The Atlantic Multidecadal Oscillation

By Joe D'Aleo
Monday, May 5, 2008
http://www.intellicast.com/Community/Content.aspx?a=127

Last week, we discussed the Pacific decadal Oscillation (PDO) and its impact on the frequency of El Ninos and La Ninas, which have an effect on the position of global troughs and ridges and through them global patterns of temperatures and precipitation.

The Atlantic also has a multidecadal oscillation called the Atlantic Multidecadal Oscillation or AMO which has a period of about 30 to 35 years per phase (a cycle length of around 70 years).

The UN IPCC notes correctly the oscillations of the Atlantic Multidecadal Oscillation (AMO) is likely due to changes in the strength of the thermohaline circulation. Dr. William Gray of Colorado State University has talked about this for years and continues to do so in his seasonal outlooks and presentations..

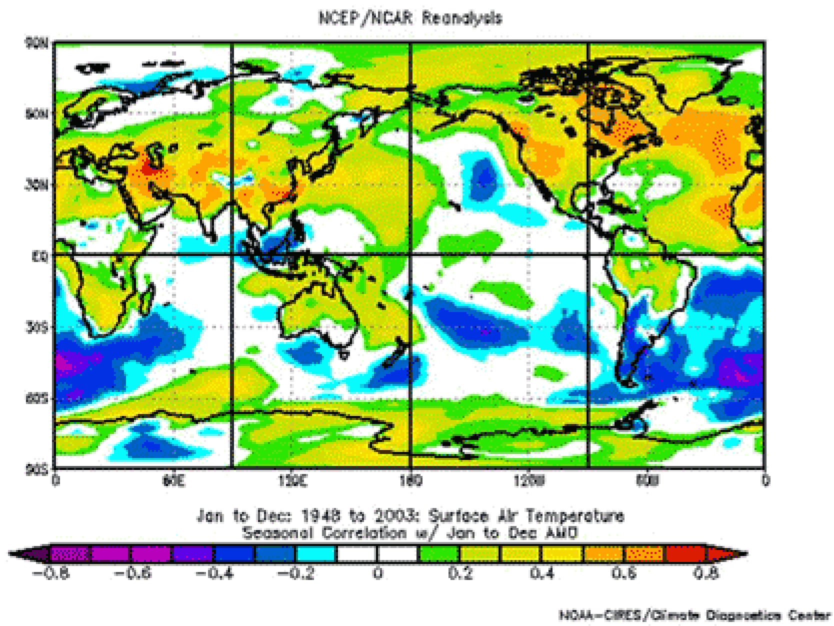
The IPCC AR4 even discussed how Walter and Graf (2002) related the AMO with the NAO (North Atlantic Oscillation) a better known more variable atmospheric flip flop in the central and eastern North Atlantic. This relationship was shown to be strongly negative during the cool (negative) phase of the AMO but weaker with the warm (positive) phase.

Like the PDO, the AMO is characterized by multiple decades of predominant warmth or predominant coolness in the ocean basins. They both have a tendency to be tri-polar, that is for the warmth in the warm phases to be found in the north and tropical oceans with a band of cooler water in between and in the cooler phases, coolness in the north and tropical belts with relative warmth in-between.

