Ocean Multi-Decadal Changes and Temperatures

By: Joseph D'Aleo, CCM

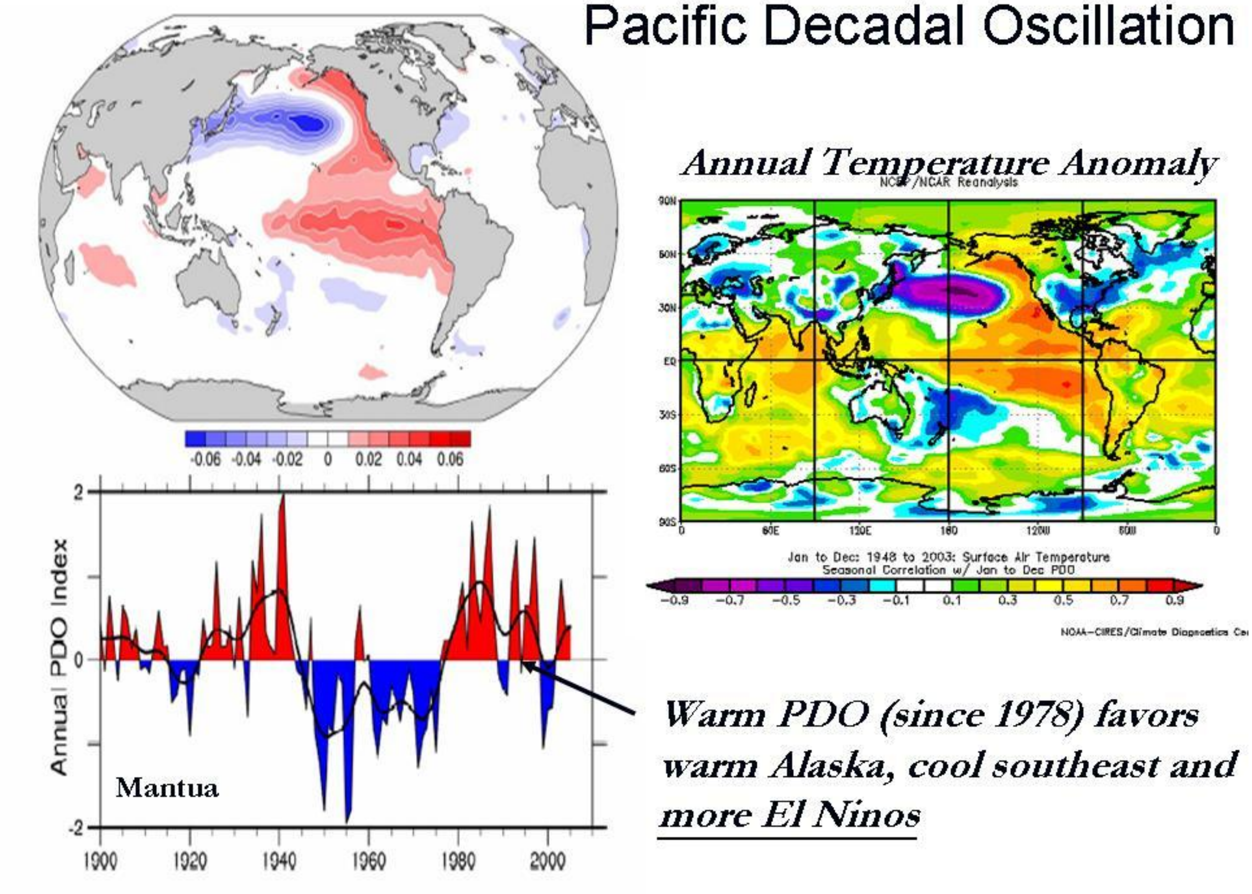
IPCC chapter 3 did a good job explaining the patterns of climate variability through global teleconnections and defining the circulation indices including the short term and decadal scale oscillations in the Pacific, and Atlantic. It noted that the decadal variability in the Pacific (the Pacific Decadal Oscillation or PDO) is likely due to oceanic processes. Extratropical ocean influences are likely to play a role as changes in the ocean gyre 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 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 a full basin Pacific trend in ocean temperatures they called the Pacific Decadal Oscillation. They found water temperatures and overlying pressure tendencies stayed in one mode predominantly for a few decades and then would flip to pretty much the opposite mode.

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. It turns out the PDO mode went from predominantly negative as it had been since 1947 to positive and remained so most of the time since.



Warm PDO (since 1978) favors warm Alaska, cool southeast and more El Ninos

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

In addition, as atmospheric pressure is 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.

