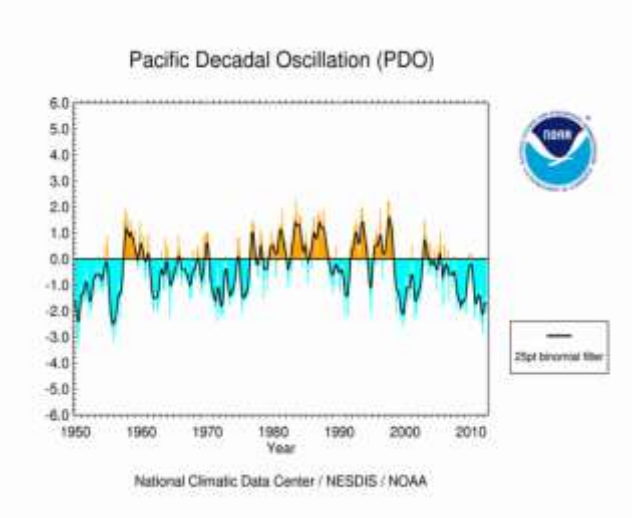


Figure 4: Behavior of the Pacific Decadal Oscillation (PDO) since 1950.

Another factor that may have an impact on the winter season storm track is the fact that the Pacific Decadal Oscillation (PDO) is in its negative phase. The PDO is an ENSO-like oscillation that occurs in the North Pacific (Northward of 20° latitude). However, unlike ENSO, the PDO tends to have a period of variability on interdecadal time scales (Figure 4). This means that one phase of the PDO will usually last a decade or two. The

figure above displays the behavior of the PDO since 1950. The red areas represent times in which the PDO was predominately in its positive phase. Conversely, the blue areas represent times that the negative phase dominated. The figure shows that the phase of the PDO has predominantly remained negative for the past several years and it continues to strengthen.

Figure 5 below displays the characteristics of the two phases of the PDO. The positive phase is characterized by warmer than average eastern Pacific water and cooler western and north central Pacific water. However, during the negative phase, the warmest SST anomalies are confined to the western and north central Pacific with relatively cool SSTs across the eastern Pacific.

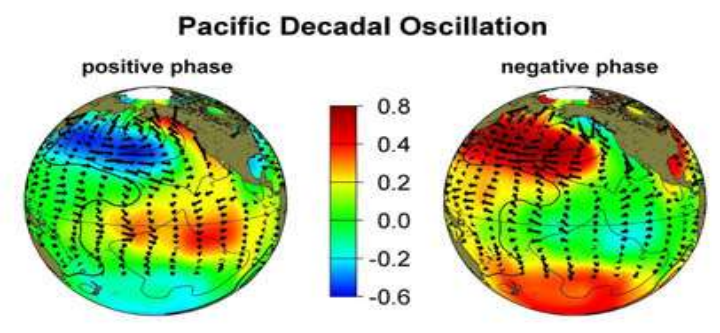


Figure 5: The typical sea surface temperature anomalies typically associated with the positive (left) and the negative (right) phases of the PDO. Figure reproduced from http://jisao.washington.edu/pdo/

The typical winter season conditions associated with negative and positive PDO phases are shown in figure 6. Notice that conditions are nearly the opposite from one phase to the other. For example, the jet stream tends to be very strong across the central Pacific during the positive PDO and very weak during the negative phase. The result of this weaker Pacific Jet during the negative phase leads to increased blocking (meridional or north to south flow) across the North Pacific, and consequently buckles the polar jet southward across western Canada and the northwestern and north central portion of the United States. This allows cold air to spill southward across Alaska, western Canada and the northern portions of the U.S. However, warmer winter season conditions are favored across the southeastern CONUS, where the jet stream lifts back northward across eastern Canada. The active jet across the central portion of the country during these episodes also favors above average winter season precipitation across the Ohio valley and Great Lakes Region.

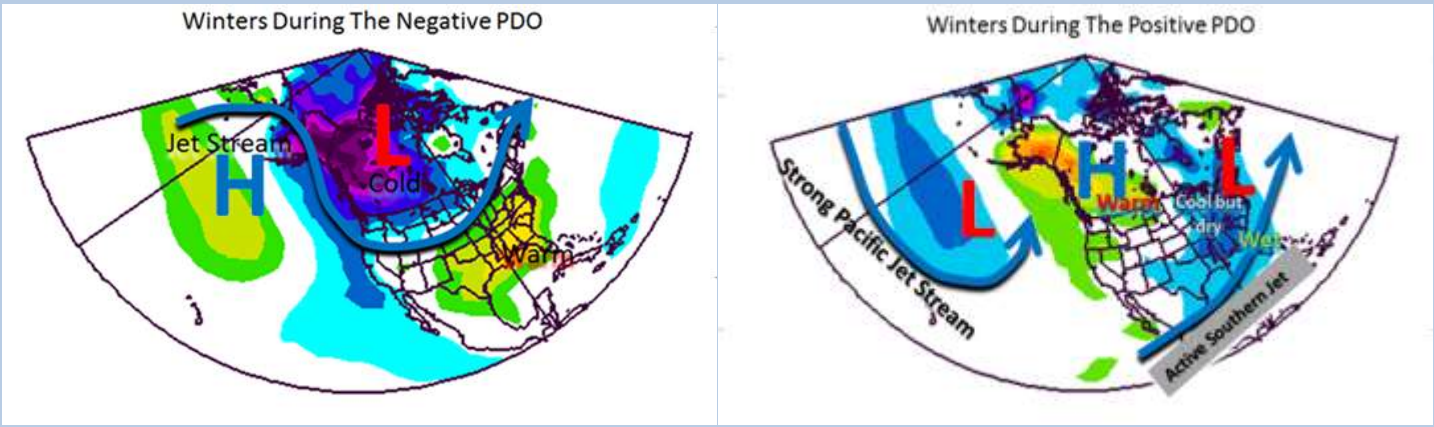


Figure 6: Typical winter season conditions during the negative PDO (left) and the positive PDO (right). The large blue arrow indicates the approximate placement of the Jet

Research has shown that the PDO can act to modulate the typical effects of ENSO. Specifically, it has been suggested that constructive interference occurs when El Nino events coincide with a positive PDO. As a result, the El Nino event is more efficient in producing the typical El Nino signal across North America during the winter. The same can be said for La Nina events during the negative phase of the PDO. However, when El Nino links up with the negative PDO or La Nina links up with a positive PDO then destructive interference occurs, resulting in a modified effect on the mean winter season flow pattern across North America.