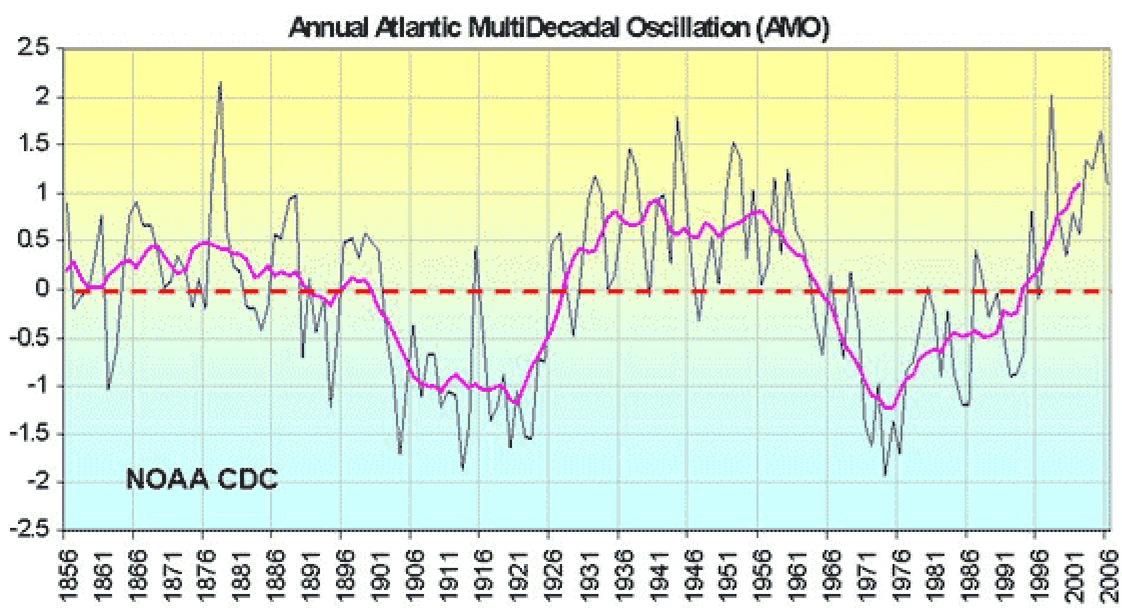
In the warm phase, the following annual correlation with surface air temperatures is seen. In the ocean areas, the ocean temperatures and surface air temperatures are virtually the same. Note the higher correlation of warmth in the tropics and subtropics and further north in the North Atlantic. Note relative coolness nearer 30N especially further west. Also note how during the warm phase, much of the northern hemisphere tends to be warmer than normal on an annual basis, including the arctic and Greenland (the topic next week).

Atlantic Multidecadal Oscillation

Correlates with general warmth, statistically significant in places



The AMO cycle looks like this extending back into the 1850s. It is simply here defined by the NOAA CDC as the average temperature anomaly between 0 and 70 degrees North in the Atlantic. I have normalized it into units of standard deviations on an annual basis.

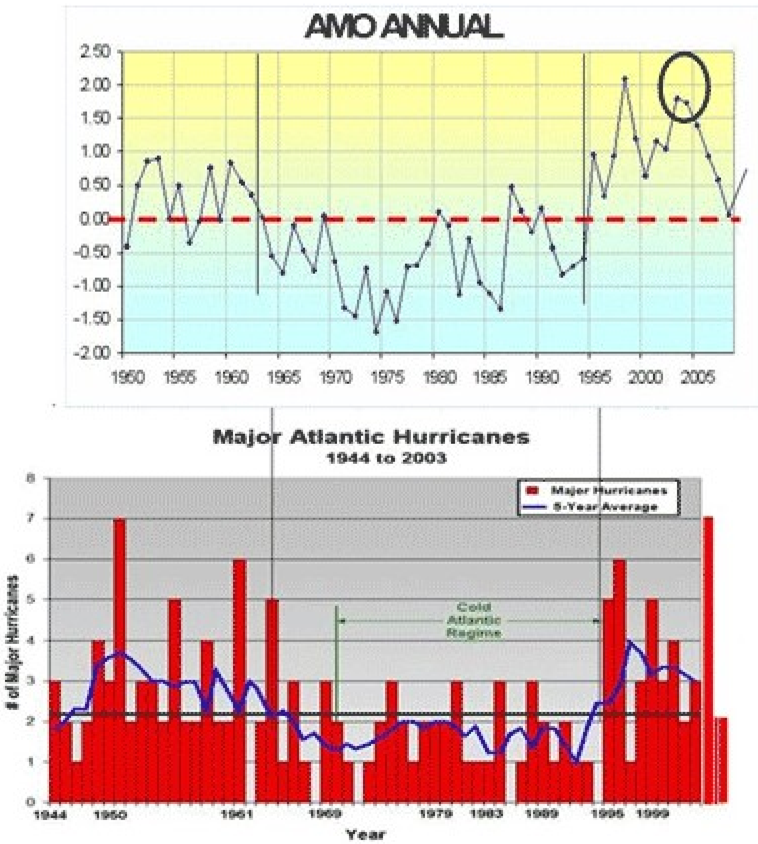


Mean ocean temperature anomalies in the Atlantic from 0 to 70N

You can clearly see the peaks in the 1870s, 1940s and around 2000. The highest value was achieved in the late 1870s, the second in 1998 (post the super-El Nino). The AMO was quite high also in 2004 and 2005, the years of the active Atlantic hurricane season.