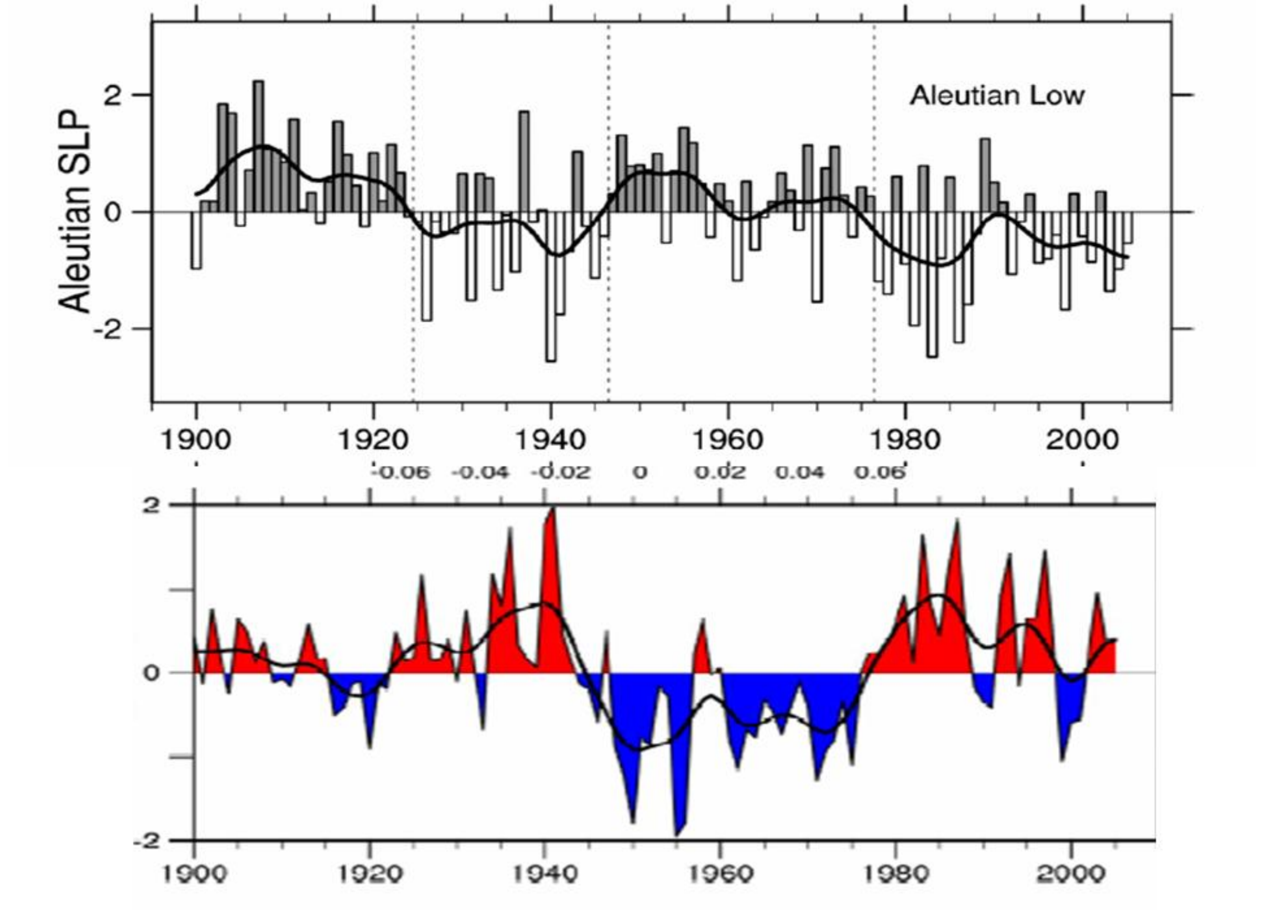


Figure 2. Aleutian low strength top as compared with the PDO bottom from 1900 to 2005. Note the inverse relationship. Images sourced from AR4.

As suggested by 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 in recent decades. Notice 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.

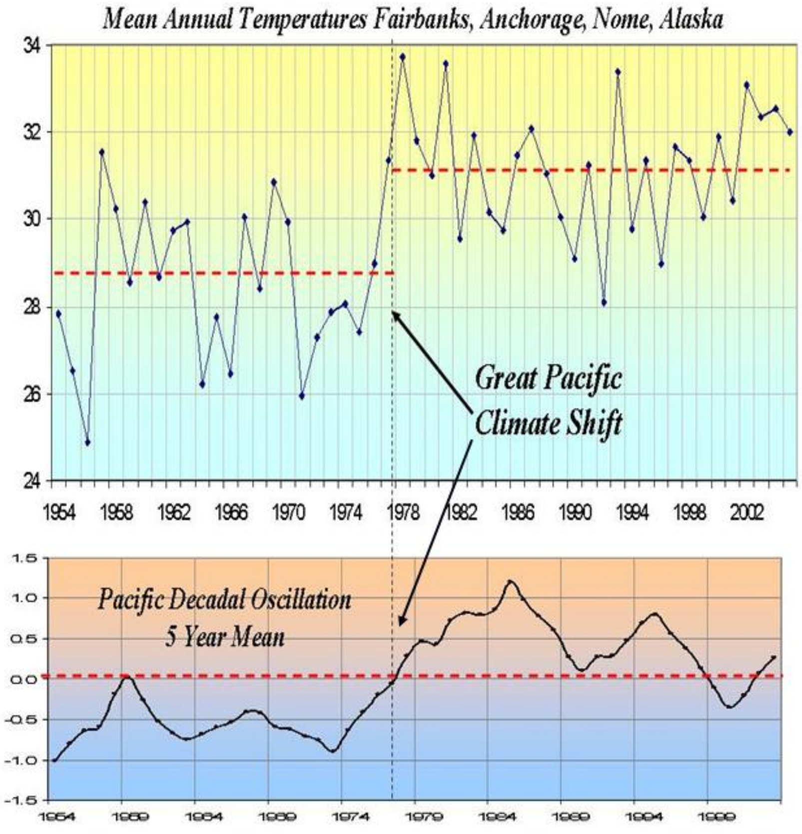


Figure 3: Temperature Data for Fairbanks, Anchorage, Nome from NOAA. PDO index from NOAA CDC Climate Indices.