Compare the top of figure 6 (negative PDO) with the figure for La Nina in figure 2 above. Notice that the jet stream, represented by the large blue arrow, behaves similarly in both. Both negative PDO and La Nina events favor blocking high pressure across the North Pacific and the downstream southward buckling of the jet stream across western Canada and the northern CONUS. So, it should not be too surprising that when La Nina and a negative PDO are in place across the Pacific that the effects to the winter season jet stream across North America will be enhanced. The PDO can also have a similar effect on ENSO neutral events.

So the question is what are the favored atmospheric circulation patterns during a negative PDO concurrent with ENSO Neutral conditions? Figures 7 and 8 below indicate that the phase of the PDO helps drive drastically different conditions across the Pacific region during ENSO Neutral winters. During a negative PDO, increased mid and upper level atmospheric high pressure tends to be favored across the North Pacific during ENSO neutral events, while lower than normal atmospheric pressure is favored during a positive PDO and ENSO Neutral event.

The consequences of these different pressure patterns across the Pacific drive different jet stream patterns across North America during the winter. The tendency for higher pressure in the mid and upper levels of the North Pacific during a negative PDO and ENSO Neutral event acts as a block to the flow pattern and buckles the winter season jet stream southward across the northern CONUS. This is similar to the composite shown for the negative PDO events in figure 6. This jet stream pattern favors colder conditions across much of the northern half of the CONUS and above average precipitation across portions of the Ohio and Tennessee Valleys. In contrast, the tendency for lower pressure across the central and northern Pacific during a positive PDO and ENSO Neutral event favors a northwesterly jet stream pattern across the central states. This tends to produce below average precipitation across the Ohio and Tennessee Valleys.

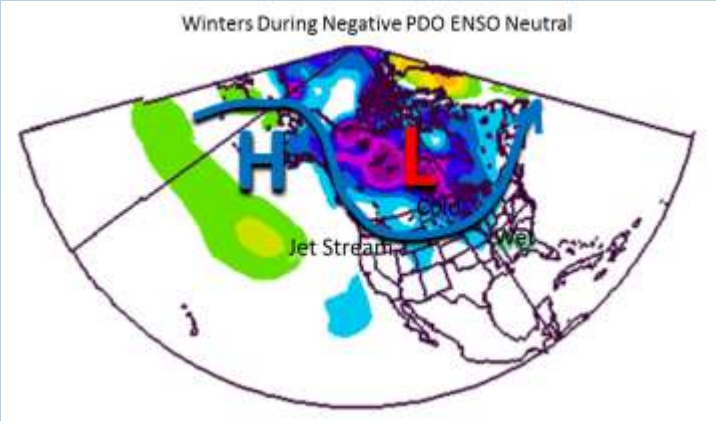


Figure 7: Typical winter season conditions during negative PDO Neutral events. The large blue arrow indicates the approximate placement of the Jet stream.

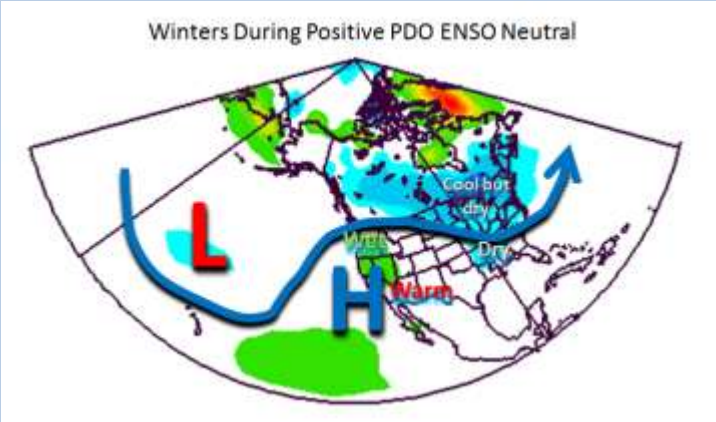


Figure 8: Same as figure 7 except during positive Neutral events.

So what are some of the typical effects locally? Table 1 below displays normal temperatures and snowfall amounts for each winter season month along with the average departures from average for each particular event (Note that the averages calculated here are for a long period running from 1900 to 2011 and not the 1981-2010 normal). Additionally, figure 9 displays the distributions for winter season temperatures (left) and snowfall (right). This data indicates that there is a slight tendency for ENSO Neutral events to produce below average temperatures across the region. This is especially true during the negative PDO events. However, none of this temperature data was found to be statistically significant for the area. This is likely due to the fact that we tend to lie on the boundary between areas that are more prone to being cold across the north central CONUS and those areas more favored for warmer conditions across the south. Considering this, it is likely that we experience a bit of both warm and cold periods during these winter seasons.

Unlike with temperatures, snowfall showed a high bias of nearly 7 inches during negative PDO ENSO Neutral winters, which was found to be statistically significant. In fact, some of the snowiest winters in Chicago's history occurred during these particular events, including the 1978-79 winter season. Furthermore, the distribution shown on the right hand chart in figure 9 for the negative PDO Neutral events (shown in red) also indicates the tendency for more snowy winter seasons, with a large skew towards the snowy winters (above category). This signal for increased precipitation and snowfall is due to the fact that these negative PDO Neutral events favor a stronger upper level westerly jet stream right across the central section of the country (figure 7 above). The presence of this would increase the odds of having a more active weather pattern with a larger number of potent winter storm systems.

Table 1: Monthly and winter season average temperatures and their departures from average during both positive and negative PDO ENSO Neutral events (left) and for snowfall (right).