THE AMO AND ATLANTIC HURRICANES

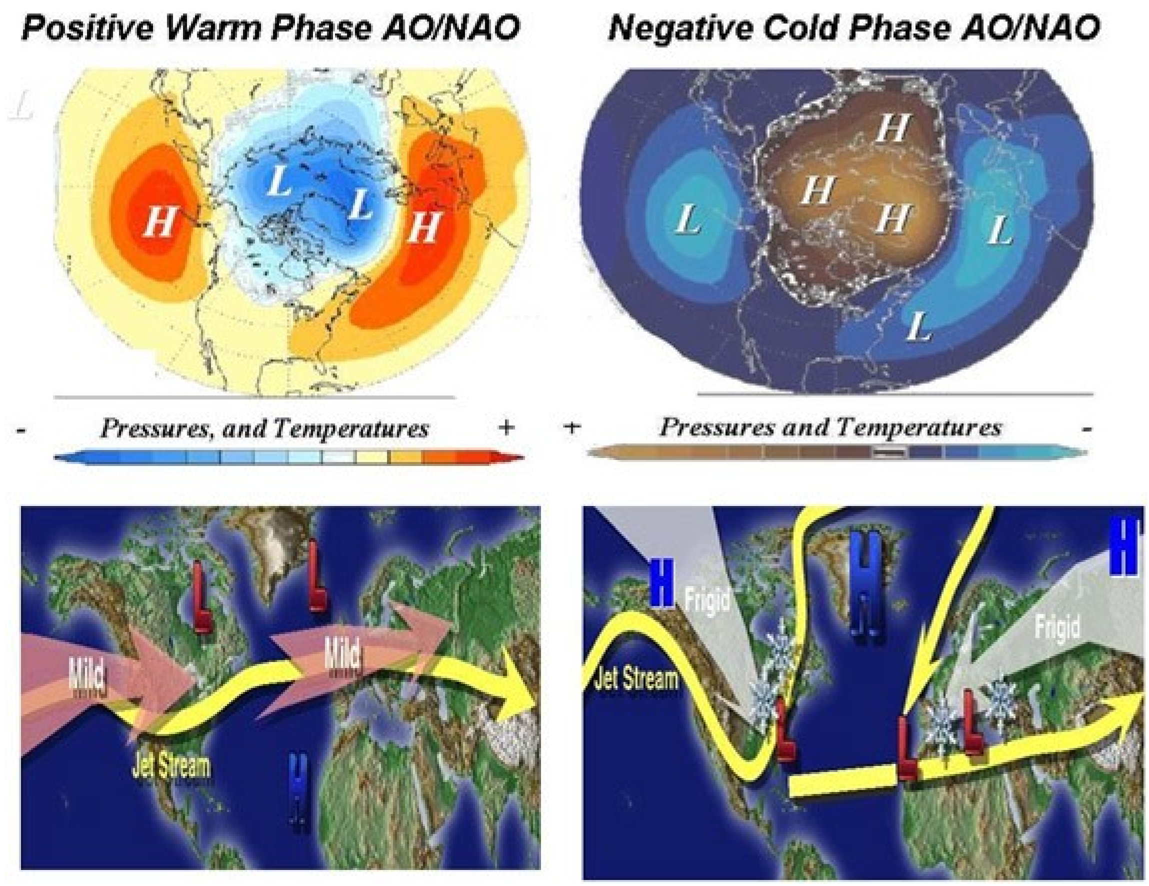
Here is a plot of the AMO and the number of major (CAT 3-5) Atlantic hurricanes by season. I have used the annualized AMO.



You can see as Bill Gray has noted, the frequency of Atlantic major hurricanes (CAT 3-5) is approximately doubled in the warm AMO phases. The last phase change in 1995 brought a sudden increase in Atlantic storms. In a future Intellicast Dr. Dewpoint post in Mid-May we will discuss how the PDO and ENSO modulate the AMO tendencies and can provide clues as to where hurricanes are most likely to go during the hurricane season.