In addition, as figure 1 shows the PDO positive warm phase brings warmer temperatures to western North America and is correlated with warmth in the four NINO regions and thus more El Ninos (8) than La Ninas (4) in the period from 1978 to 1997 when the PDO was consistently positive. This is shown in the plot of Wolter's Multivariate ENSO Index (MEI).

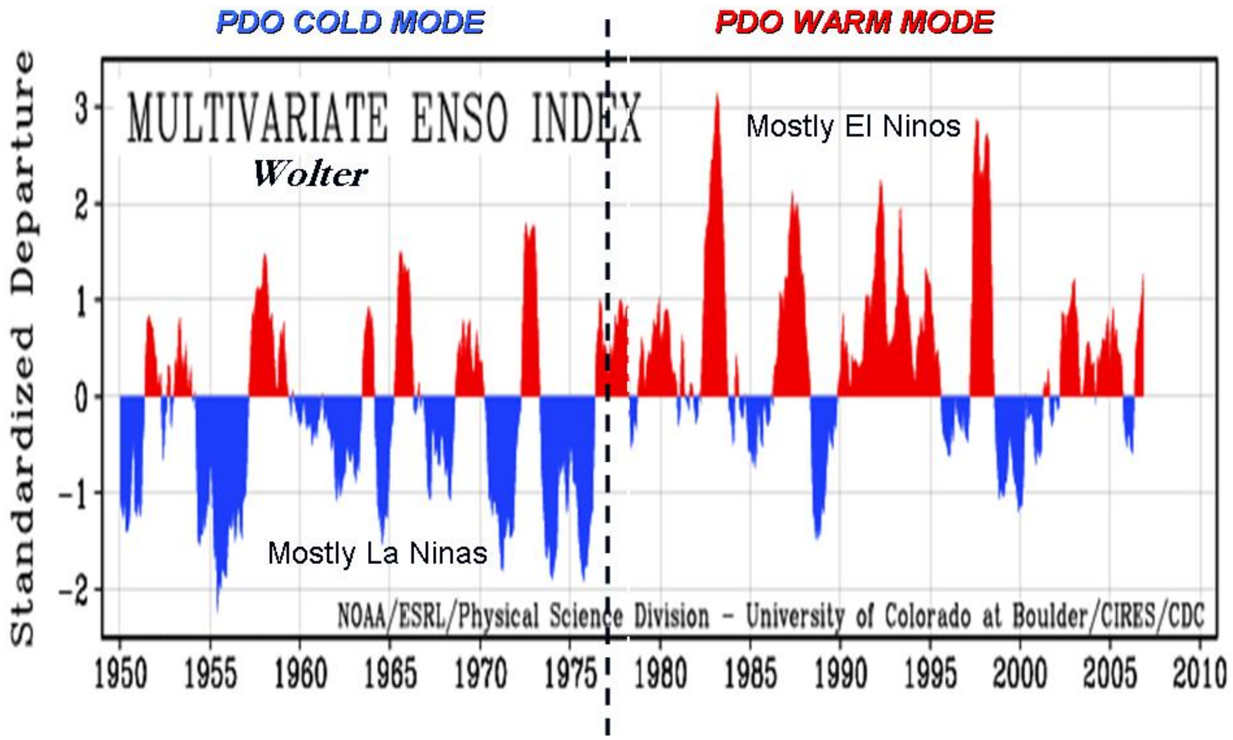
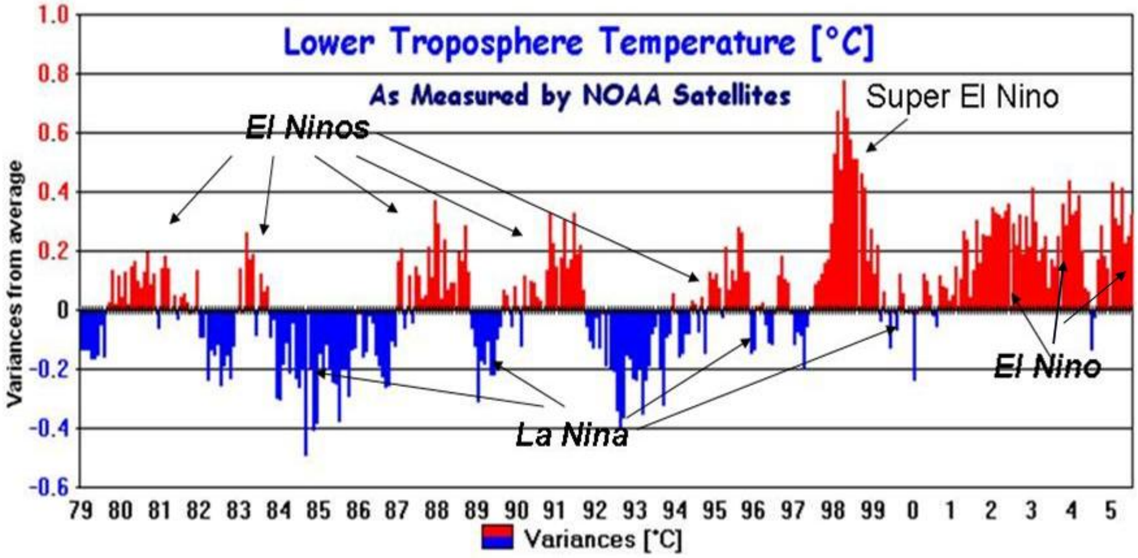