Winter Temperatures in Chicago			
	Normal	*-PDO Neutral*	*+PDO Neutral*
December	***28.7°F***	***-1.5°F***	***-0.4°F***
January	**24.3°F**	**-1.2°F**	**-0.8°F**
February	**27.2°F**	**+2.1°F**	**-0.7°F**
Winter Season	**26.7°F**	***-1.3°F***	**-0.5°F**

Winter Snowfall in Chicago			
	Normal	*-PDO Neutral*	*+PDO Neutral*
December	***8.7"***	***+2.40"***	***-2.00"***
January	**10.2"**	**+2.15"**	**-1.39"**
February	**8.6"**	**-2.6"**	**+1.49"**
Winter Season	**27.4"**	***+6.9"***	**-1.12"**

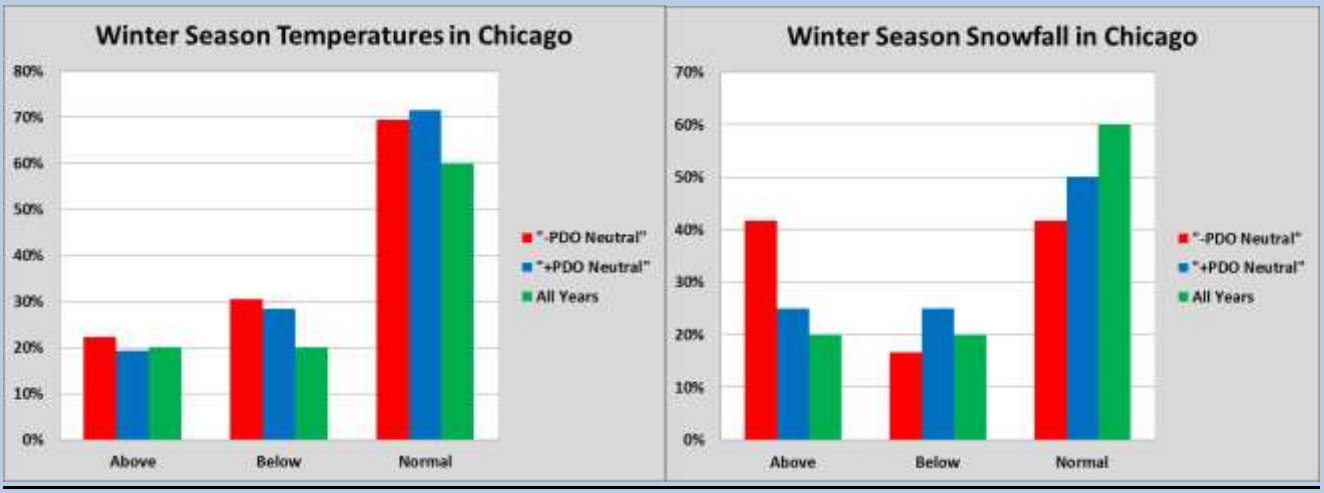


Figure 9: Distribution of winter season temperatures (left) and snowfall (right). The bars indicate the distributions during the: –PDO ENSO Neutral years (red), +PDO ENSO Neutral years (blue) and for Climatology (green). Climatology was calculated by classifying the middle 60% of the seasonal temperature and snowfall data from 1900-2011 as being near normal. The above and below each represent the highest and lowest 20% extremes from the 1900-2011 dataset.

The North Atlantic/Arctic Oscillation

Both ENSO and the PDO discussed above deal with natural variability across the Pacific. However, another important driver of the storm track during the winter season is the North Atlantic Oscillation (NAO). The NAO is related to the Arctic Oscillation (AO), only it focuses on conditions across the North Atlantic. The AO and NAO 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. The NAO can significantly alter the winter jet stream pattern across North America over what the ENSO and the PDO phases might otherwise suggest.

Similar to the PDO, 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 10). The positive phases of the AO and NAO are the opposite of the negative phase (top left of figure 10).

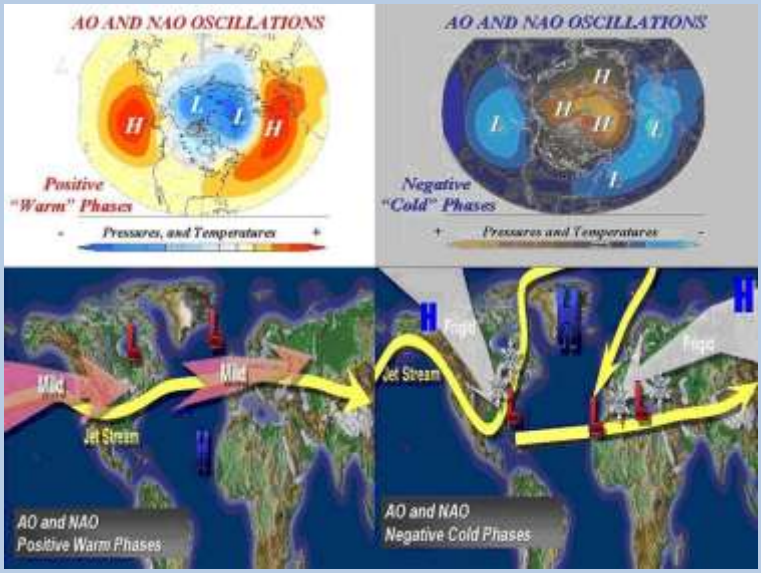


Figure 10: The Positive and Negative Phases of the AO and NAO (icecap.us)

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 10). 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 can tend to be colder during prolonged periods of the negative phase of the AO and NAO (left side of figure 11).

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 8). 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 11).

