Ocean Multi-Decadal Changes and Temperatures

By: Joseph D'Aleo, CCM

IPCC AR4 did an exemplary job explaining the patterns of climate variability through global teleconnections and defining the circulation indices including the short term and decadal scale oscillations in the Pacific, and Atlantic. It noted that the decadal variability in the Pacific (the Pacific Decadal Oscillation or PDO) is likely due to oceanic processes. Extratropical ocean influences are likely to play a role as changes in the ocean gyre and Aleutian low evolve and heat anomalies are subducted and reemerge. The Atlantic Multidecadal Oscillation (AMO) is thought to be due to changes in the strength of the thermohaline circulation.

Though the IPCC AR4 describes some of the recent research on these phenomena, it does not draw out their importance for explaining global climate changes over multi-decadal intervals.

The Pacific Decadal Oscillation and Its Effects

JPL and University of Washington scientists (Mantua et al., 1997) when examining conditions that might explains multidecadal tendencies in the success of salmon fisheries found patterns a full basin North Pacific sea surface temperature anomalies and overlying surface pressure stayed in one mode predominantly for a few decades and then would flip to the opposite mode. They called this apparent oscillation the Pacific Decadal Oscillation (PDO).

Even before the PDO was discovered, climatologists had noted that an event called the "Great Pacific Climate Shift" occurred in the late 1970s with a major shift in Pacific ocean temperature regimes. The PDO mode went what was later called the cold or predominantly negative mode which had persisted since 1947 to what was termed the warm or positive mode.

The positive mode is correlated with warm water anomalies off the west coast of North America from Alaska south and in the eastern and central tropical Pacific 'NINO' regions. The result in terms of sensible weather was a tendency for warmth in western North America and Alaska and cold in the southeastern United States (Hansen 1999).

Also the sea surface warmth in the NINO regions suggests a predisposition for El Ninos over La Ninas during the positive PDO decades and for La Nina over El Nino during negative PDO modes.

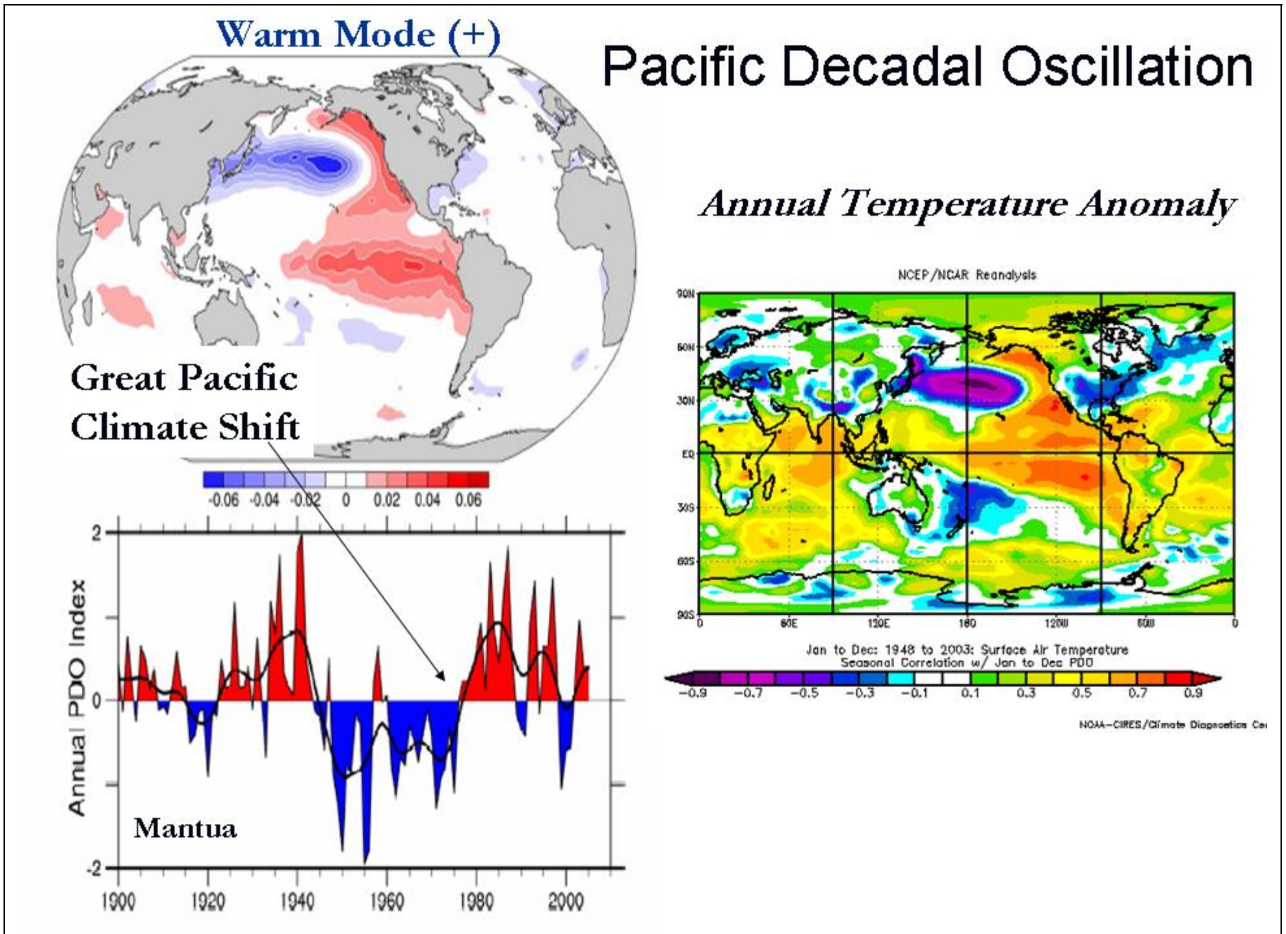

Figure 1: PDO cycle bottom left shows the Great Pacific Climate Shift in 1977/78 to the positive or warm mode. The PDO warm mode sea surface temperature anomalies (top left) and annual mean surface temperatures (right) are shown.