Figure 4: Wolter Multivariate ENSO Index (positive values (generally greater than 0.50 represent warm events (El Ninos) and negative (more than -0.5) cool events (La Ninas)

In the prior cold PDO period, one would expect the opposite with a cold Alaska and western US and a warmer southeast and 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 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.



El Ninos lead to global warming and La Ninas to cooling

MSU data Spencer Christy

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 lengthy and 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 (the most important being sulfur dioxide) and ash high up into the atmosphere 80,000 to sometimes 100,000 feet or more. In the high stable atmosphere, sulfur dioxide gases get transformed to sulfate aerosols which can reside in the stable high atmosphere for several years. These act as little mirrors reflecting the sun’s radiation back to space and thus reducing the amount of suns energy reaching the surface.

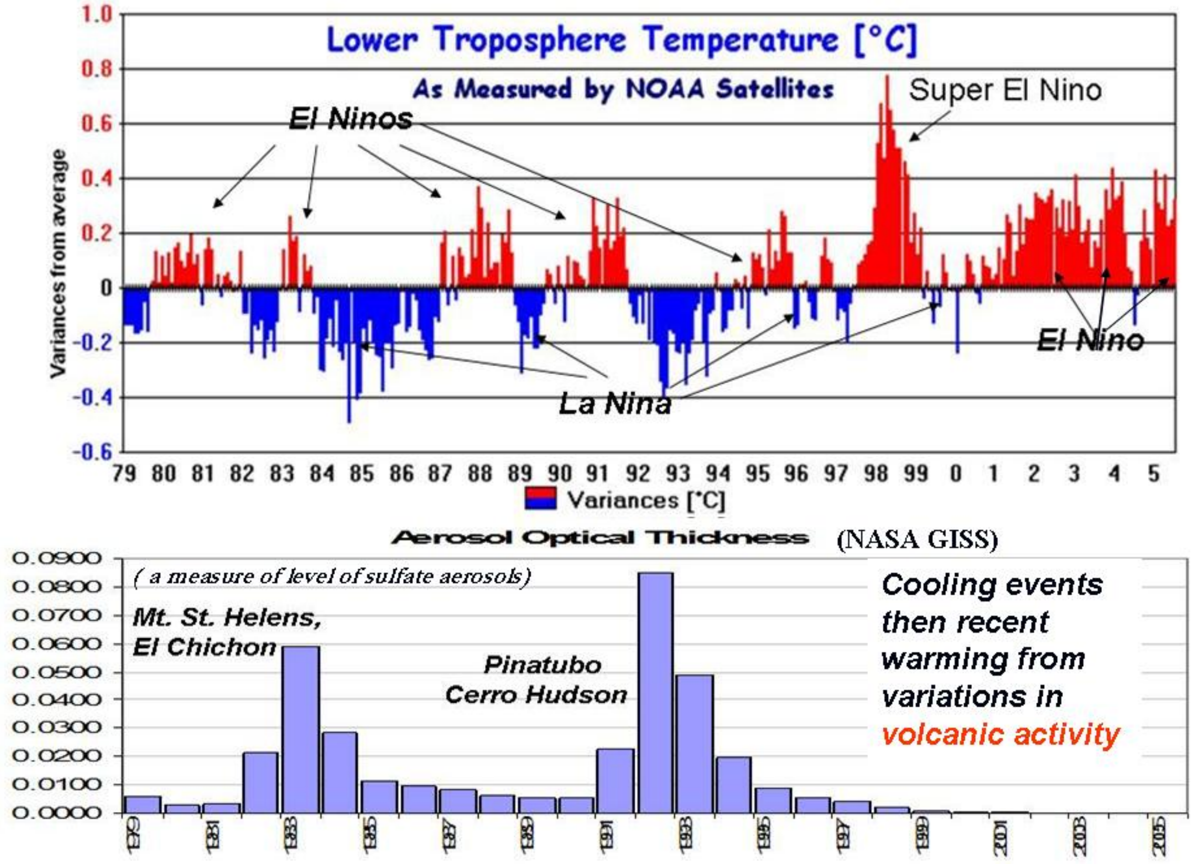
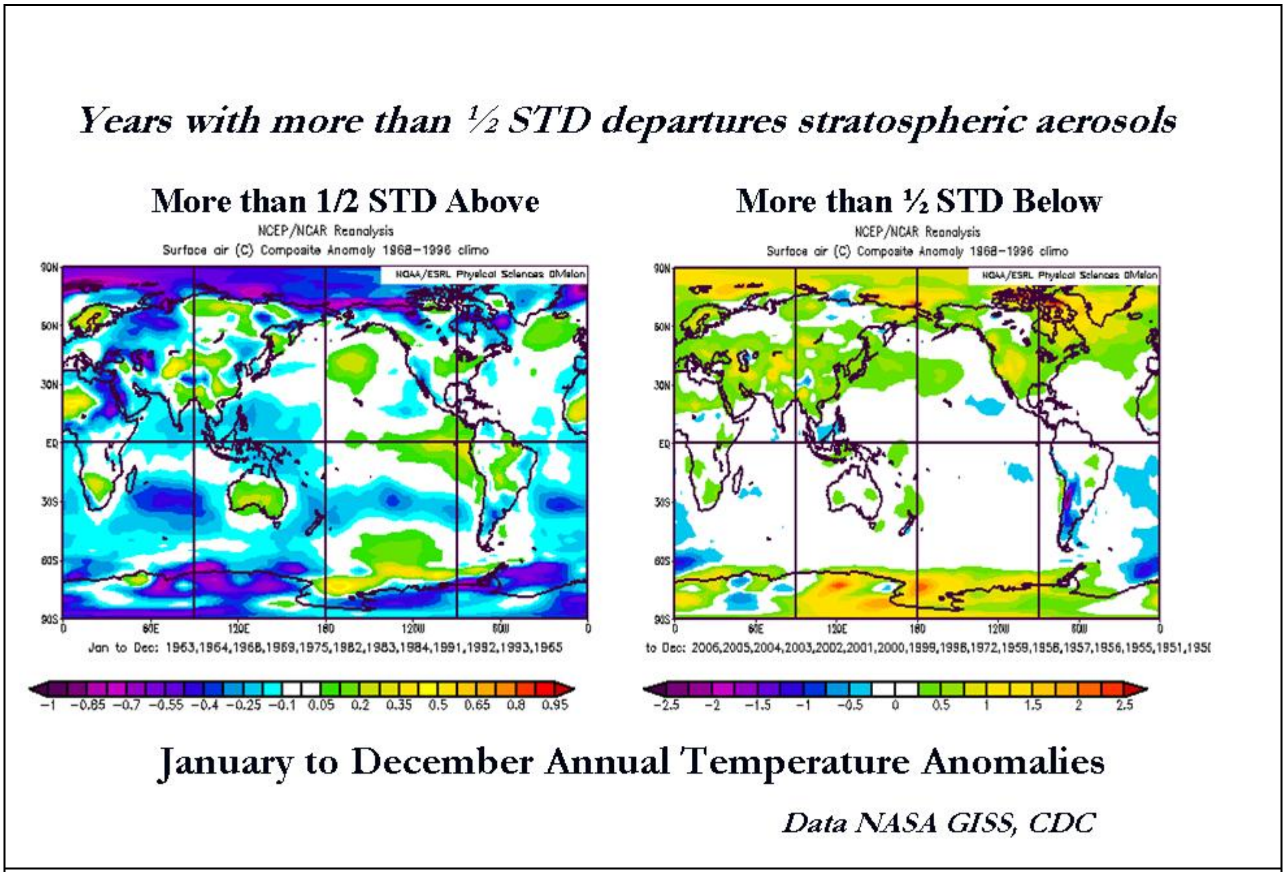