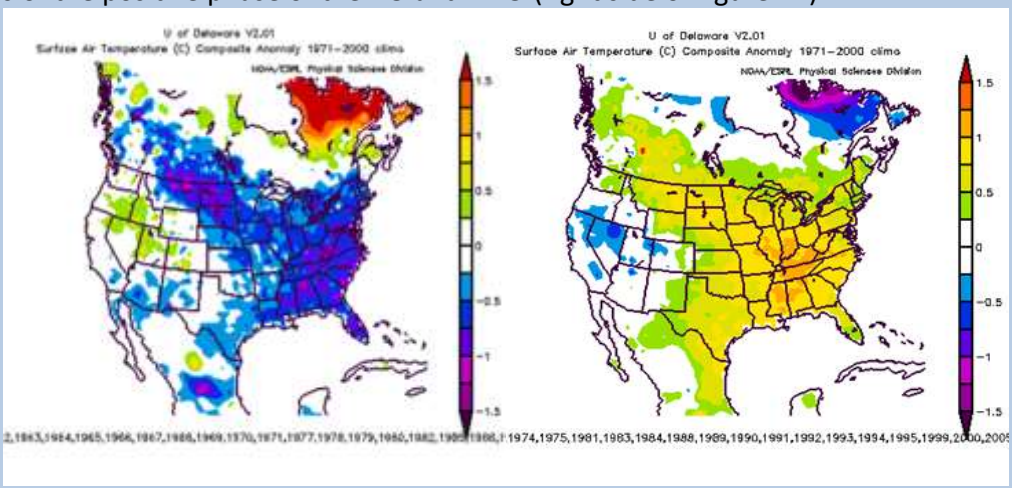


Figure 11: Winter season surface temperature anomalies during a negative NAO (left) and during the positive NAO (right)

Given the impacts the NAO has on the winter season conditions; it is definitely another very important player for determining what this winter will bring. Unfortunately, the NAO is very difficult to predict more than a few weeks in advance, so many long range forecasts do not take this into account. Research has shown the NAO to have variability on timescales ranging from a few weeks all the way up to several decades. The negative phase of the NAO tended to dominate the winters of 2009-10 and 2010-11, which helped lead to some cold and snowy winter seasons. However, last winter the NAO remained strongly positive through much of the winter season (Table 2 Below). This helped produce a very warm winter across a good portion of the CONUS. So the big question is how will the NAO behave this winter? The NAO has been predominately negative for the past several months. If this trend continues, there could be better odds for colder conditions this winter. However, if we transition into a more persistent positive phase our chances for having warmer than average conditions will increase this winter.

Table 2: North Atlantic Oscillation (NAO) index for the winter season months over the past three winters.

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	**+2.5**	**+1.2**	**+0.4**

Winter 2008-2009- A –PDO ENSO Neutral winter

Here's a look back at the most recent –PDO ENSO Neutral Winter, 2008-2009. The large scale flow (jet stream) pattern at the upper levels of the atmosphere was highly indicative of the composite found in Figure 7, with a pronounced blocking high pressure over the north Pacific shown by the warm colors, and lower than normal pressures (cool colors) extending southward from Canada into the north central and northeastern United States.

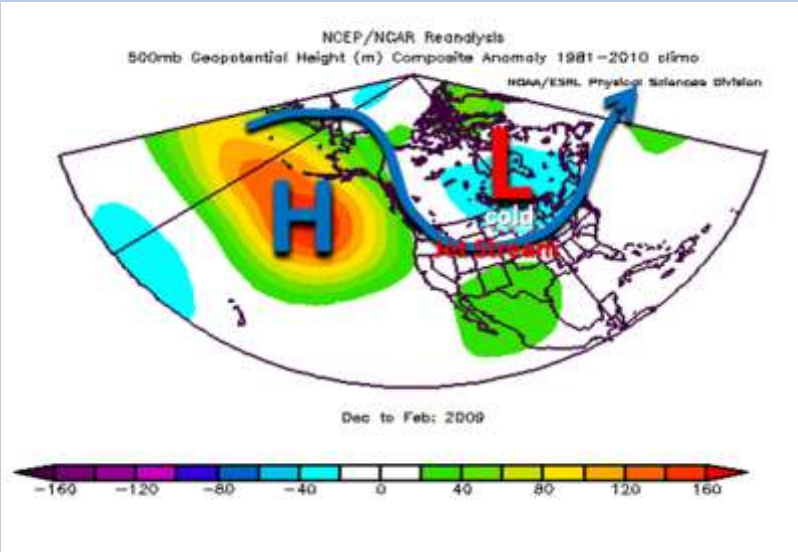


Figure 12: Mid/upper level atmospheric pattern during winter 2008-2009

Given the overall jet stream pattern, temperature and precipitation anomalies also generally fell within range of the composite for –PDO ENSO Neutral events in terms of the general location of the coldest temperatures and the most precipitation. This is shown in Figure 13 on page 11. You can see that the below normal temperatures were situated across the northern tier of the US as is typical during –PDO ENSO Neutral winter episodes, but significantly colder than normal temperatures extended down into our region. Furthermore, the typical signal for well above normal precipitation certainly existed in the Ohio and Tennessee valleys, but also extended into the Great Lakes region. Combined with the cold temperatures, the result was well above normal snowfall.