Figure 1: PDO sea surface temperature and PDO variations from the ASPM Chapter 3 and annual temperature correlation with PDO from NOAA CDC Reanalysis

In addition, as the AR4 implied, since atmospheric pressure was correlated with water temperatures, the Aleutian low changed in sympathy with the PDO, become stronger (lower pressure) during the warm positive PDO phases and weaker on average in the cold negative PDO periods (figure 2).

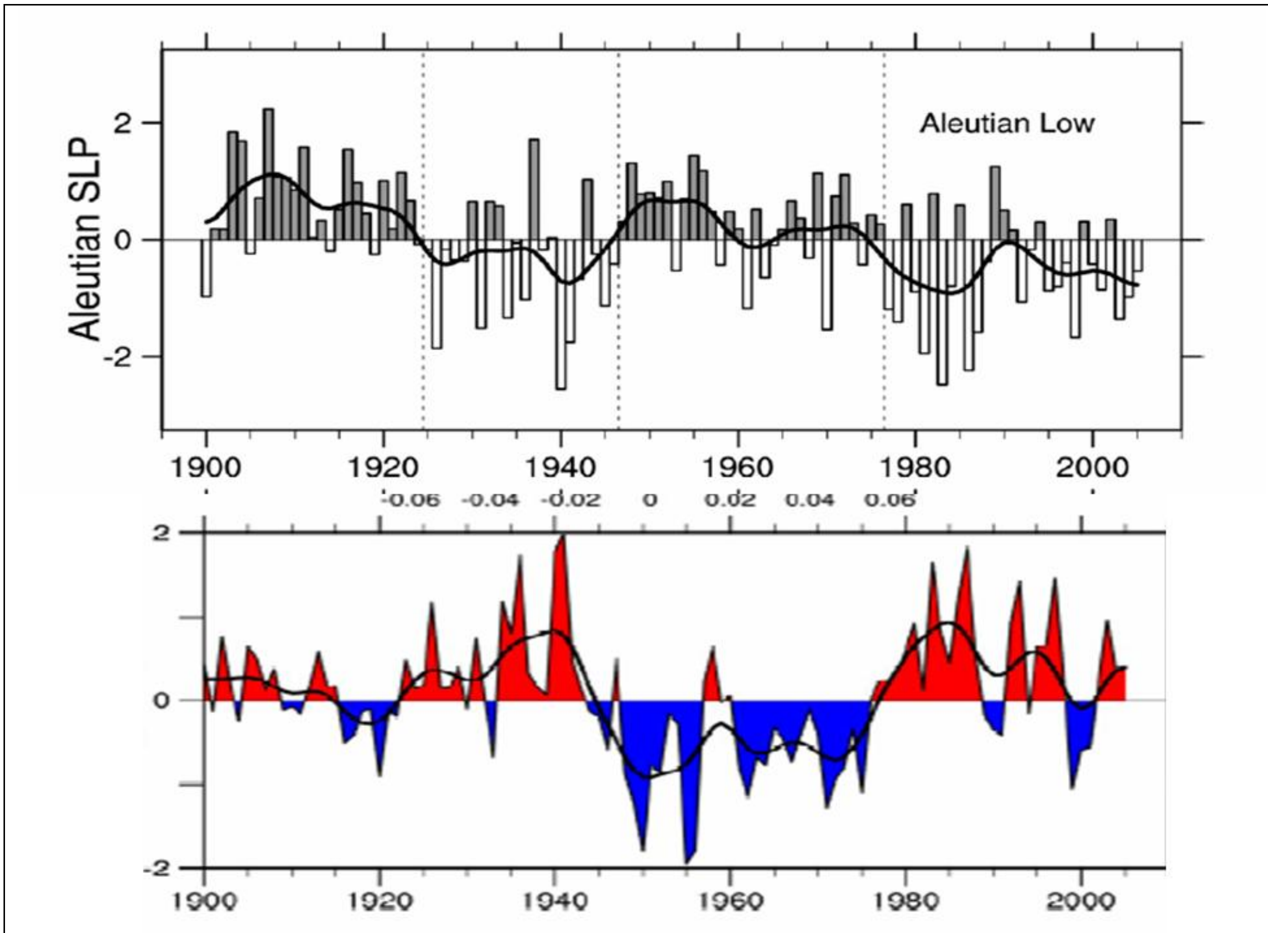

Figure 2. Aleutian low strength top as compared with the PDO bottom from 1900 to 2005. Note the inverse relationship. Images sourced from AR4.

With a stronger Aleutian low which brings southerly winds to Alaska and the warmer water off the coast, it is not surprising Alaska entered a warmer regime after the Great Pacific Climate shift. Notice however though how all the warming occurred in the first two years of the major shift when the greatest change in water temperatures occurred and have remained steady since.