Figure 6: The level of sulfate aerosols (courtesy of NASA GISS) during the satellite era. Note the high levels in the early 1980s and 1990s after the major eruptions of Mt. St. Helens, El Chichon, Pinatubo and Cerro Hudson. Notice the lowest levels of the record since 2000 which may have contributed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



Years with more than ½ STD departures stratospheric aerosols

More than 1/2 STD Above

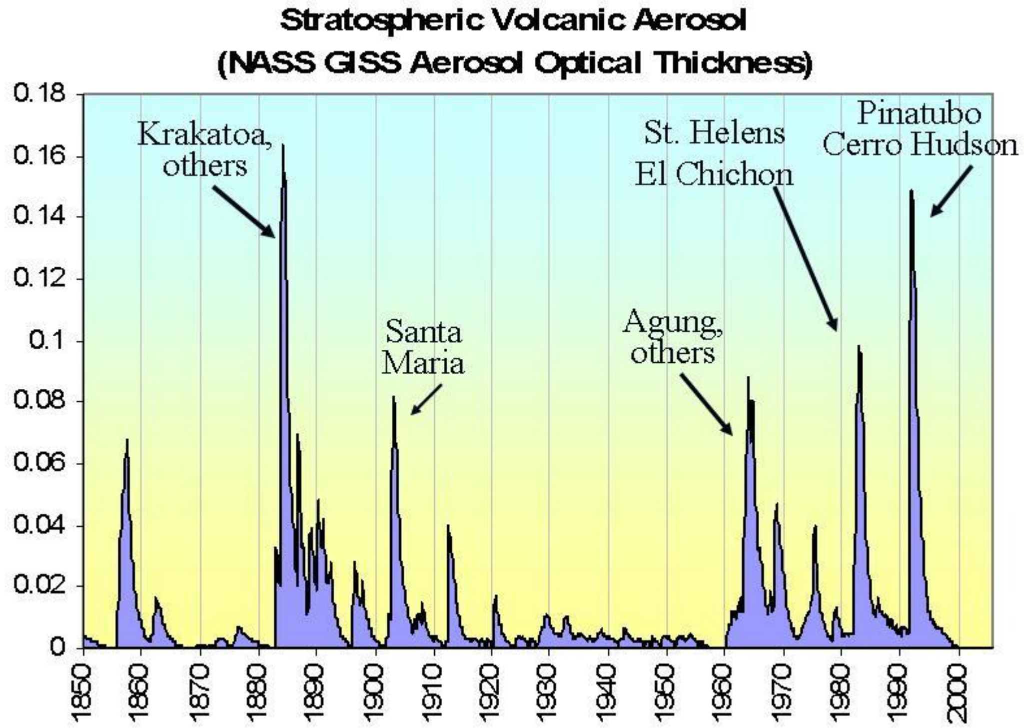