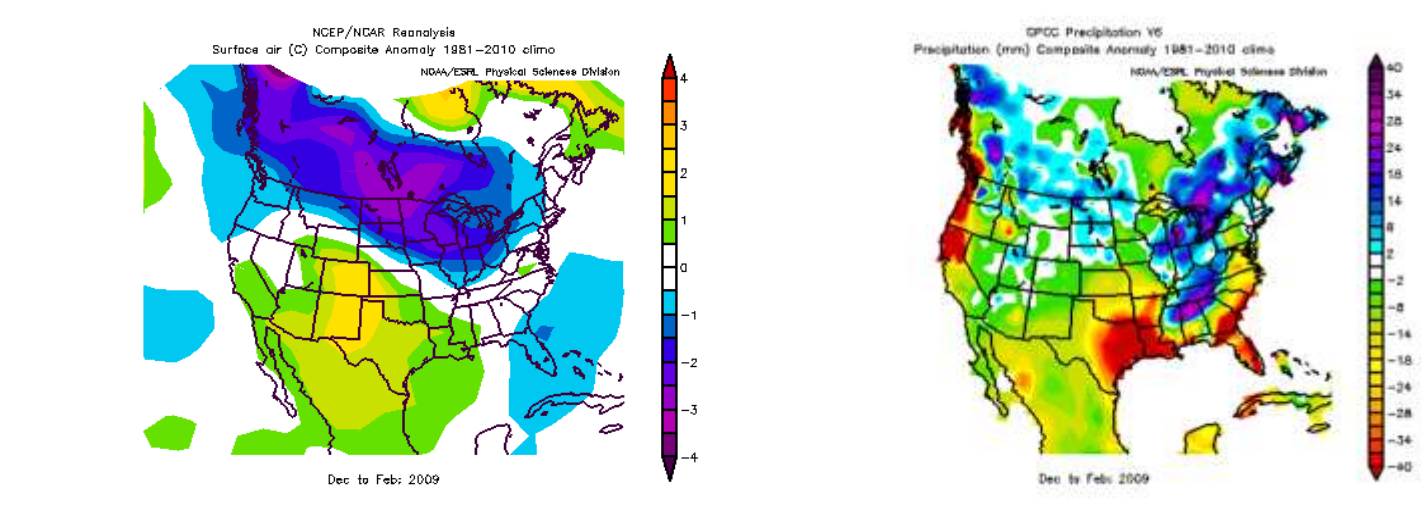


Figure 13: Temperature Anomalies Winter 2008-2009 (left) and Precipitation anomalies (right)

The end result for the local area is summed up well by the table below, which contains winter 2008-2009 statistics for Chicago and Rockford, our two official climate sites. What is interesting about the data is that it fits the overall trend in winter temperatures and snowfall during –PDO ENSO Neutral Winters found in Table 2. The coldest temperatures and most snowfall occurred in December and January, and the mildest temperatures and lower snowfall amounts occurred in February. Overall, In Chicago, 2008-2009 was the 11th snowiest and 24th coldest meteorological winter on record and in Rockford, 2008-2009 was the 5th snowiest and tied for the 20th coldest meteorological winter on record.

Table 3*:* Winter 2008-2009 Summary				
Chicago	***December***	***January***	***February***	***Winter Season***
Temperatures	***22.9***	***15.8***	***28.2***	***22.4***
Departure from 1981-2010 normal	**-4.8**	**-8.0**	**+0.5**	**-4.0**
Snowfall	**21.9**	**21.5**	**4.5**	**47.9**
Departure from 1981-2010 normal	**+13.4**	**+10.7**	**-4.6**	**+19.5**
Rockford				
Temperatures	**19.4**	**13.8**	**26.2**	**19.8**
Departure from 1981-2010 normal	**-5.0**	**-7.7**	**+0.3**	**-4.4**
Snowfall	**28.9**	**12.6**	**7.8**	**49.3**
Departure from 1981-2010 normal	**+17.6**	**+2.4**	**+0.1**	**+20.1**

With the jet stream pattern during –PDO winters favoring a significant build-up of cold air over Canada and the far northern tier of the US, it stands to reason that when the regional weather pattern becomes favorable to tap into this cold air, periods of notable cold can occur in the local area. The winter of 2008-2009 was no exception, with a period of extreme cold from January 15th to January 16th.

Table 4: ***January 15-16 2009 Cold Wave***

	Chicago	Rockford
January 15	High: -1 Low: -13→ ***28 deg below normal***	High: -6 Low: -17→ ***29 deg below normal***
January 16	High: 0 Low: -18→ ***28 deg below normal***	High: 0 Low: -25*→ ***30 deg below normal***

**** Record low for the date. Tied for the 3rd coldest temperature on record in Rockford.***

On the other side of the coin, while the cold outweighed the warmth in the winter of 2008-2009, there were a few days that exhibited extreme warmth. Three days in Chicago and two days in Rockford saw the daily average temperature in excess of 20 degrees above normal, including highs of 61 degrees on both December 27th and February 10th in Chicago. Similar to La Nina winters, it is not uncommon in –PDO winters in northern Illinois and northwest Indiana to see bouts of extreme warmth when the local area resides on the warm side of the storm track, even in predominantly colder than normal seasons.

What makes the cold and snow observed even more impressive is that it occurred without contribution from a deeply negative NAO/AO. Below are the monthly and winter average NAO and AO values for 2008-2009.

Table 5: Monthly and Seasonal NAO/AO Values for winter 2008-2009

	December	**January**	**February**	**Winter Average**
NAO	-0.28	-0.01	0.06	-0.08
AO	0.65	0.82	-0.67	0.27

With a basically neutral signal from the NAO/AO, it appears that in 2008-2009, a principle factor in support of the predominantly cold and snowy winter was the persistent strong blocking ridge over the North Pacific. While strong blocking (-NAO/-AO) over the North Atlantic and Arctic would be even more supportive of persistent cold in the western Great Lakes, the data from 2008-2009 demonstrates that we can have a cold winter without a predominantly negative NAO/AO and the importance of ridging near Alaska.

Are there any clues in the upper level pattern this fall as to how the winter season upper pattern may behave?

The image below shows that there has been a tendency for persistent blocking high pressure over the far north Pacific (warm colors) from October 1st-November 11th.

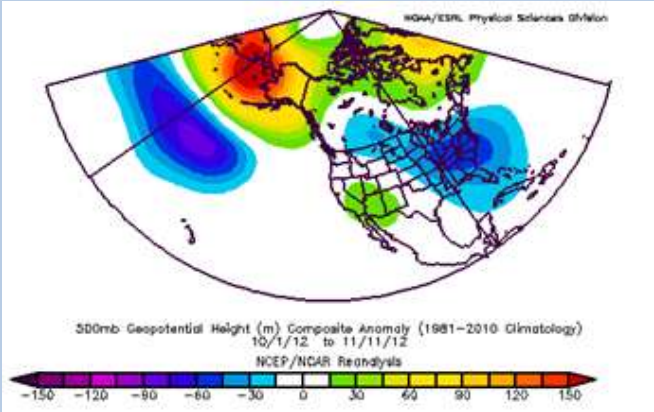


Figure 14: Mid/upper level atmospheric pattern Oct 1-Nov 11 2012

This is a marked departure from the fall of 2011 (below), when there were lower than normal pressures (cold colors) over the north Pacific region, with the higher than normal pressures (warm colors) were displaced to the south of the Aleutian Islands.