AMO AND THE NORTH ATLANTIC OSCILLATION

The North Atlantic Oscillation is a flip flop of relative pressure between the far North Atlantic (Iceland to near Greenland) to the subtropical North Atlantic (Portugal or the Azores). The pressures tend to be low in the mean in the North Atlantic and high to the south but sometimes these tendencies are exaggerated and at other times reversed. It is these extreme anomalies that have a major effect of temperatures and precipitation in both Western Europe and eastern half of North America. It is a portion of a larger scale oscillation called the Arctic Oscillation that extends from the North Atlantic across the poles to the North Pacific. Usually the NAO and AO are in the same phase, when they are, they tend to be more stable and have more prolonged effect. Often the atmospheric NAO and AO vary more month-to-month even week-to-week than the more stable ocean based AMO.



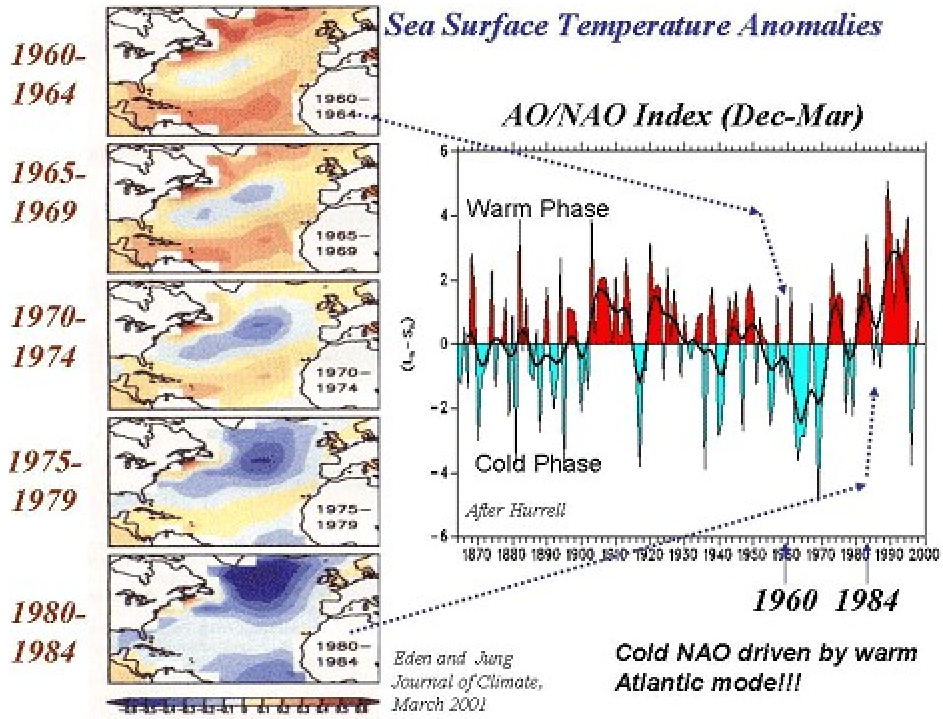
You can see from the chart above when pressures and temperatures are unusually low in the North Atlantic and arctic and high to the south the jet stream tends to be flat (more zonal west to east) leading to milder Pacific air dominatng in North America and milder Atlantic air across western Europe. When the flip occurs and warmth gets trapped in high latitudes and blocking high pressure centers develop (called blocks because they prevent the west to east movement of cold air), they cause the jet stream to buckle. That usually results in an eastern US trough into which cold air pours and east coast snowstorms or nor'easters in winter.

Central New England during the very blocky winter 2000/01.

In Europe, the blocking in North Atlantic, allows cold Siberian air to be drawn west to Western Europe with frigid temperatures and snows in places that normally see little of it.