More than ½ STD Below

January to December Annual Temperature Anomalies

Data NASA GISS, CDC

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.



Volcanic aerosols in the high atmosphere block solar radiation and increase cloud cover leading to widespread cooling, especially significant in summer

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.

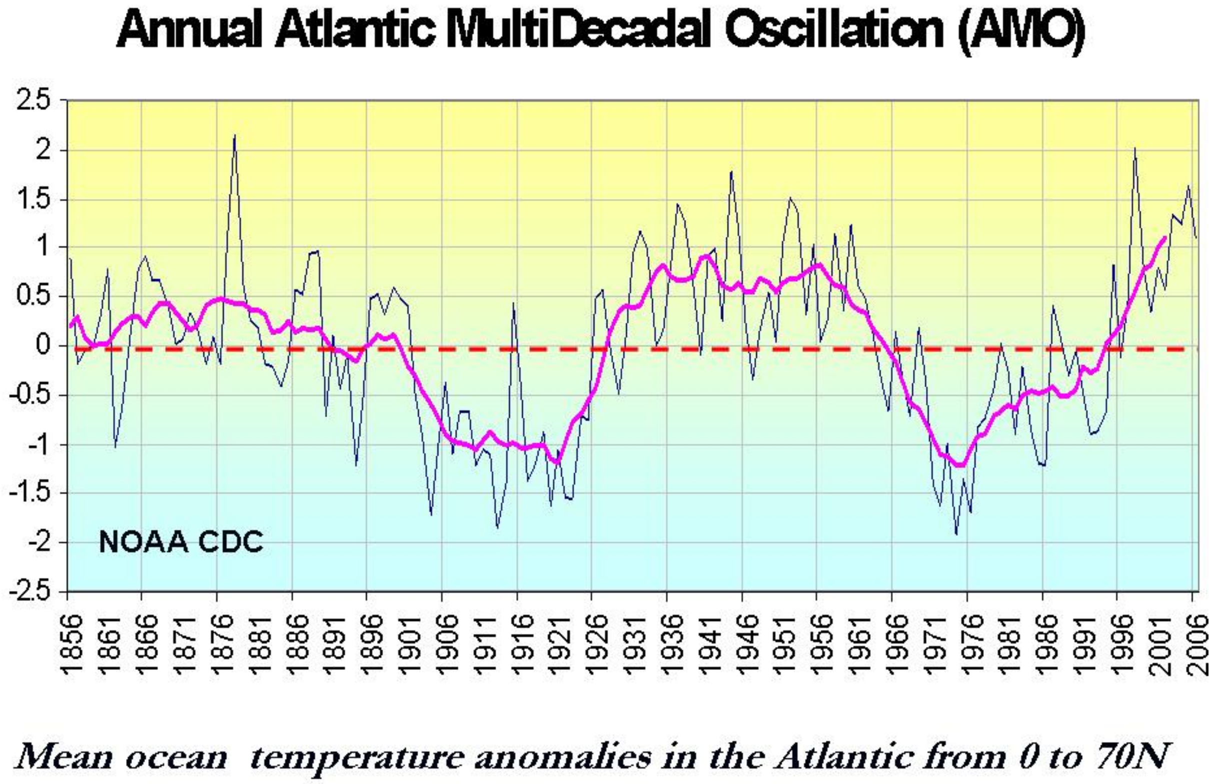
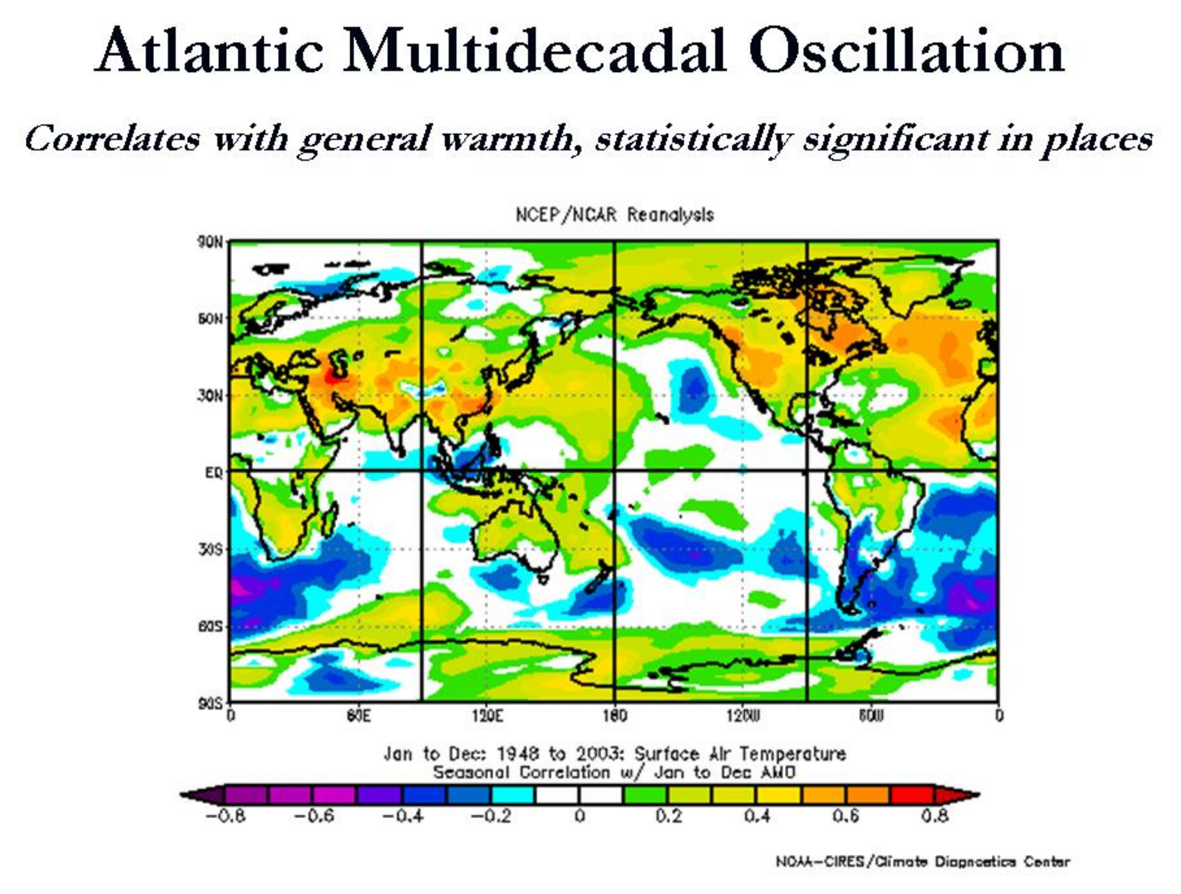