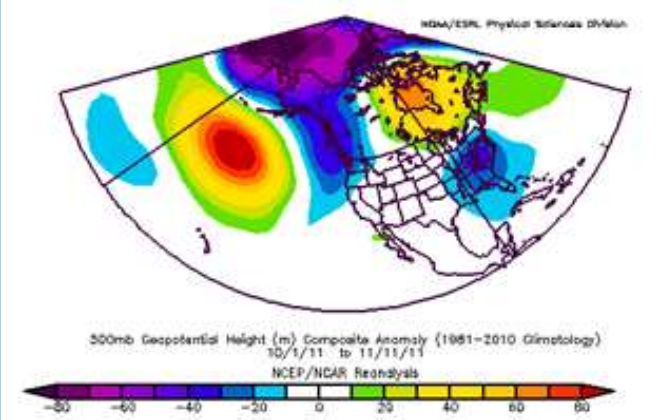


Figure 15: Mid/upper level atmospheric pattern Oct 1-Nov 11 2011

The fall jet stream pattern in 2011 appeared to have been a prelude to the winter 2011-2012 pattern shown below, one that not only featured predominantly positive NAO and AO values, especially early in the winter, but an unusually strong and persistent vortex (lower than normal pressures) near Alaska. A combination of a positive NAO/AO and much lower than normal pressures over the north Pacific is a pattern that prevents much of the cold air that typically drains south into southern Canada and the northern tier of the US from doing so. Furthermore, any cold air masses observed tended to quickly move off to the east, followed rapidly by a warming

trend, due to a lack of blocking over the north Pacific, north Atlantic and Arctic. These are some of the factors that certainly played a role in the near record warmth and lack of snow last winter.

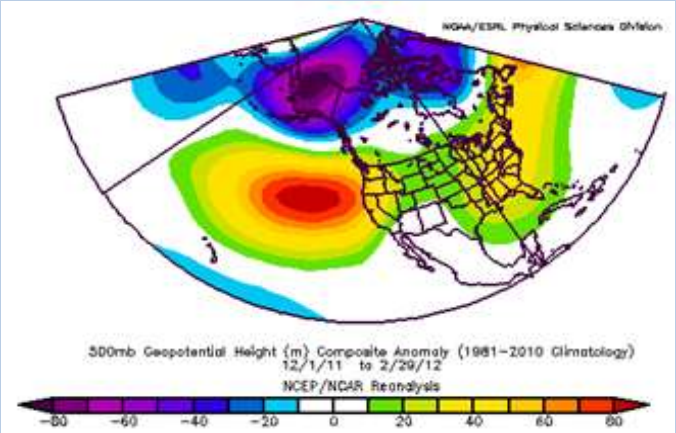


Figure 16: Mid/upper level atmospheric pattern winter 2011-2012

Time will tell whether the different pattern we have seen thus far this autumn will end up persisting into December and January, but the typically reliable ensemble forecast from the European Centre for Medium-Range Weather Forecasts (ECMWF) and the Global Ensemble Forecast System (GEFS-NCEP) project that the blocking high pressure over the far north Pacific will persist through the end of November into early December. Furthermore, at that time, the ensemble forecasts even project the development of higher than normal pressure near Greenland and over the Arctic, which suggests the potential for a –NAO/-AO. With the various ensembles consistently showing this general upper level pattern, confidence is growing that the mild weather of Thanksgiving week will likely be replaced by a colder than average and possibly active weather pattern from the end of November through at least the first week of December. Blocking patterns of this nature tend to be stable and tough to quickly break down.

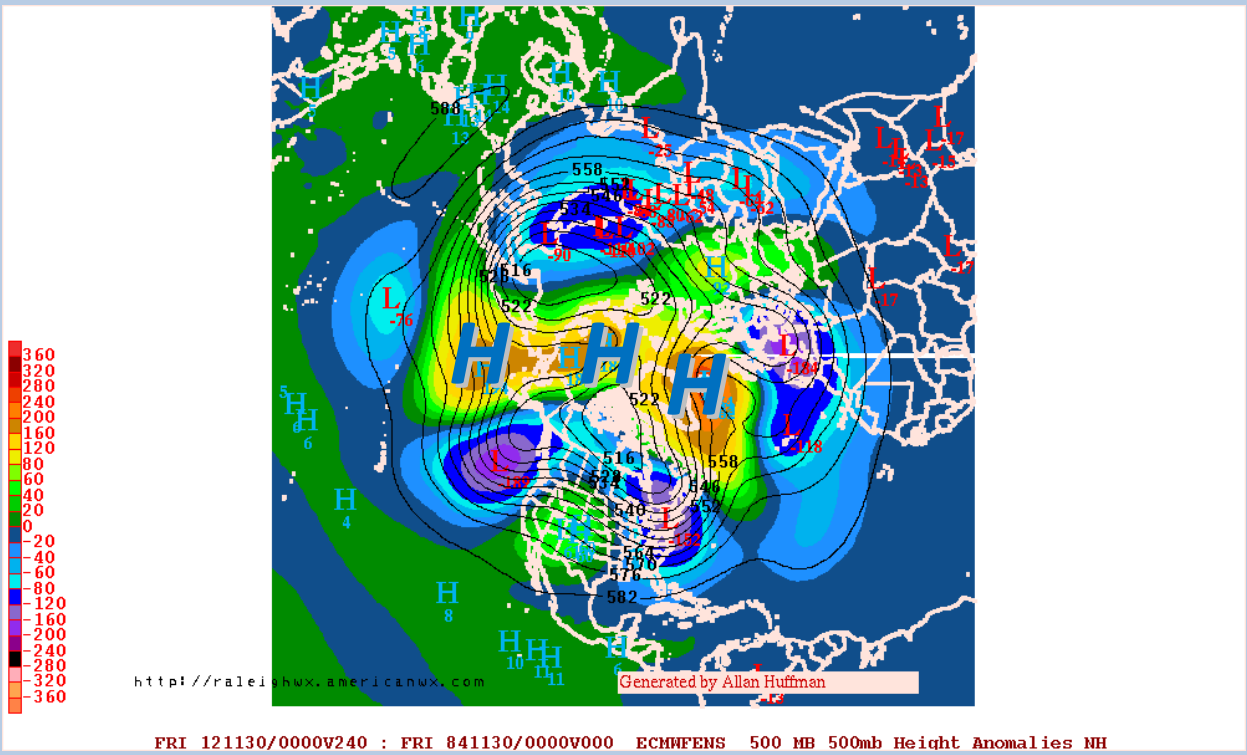


Figure 17: ECMWF Ensemble Forecast for Upper Level Pressure Anomalies valid 6pm CST 11/29/12

To highlight the growing potential for this high latitude blocking to persist through the first week of December figure 18 below is the GEFS forecast valid 12am 12/6. It shows the persistent higher than normal pressure over the Bering Sea and just south of Greenland, as well as across the North Pole, which would portend a continuation of a –NAO and –AO (shown in the GEFS NAO forecast in Figure 19).