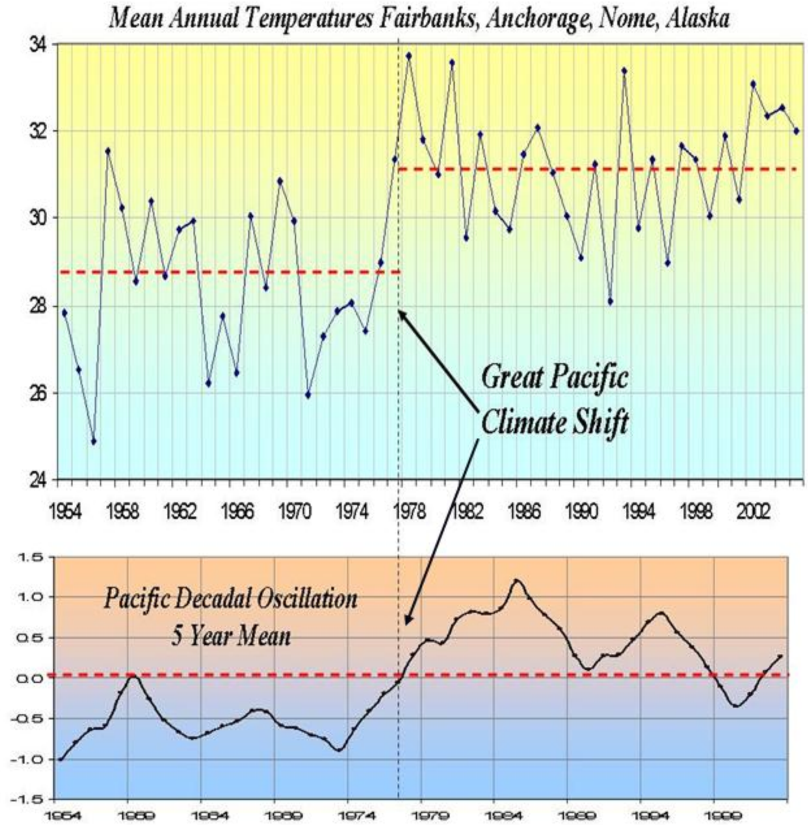

Figure 3: Temperature Data for Fairbanks, Anchorage, Nome from NOAA. PDO index from NOAA CDC Climate Indices.

The PDO has flipped negative again. It started with a cold northern and eastern Pacific this past winter despite the moderate El Nino. Now La Nina appears to be developing and the PDO turned negative this March. It remains to be seen whether this will persist and mark the beginning of multiple decades of mainly negative PDOs.

As shown earlier in figure 1, the PDO positive warm phase brings warmth in the four NINO regions and thus more El Ninos. Indeed this is shown in the plot of Wolter's Multivariate ENSO Index (MEI) which has nearly double the frequency of El Ninos versus La Ninas in the recent warm phase.

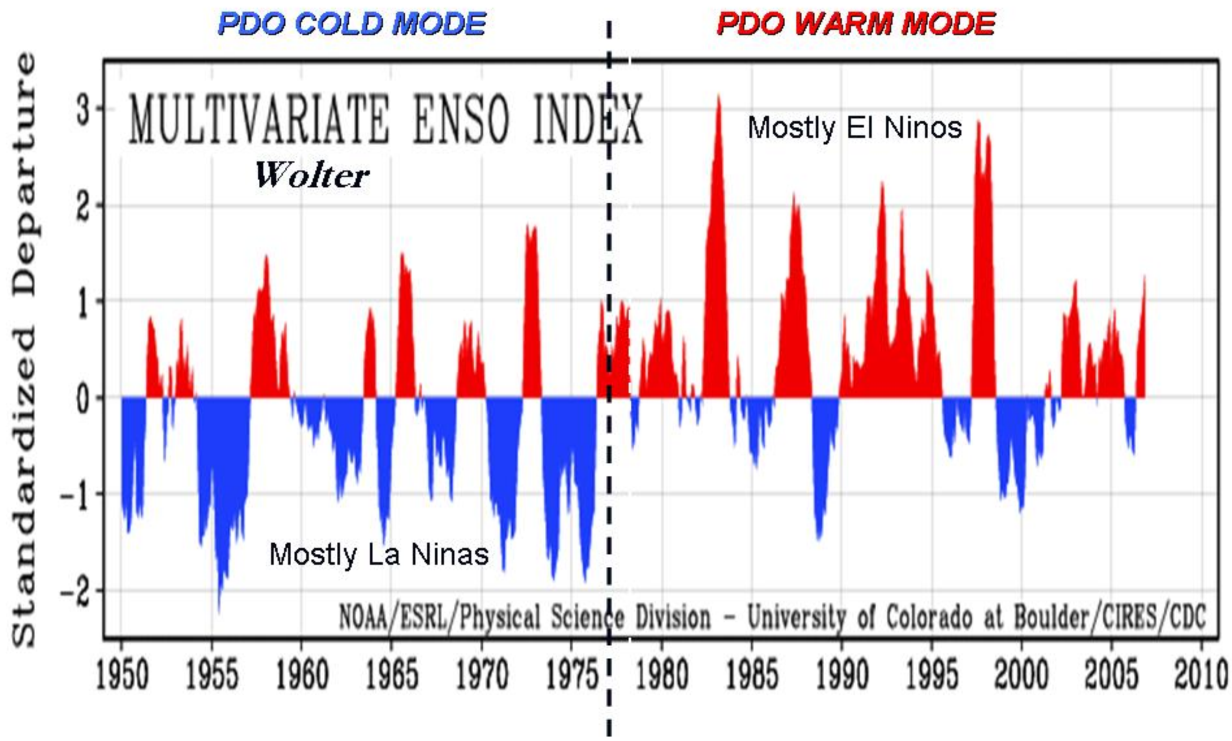

Figure 4: Wolter Multivariate ENSO Index (positive values (generally greater than 0.50 represent warm events (El Ninos) and negative (more than -0.5) cool events (La Ninas))

In the prior cold PDO period with cold tropical Pacific waters favored, one would expect the opposite with more La Ninas and that too was observed in Figure 4.