Figure 9: Atlantic Multidecadal Oscillation (NOAA CDC) – the mean ocean temperatures from 0 to 70 degrees north latitude. Note the approximate 70 year cycle.

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 though 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..


Atlantic Multidecadal Oscillation

Correlates with general warmth, statistically significant in places

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 we plot and add the two indices (after normalizing them) 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.

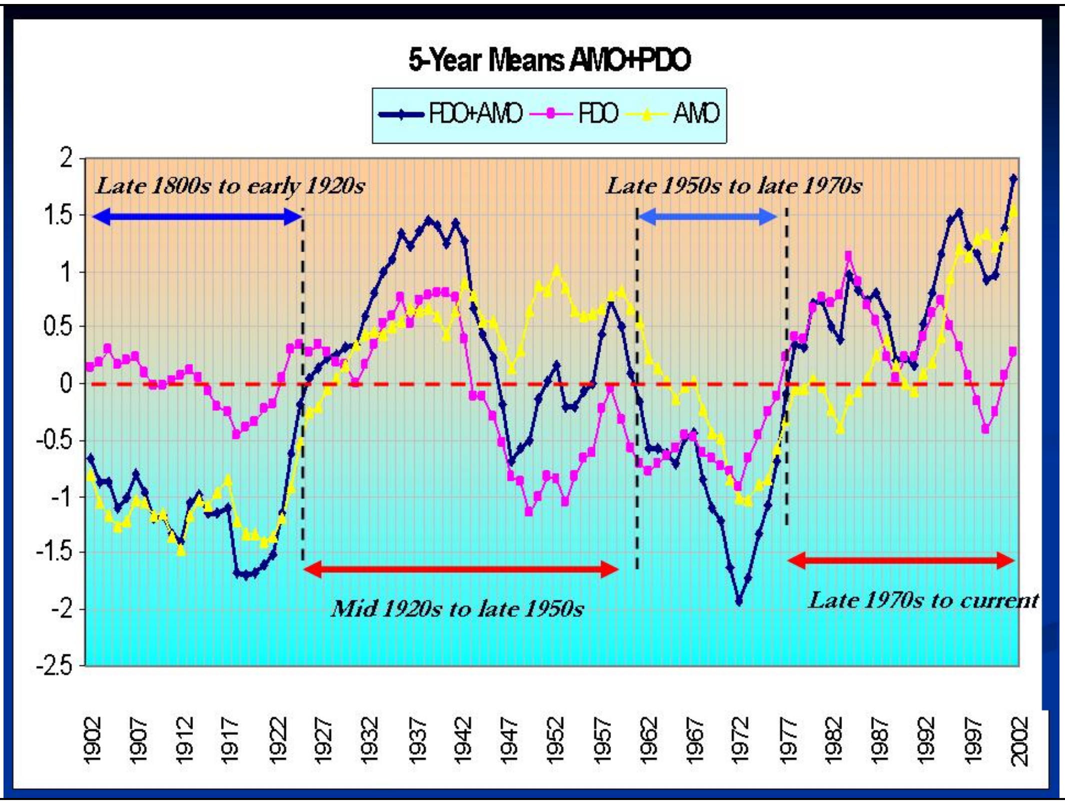


Figure 11: AMO+PDO (standardized and then added) reflects tendency for global warmth or coolness. The indices suggest coolness up to the late 1920s, warmth till the late 1950s, then coolness to the late 1970s and then a return to warmth.

This matches the NCDC USHCN time series very well **(r-squared of 0.86!).**

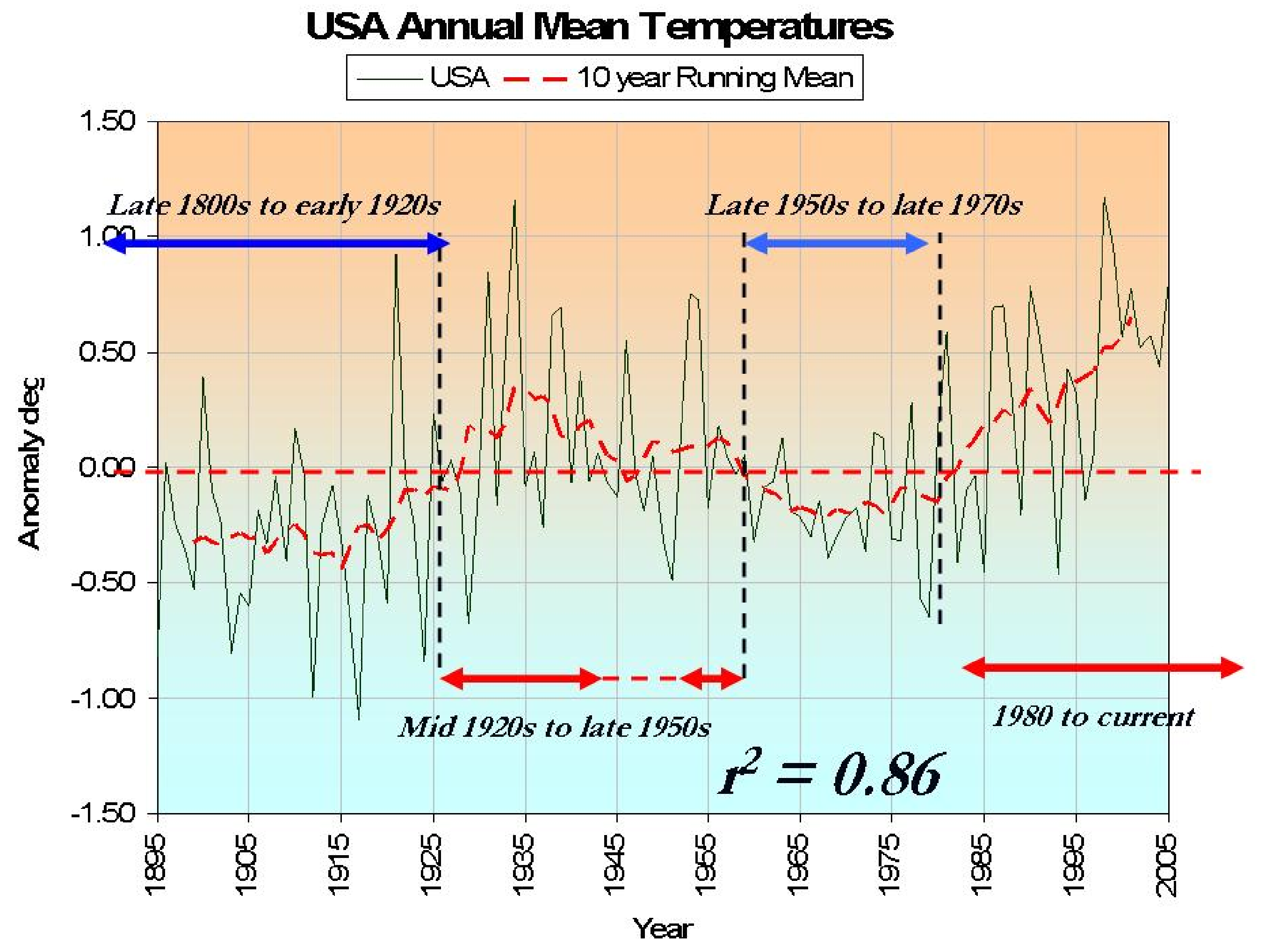


Figure 12: Ocean warm and cold periods (PDO+AMO) and NCDC USHCN Annual Mean Temperatures

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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