THE RELATIONSHIP WITH THE AMO

Can be seen from the following two diagrams:



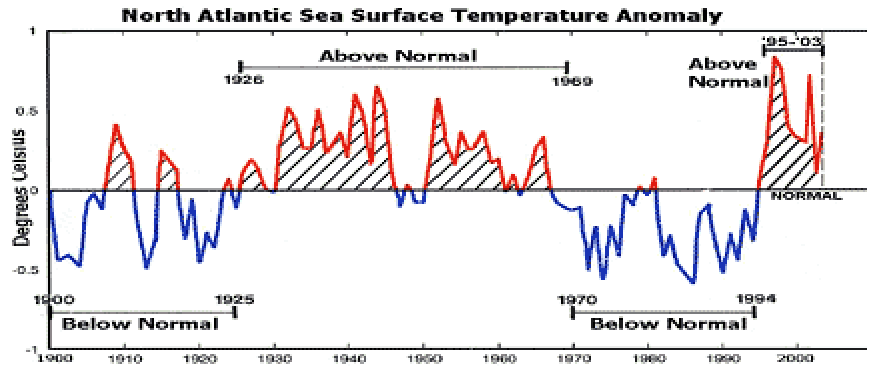
Note during the 1960s when the Atlantic was in its warm modem the AO, NAO were negative (cold). That was a cold and snowy decade. Note how the Atlantic evolved into its cold phase by the 1980s and the AO and NAO were predominantly strongly positive.

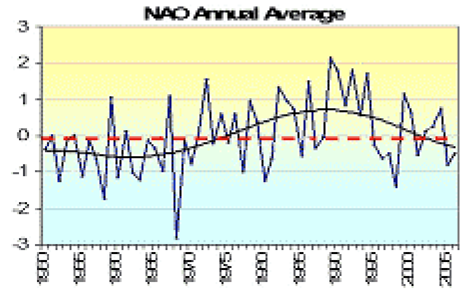
Here you see the two indices the AMO and NAO (both standardized) graphed together. You see the inverse relationship.

EFFECTS OF AMO AND PDO ON TEMPERATURES

We have shown last week how the warm PDO mode is associated with more frequent El Ninos which are accompanied and followed by a global warming. The warm mode of the AMO although it can lead to cold and snowy periods in winter, on an annual basis correlates with widespread global warmth (see first figure in this post).

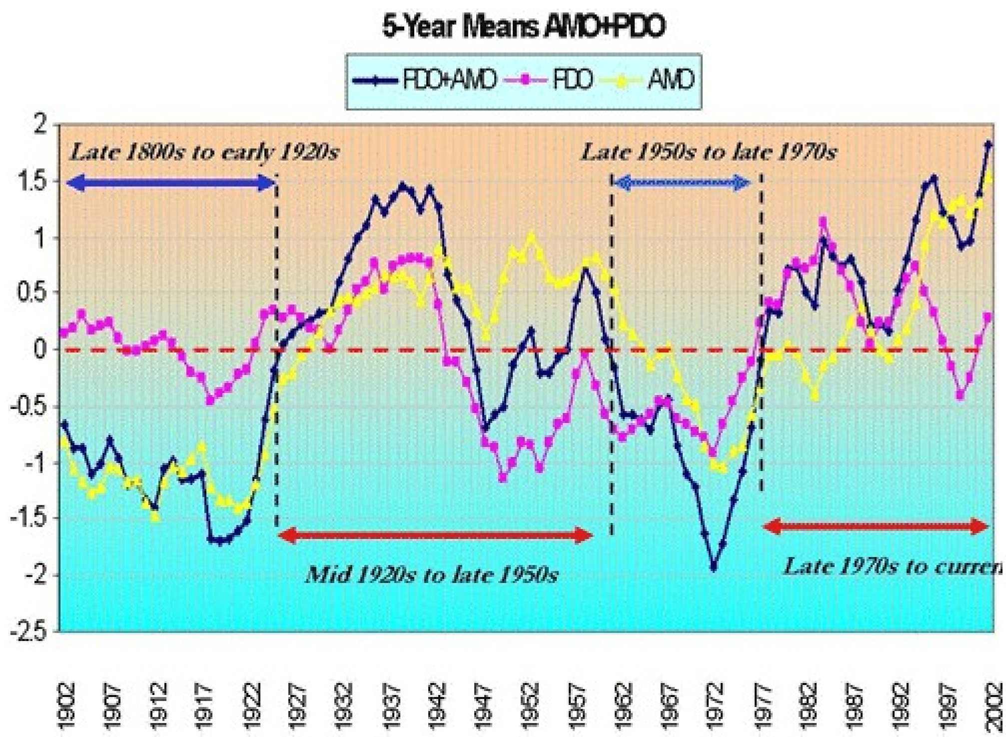
Thus when both the PDO and AMO are in their warm mode, one might expect more global warmth and when they are both in their cold mode, general global coolness. Although one might argue they are just reflecting the overall warming and cooling, recall that the ocean transitions from one mode to the other in both cases are abrupt, occurring in just a year or two, suggesting as the AR4 does that these oscillations are ocean gyre or thermohaline circulation based and thus natural.