El Ninos generally produce a global warming as the extensive area of warm water in the eastern and central Pacific adds heat and moisture which is taken poleward by large scale atmospheric circulations (Hadley cell) and enhanced southern stream storms. On the other hand, La Ninas, are found to correlate with global cooling. This can be seen from satellite measurements (Spencer and Christy MSU) of the lower troposphere in figure 5. Those measurements began after the great Pacific climate shift and we can see the dominant El Ninos has contributed to global warmth during that period.

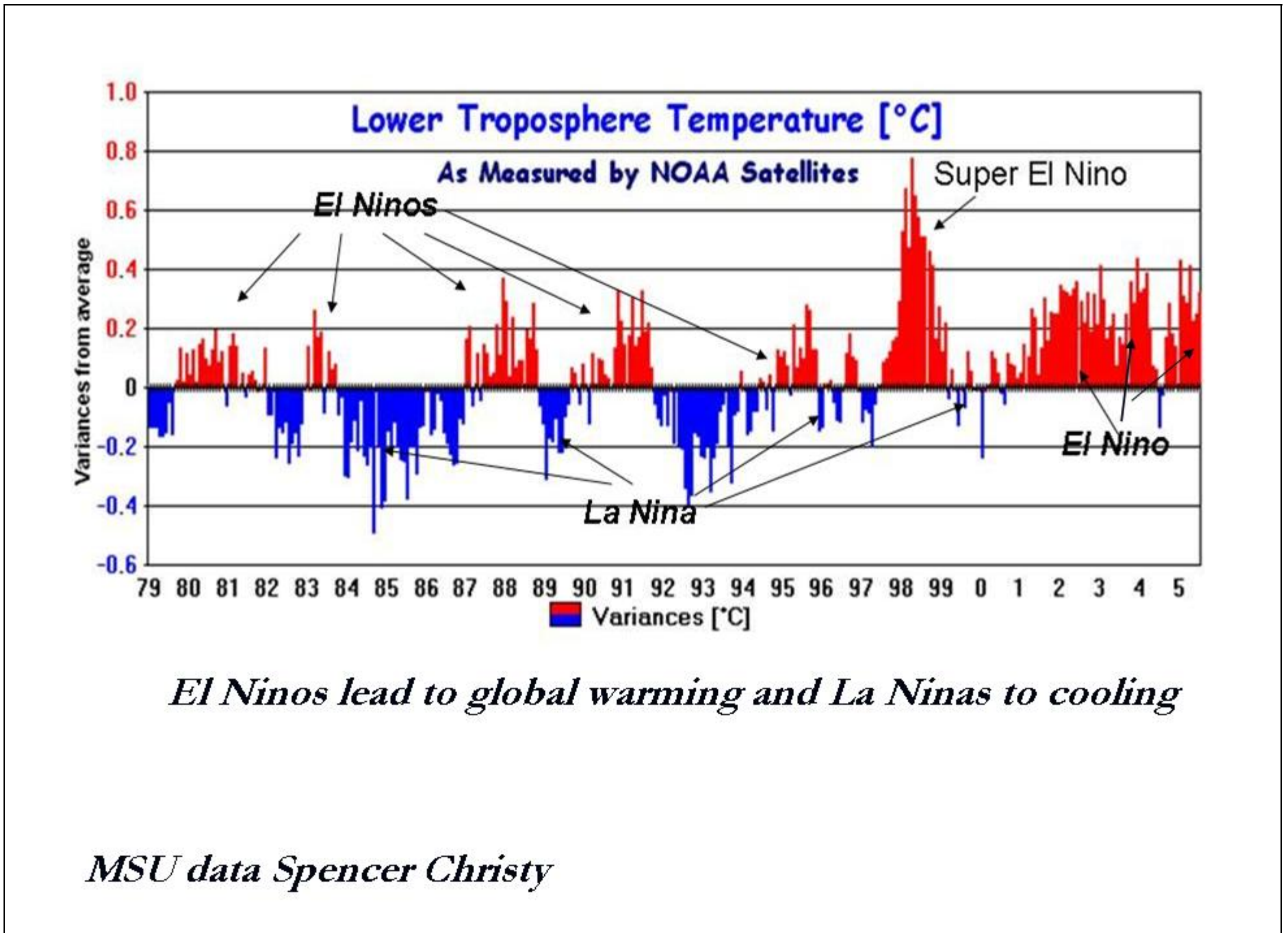

Figure 5: Global average lower tropospheric temperature anomalies as measured by satellite. Note the tendency for El Ninos to produce global warmth and La Ninas coolness. Note the super El Nino of 1997/98 which produced the warmest year on record.

You will also note in figure 5, two rather lengthy cold periods in the early 1980s and early to mid 1990s that were not associated with strong La Ninas. These cold periods were the result from major volcanic eruptions (Mt. St. Helens and El Chichon in the early 1980s, and Pinatubo and Cerro Hudson in the early 1990s). Unlike the minor volcanic eruptions that occur daily around the globe whose ash and gases may only reach a few thousand or tens of thousands of feet up where they will precipitate out in days or weeks, major eruptions can throw gases (one of the most important being sulfur dioxide) and ash high up into the atmosphere 80,000 to sometimes 100,000 feet or more. During or after the journey to the high stable atmosphere, sulfur dioxide gases get transformed to sulfate aerosols which can reside in the stable high atmosphere for several years. These aerosols act to reflect the sun's radiation back to space and thus reduce the amount of suns energy reaching the surface.