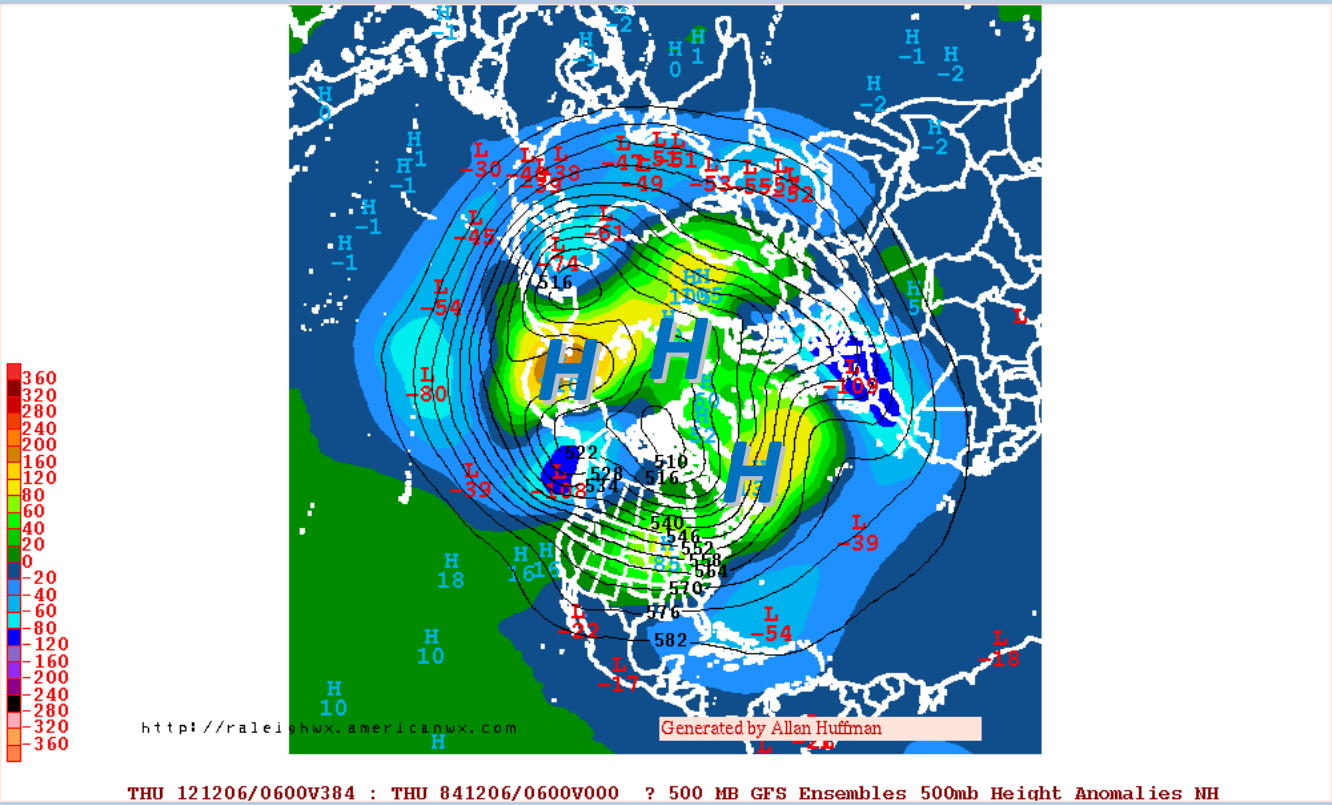


Figure 18: GEFS Ensemble Forecast for Upper Level Pressure Anomalies valid 12am 12/6/12