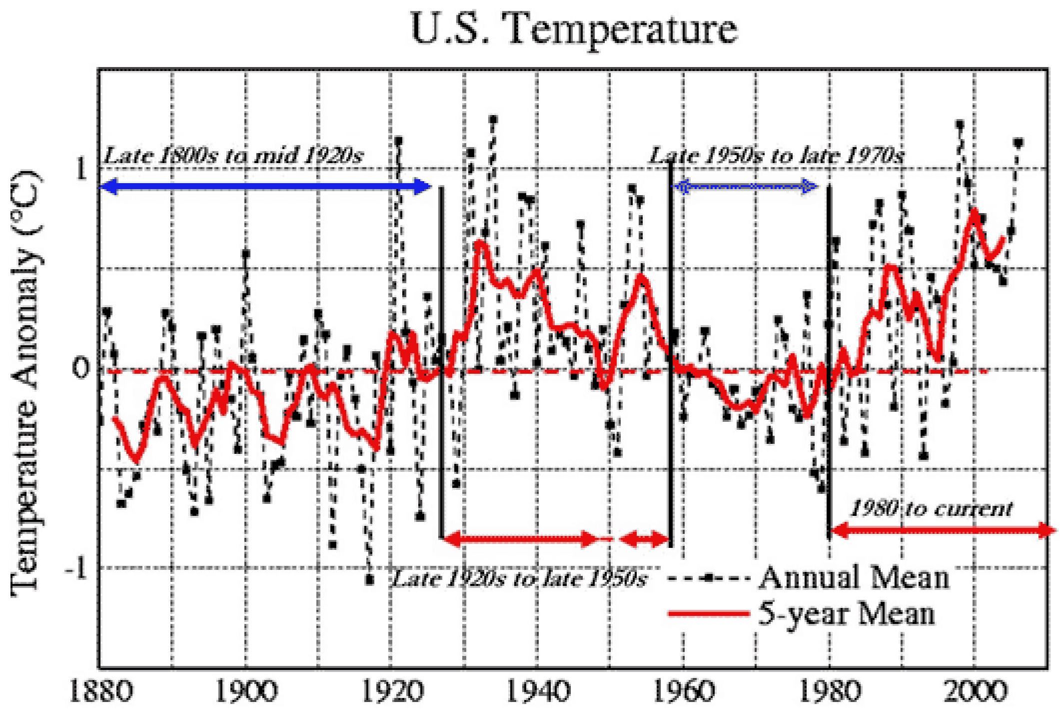


North Atlantic temperatures went above normal and NAO turned more negative starting in 1995

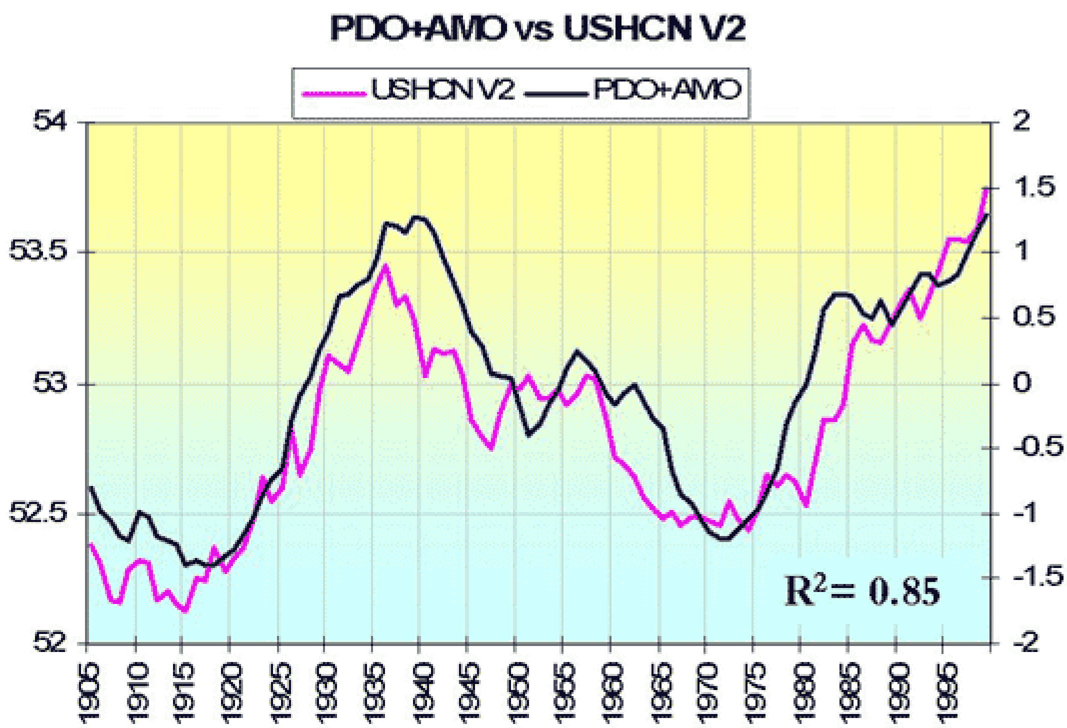
Indeed when we plot and add the two indices we see a suggestion of global cooling from the 1880s to 1920s, global warming from the late 1920s to early 1950, a global cooling from the late 1950s to late 1970s and then a global warming. Dark blue line represents the sum.