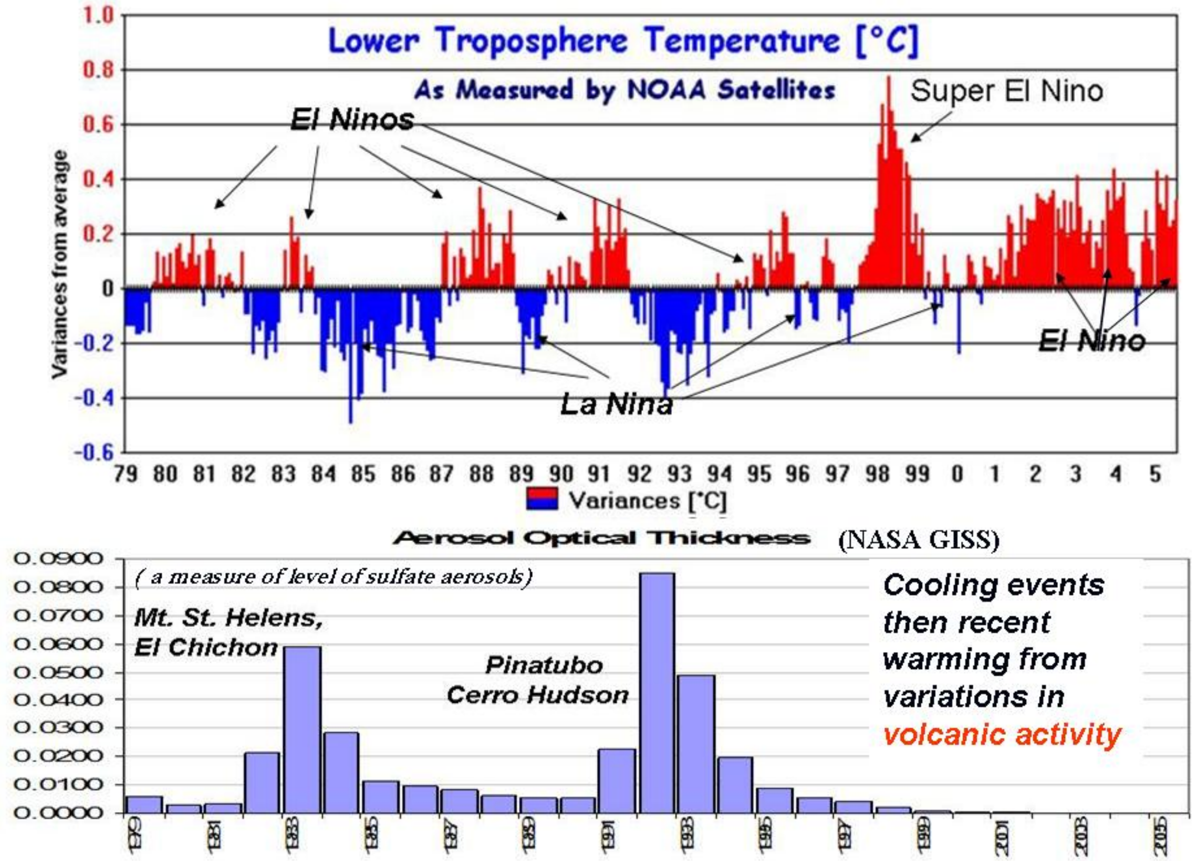

Figure 6: The level of sulfate aerosols (courtesy of NASA GISS) during the satellite era. Note the high levels in the early 1980s and 1990s after the major eruptions of Mt. St. Helens, El Chichon, Pinatubo and Cerro Hudson. Notice the lowest levels of the record since 2000 which may have contributed some to the recent warmth

Notice after Pinatubo and Cerro Hudson, no major volcanoes have occurred for the past 15 years resulting in the lowest aerosol loading in the high atmosphere at least in the satellite era (along with 3 El Ninos since 2006). This has accounted for SOME of the recent warmth. Indeed if one does a composite of all years since 1948 with stratospheric aerosols over ½ standard deviation above the long term average, one gets a very different picture of global temperatures than the composite of years with more then ½ standard` deviation below normal ash content.