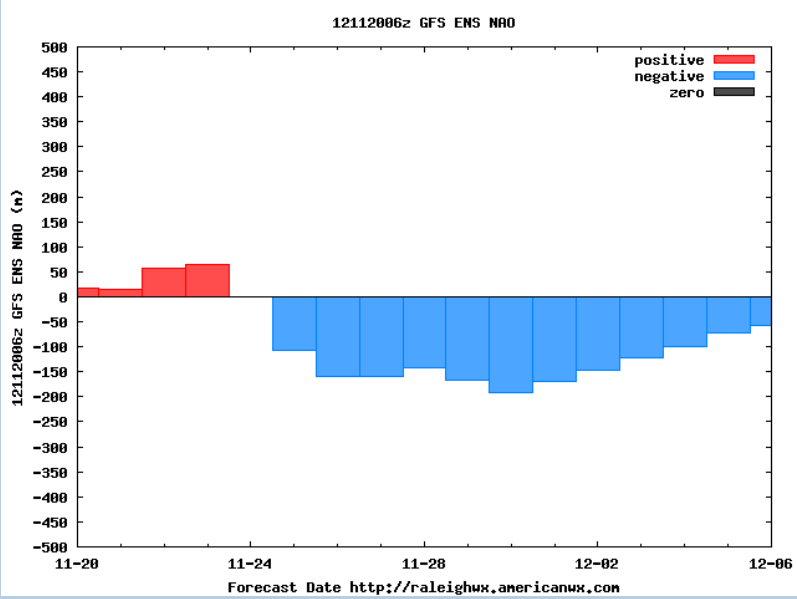
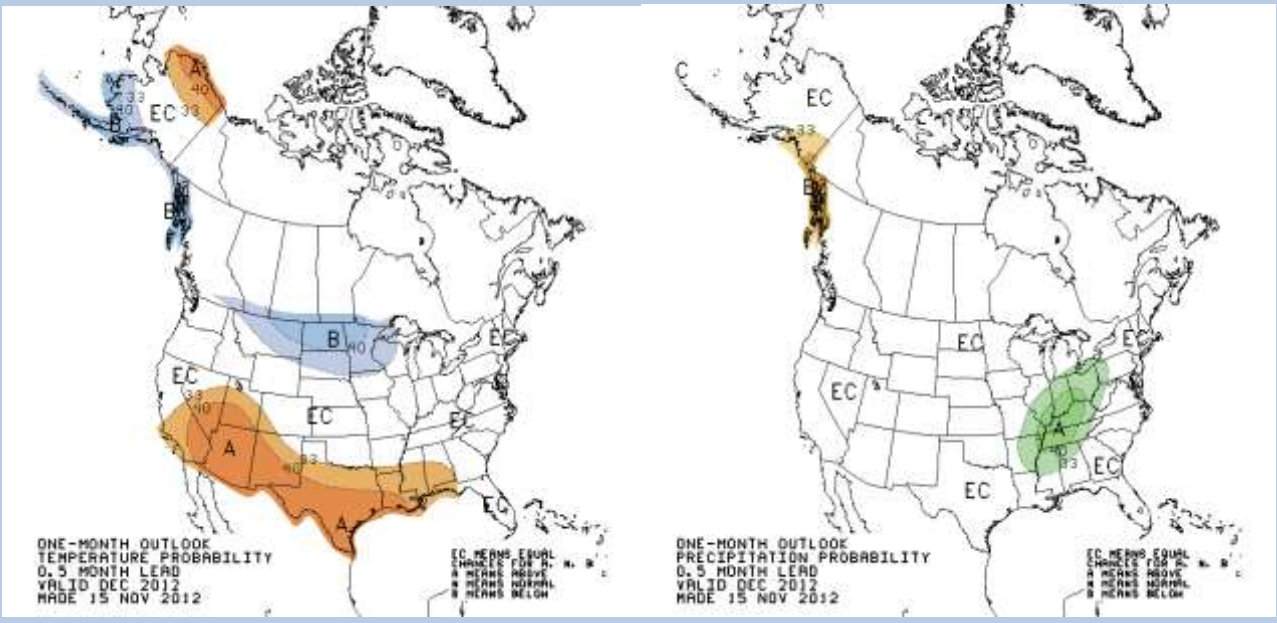
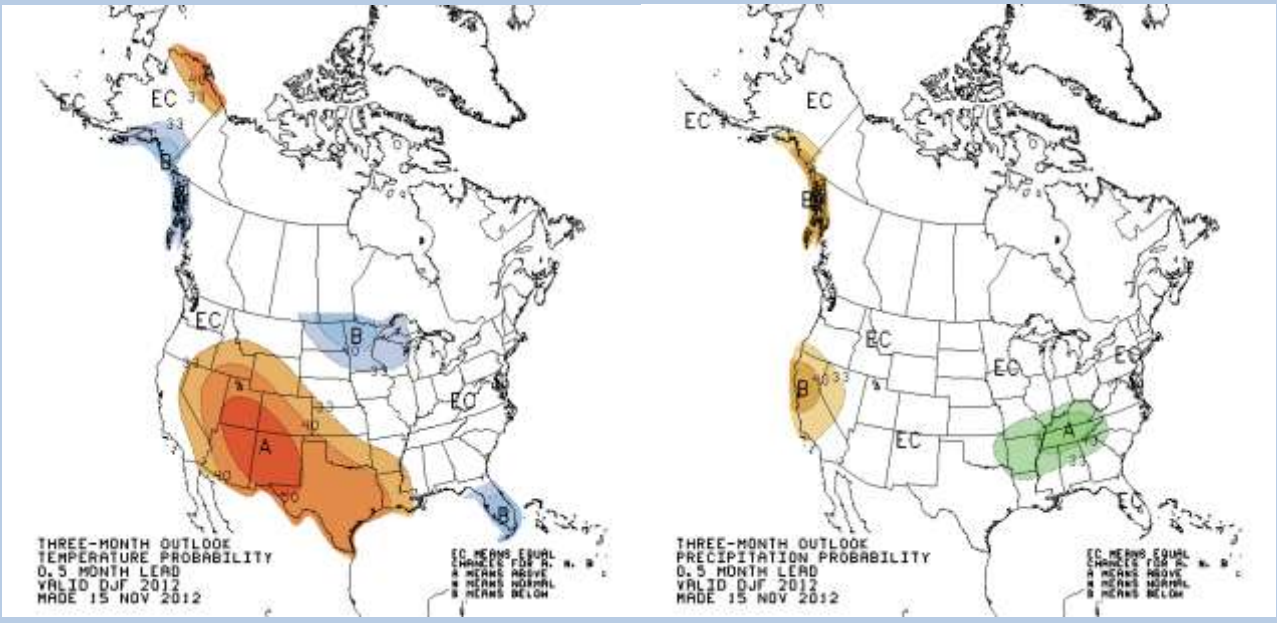


Figure 19: GFS Ensemble NAO Index Forecast through 12/5/12

So does all this mean we will have a cold and snowy winter?

The research shown above does indicate increased chances of having near average to above average snowfall this winter season, and also a tendency for near average or even colder than average conditions. However, there is still uncertainty on how the large scale weather pattern will set up the remainder of meteorological winter and things could change. The information shown above is not meant to be an official forecast, but merely a look at some of the possibilities that could set up this winter. Here is the official forecast for the month of December and the winter season (December through February) from the Climate Prediction Center. Overall the area remains in equal changes for above, below or near average temperatures and precipitation. However, they have added some enhanced probabilities for cooler than average conditions to our north and west across the Dakotas and upper Mississippi valley. In addition, they added enhanced probabilities for above average precipitation just to our south across potions of the Tennessee and lower Ohio Valleys. This forecast is supported by the –PDO.