How does that relate to US temperatures (chosen because they unlike the global are more stable and at least in version 1 of the USHCN data base were adjusted for local factors and urbanization.

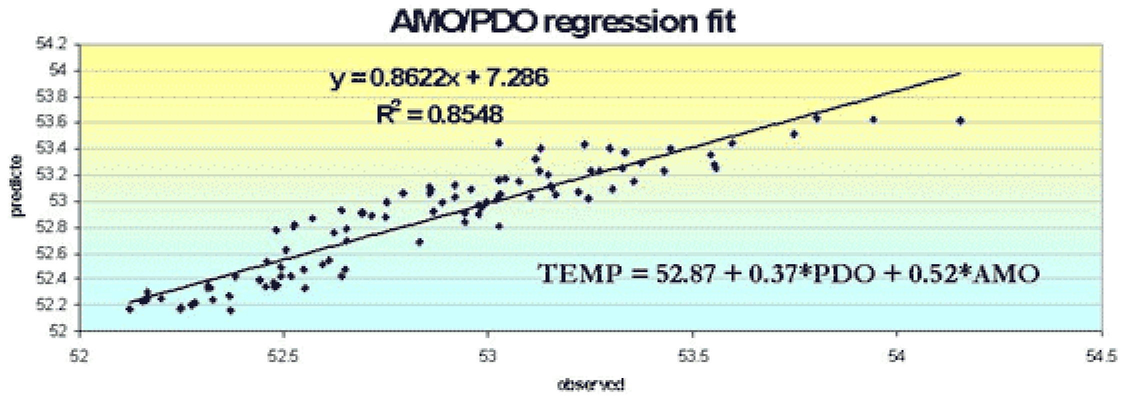


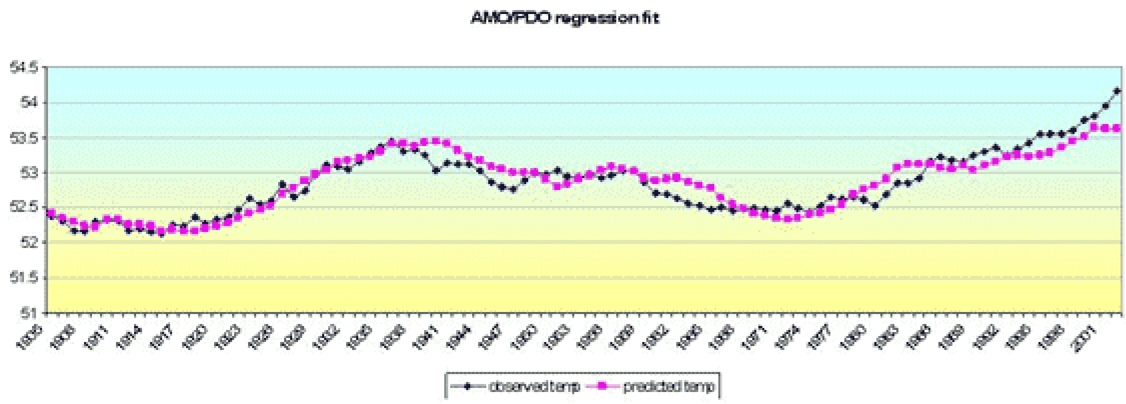
This almost exactly matched (r-squared of 0.85!) the transitions to warm and cold and cold to warm observed in the data going back to the 1890s.