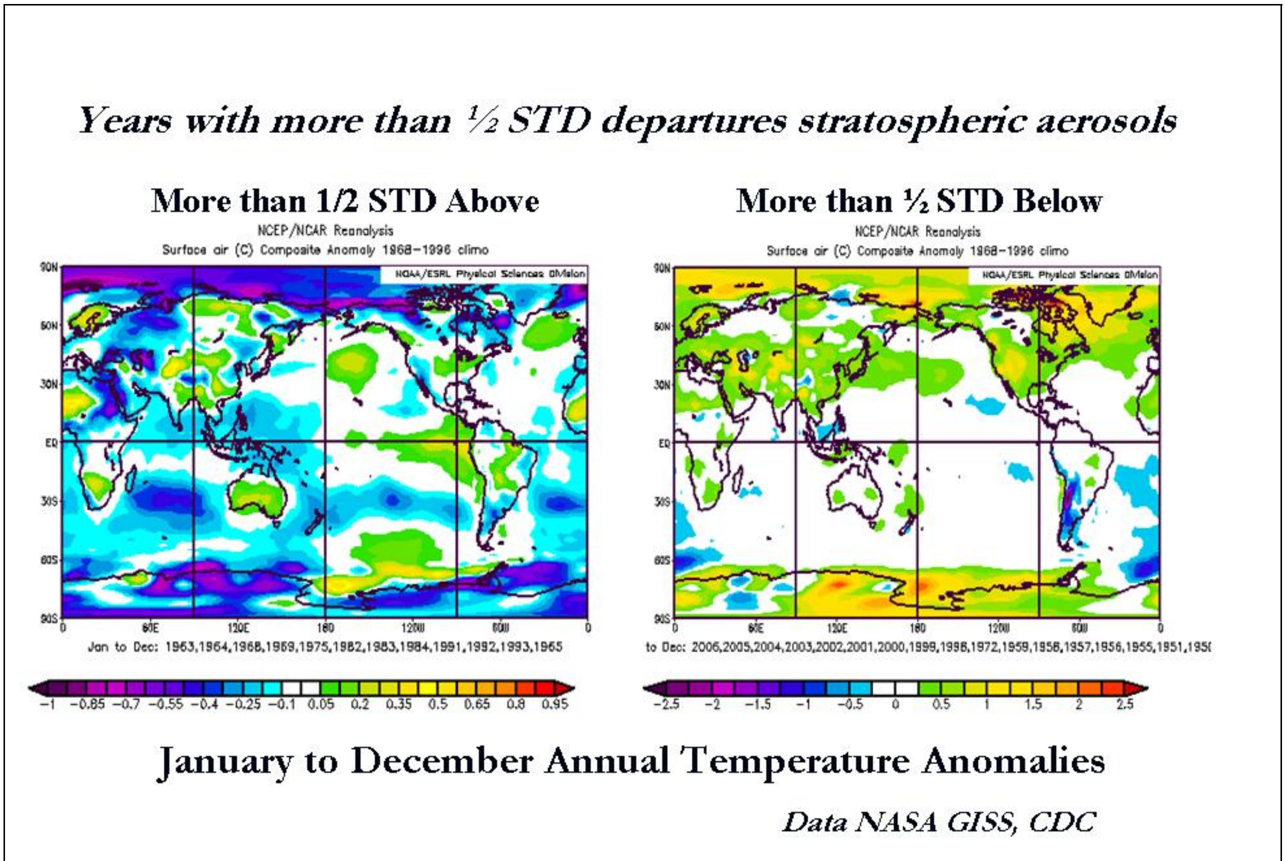

Figure 7: When aerosol levels were high, there was rather widespread coolness especially in the polar regions. When it has been low as it is currently, these same areas and most of the Northern Hemisphere continents are warm (1-2F above normal).

Historically major volcanic activity has tended to cluster in period with long periods of relative quietness between. Note the lack of activity from the 1930s to the 1950s that may have helped augment the warming then as it may be doing now and the persistently high levels of activity of the late 1800s and 1960s which may have enhanced the cooling.

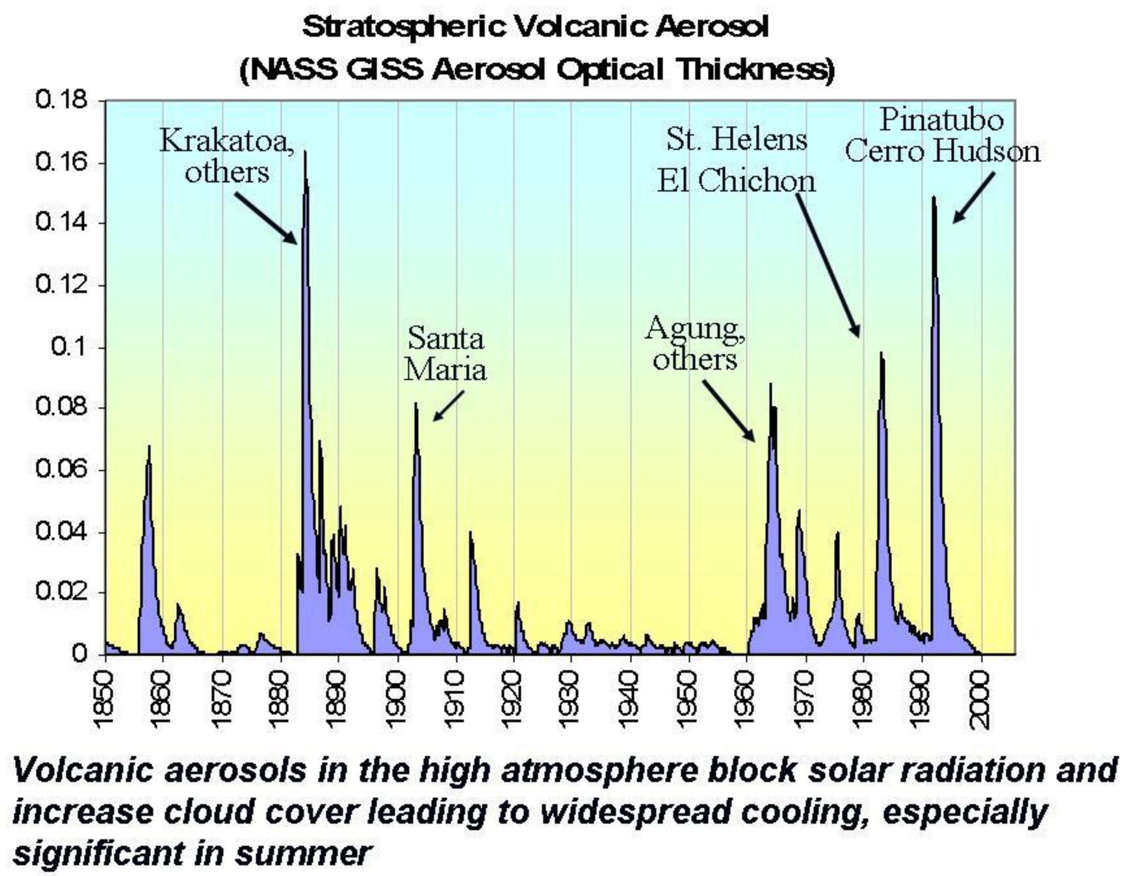

Figure 8: Stratospheric volcanic aerosol courtesy of NASS GISS from 1850 to 2006. Note the high levels in the late 1800s, the 1960s and early 1980s, 1990s, but the very low content in the 1870s, 1930s-1950s and after 2000.

The Atlantic Multidecadal Oscillation

Like the Pacific, the Atlantic undergoes decadal scale changes in ocean temperatures with a period that averages 60 -70 years or so. It can be seen to extend back to at least the 1850s in figure 9.

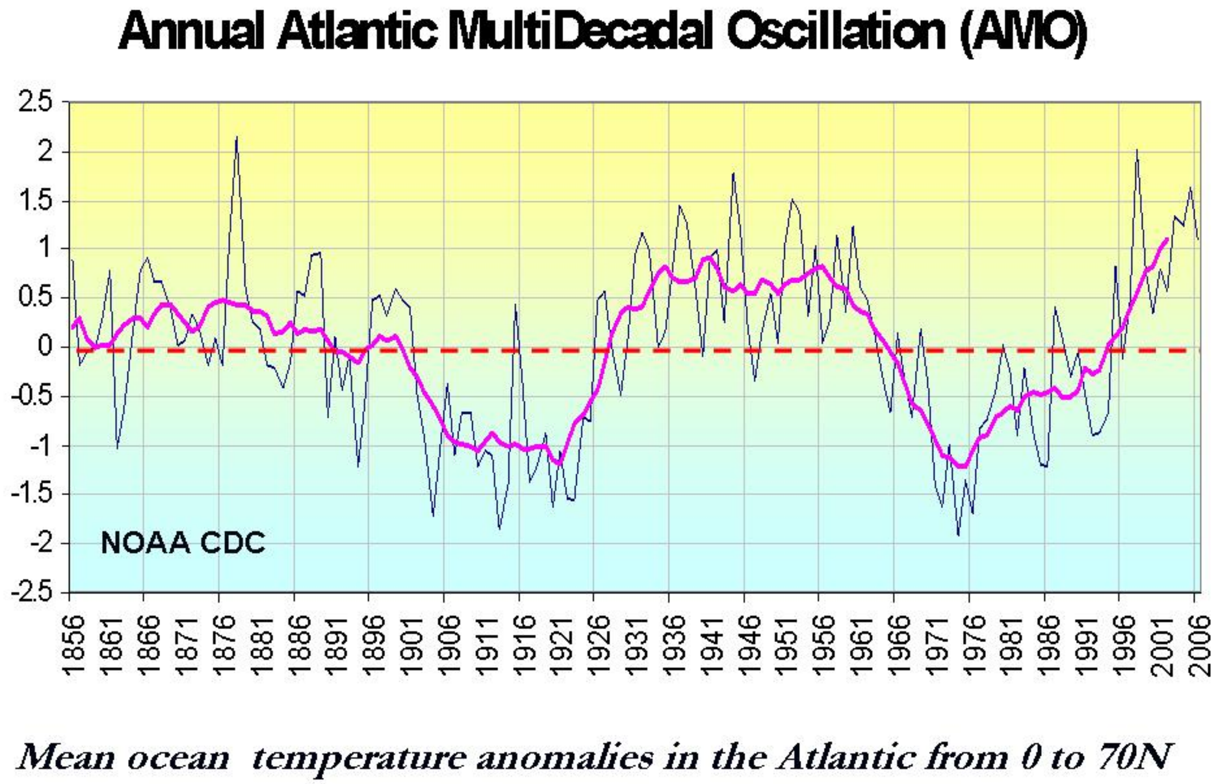

Figure 9: Atlantic Multidecadal Oscillation (NOAA CDC) – the mean ocean temperatures from 0 to 70 degrees north latitude. Note the approximate 70 year cycle.

The AMO turned positive in 1995. When it is positive it favors more Atlantic hurricane activity and often more high latitude blocking events in winters. For temperatures though, the net result on an annual basis is for general warmth, statistically significant over land areas of the Northern Hemisphere as seen in the correlation chart from NOAA CDC in figure 10.