We did a multiple regression of AMO and PDO with the temperatures and found the same r-squared value of

0.85.





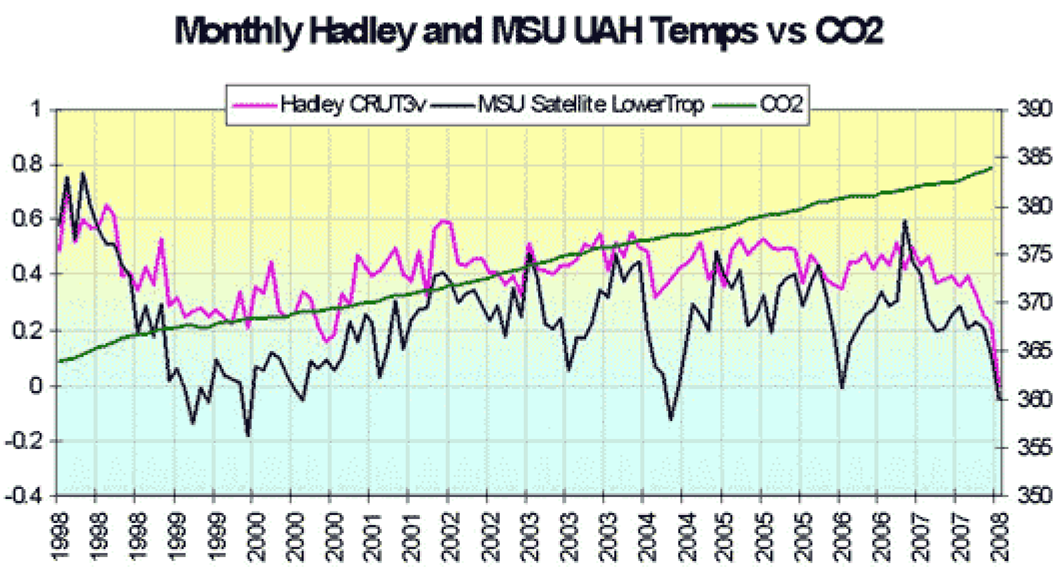
This correlation was the best of the factors we looked at (Total Solar Irradiance, CO2, PDO/AMO) with 10 year smoothing for all parameters including temperatures (which increases the correlation but would not impact the relative importance of the factors). Notice how especially in the last decade how the correlation of US temperatures with CO2 has actually turned negative for the US.

It is even 0 for the MONTHLY global temperatures data bases from satellite (UAH MSU) and surface land and ocean (Hadley) and Scripps Mauna Loa based CO2 over the last decade during which time temperatures were flat even as CO2 increased 5.5%.

Factor	Years	Correlation Pearson coefficient	Correlation Strength (r-squared)
Carbon Dioxide	**1895-2007**	**0.66**	**0.44**
Total Solar Irradiance	**1900-2004**	**0.76**	**0.57**
Ocean Warming (PDO and AMO)	**1900-2007**	**0.92**	**0.85**
Carbon Dioxide Last Decade	**1998-2007**	**-0.14**	**0.02**

With USHCN Version 2

The sun may be the primary driver, but are the oceans the 'flywheel' in the climate system?



R^2 HadCRUT3v and CO_2 = 0.001
R^2 UAH MSU LT and CO_2 = 0.005 (0.02 since 2000)

This table and chart suggests we should be spending much more time and research dollars trying to better understand and predict the oceans and the sun than on trying to model or study the impact of CO2 or spend billions or trillions trying to control it.

Next week, we will discuss the importance of this AMO and Greenland and the Arctic temperatures and ice. In two weeks, we will look at the PDO and AMO and the upcoming tropical season and why the east coast may be at special risk this year along with the western Gulf of Mexico.