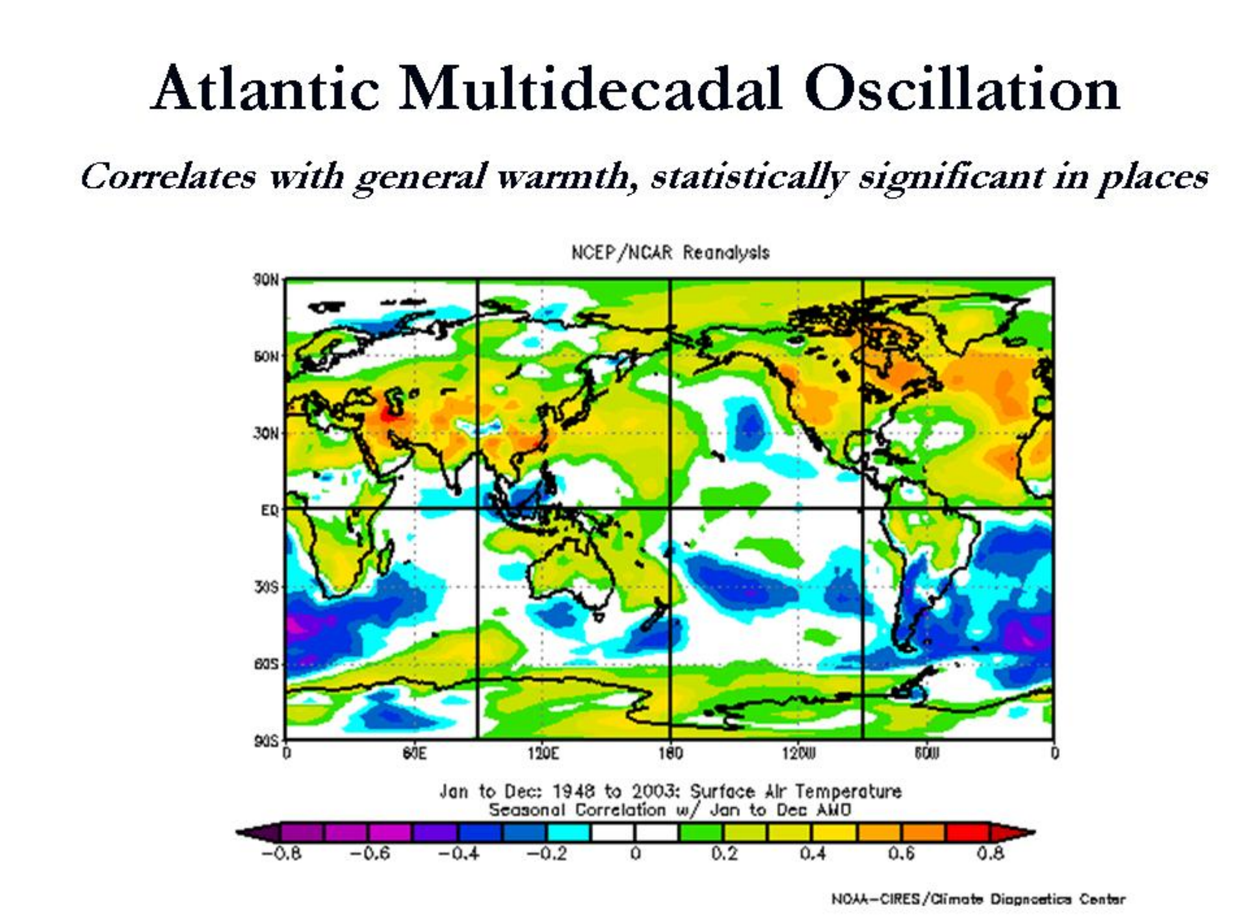

Figure 10: Annual Temperatures correlated with a positive AMO (warm Atlantic).

AMO AND PDO CYCLE OVERLAPS AND COLD AND WARM PERIODS

We have already shown 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 on an annual basis correlates with widespread global warmth.

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 transitions from one mode to the other in both cases is abrupt occurring in a year or two, suggesting as the IPCC AR4 does that these oscillation are ocean gyre or thermohaline circulation related.

Indeed when add the two indices (after normalizing them) and plot the mean value of the net result with the mean USHCN data we see a strong correlation (r-squared of 0.86) with 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.

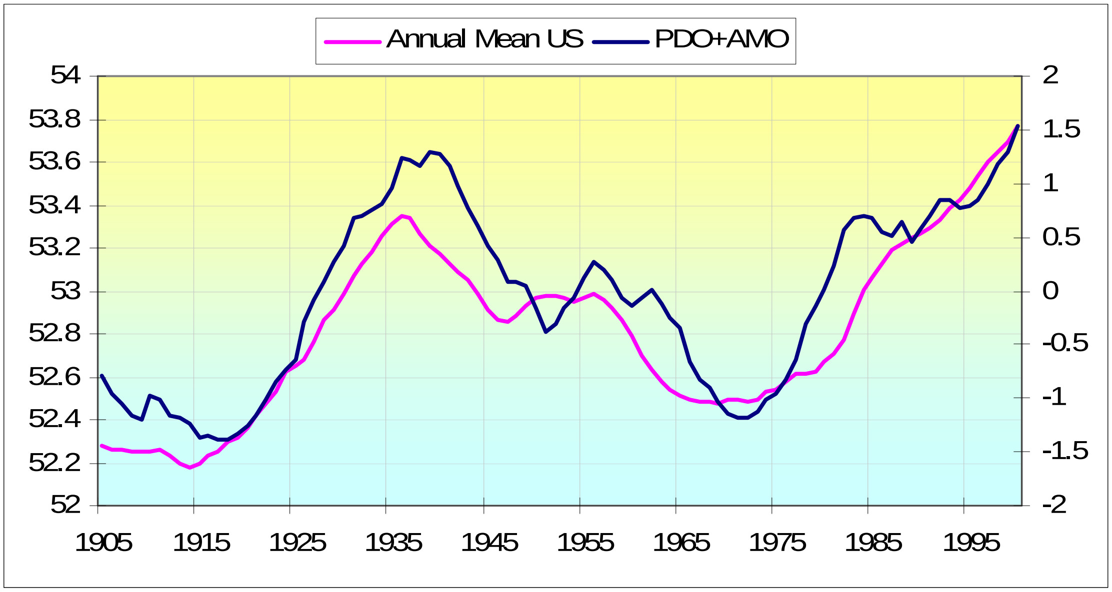

Figure 11: AMO+PDO (standardized and then added) reflects tendency for global warmth or coolness. It correlates very well with US Annual mean temperatures (r-squared of 0.86). Both index and temperatures are shown for 11 year running mean.

SUMMARY

Multidecadal Oscillations in the Pacific and the Atlantic are acknowledged to be the result of natural processes. We have shown the warm phase of the PDO leads to more El Ninos and general warmth and the cold phase to more La Ninas and widespread coolness. The warm mode of the AMO also produces general warmth especially across northern hemispheric land masses. When you combine the two effects, you can explain much of the temperature variances of the past 110 years. Major volcanic activity can act to enhance or offset the tendencies at times.

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