

Temperature Cycles in North America, Greenland and the Arctic, Relationship to Multidecadal Ocean Cycles and Solar Trends

By: Joseph D'Aleo, CCM and George Taylor, CCM

Introduction

AR4 devoted many pages to a discussion of multidecadal ocean teleconnections and various solar factors but in the end discounted them or concluded their relationship with climate changes were at best uncertain.

IPCC chapter 3 defined the circulation indices including the short term and decadal scale oscillations in the Pacific, and Atlantic and attributed their origin as natural. 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. But in the end they do not make any connection of these cyclical oceanic changes to the observed global cyclical temperature changes. They only go as far as making a possible connection to regional variances.

Understanding the nature of teleconnections and changes in their behavior is central to understanding regional climate variability and change.(AR4 3.6.1)

In chapter 2, the AR4 discussed at length the varied research on the direct solar irradiance variance and the uncertainties related to indirect solar influences through variance through the solar cycles of ultraviolet and solar wind/geomagnetic activity. They admit that ultraviolet radiation by warming through ozone chemistry and geomagnetic activity through the reduction of cosmic rays and through that low clouds could have an effect on climate but in the end chose to ignore the indirect effect. They stated:

Since TAR, new studies have confirmed and advanced the plausibility of indirect effects involving the modification of the stratosphere by solar UV irradiance variations (and possibly by solar-induced variations in the overlying mesosphere and lower thermosphere), with subsequent dynamical and radiative coupling to the troposphere. Whether solar wind fluctuations (Boberg and Lundstedt, 2002) or solar-induced heliospheric modulation of galactic cosmic rays (Marsh and Svensmark, 2000b) also contribute indirect forcings remains ambiguous. (AR4 2.7.1.3)

For the total solar forcing, in the end the AR4 chose to ignore the considerable recent peer review work (including Svensmark (1997, 2006), Lockwood and Stamper (1999) Solanki et al. (2004), Shaviv (2005) and Scafetta and West 2006) and in favor of Wang et al. (2005) who used an untested flux transport model with variable meridional flow hypothesis and reduced the net long term variance of direct solar irradiance since the mini-ice age around 1750 by up to a factor of 7. This may ultimately prove to be AR4's version of the AR3's 'hockey stick' debacle.

In this supplement, we will discuss how the ocean multidecadal cycles and secular changes in direct and indirect solar influences are much stronger candidates for explaining the observed cyclical temperature variations in the United States, Greenland and the arctic than the greenhouse effect.

OCEAN MULTIDECADAL CHANGES

The Pacific Decadal Oscillation and Its Effects

University of Washington and JPL scientists (Mantua et al., 1997) when examining conditions that might explain 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 configuration predominantly for a few decades and then would flip to the opposite pattern. Technically, Mantua defined the PDO as the pattern and time series of the first empirical orthogonal function of SST over the North Pacific north of 20°N.

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 was at this time that the PDO mode went from predominantly negative as it had been since 1947 to positive and remained so most of the time since.

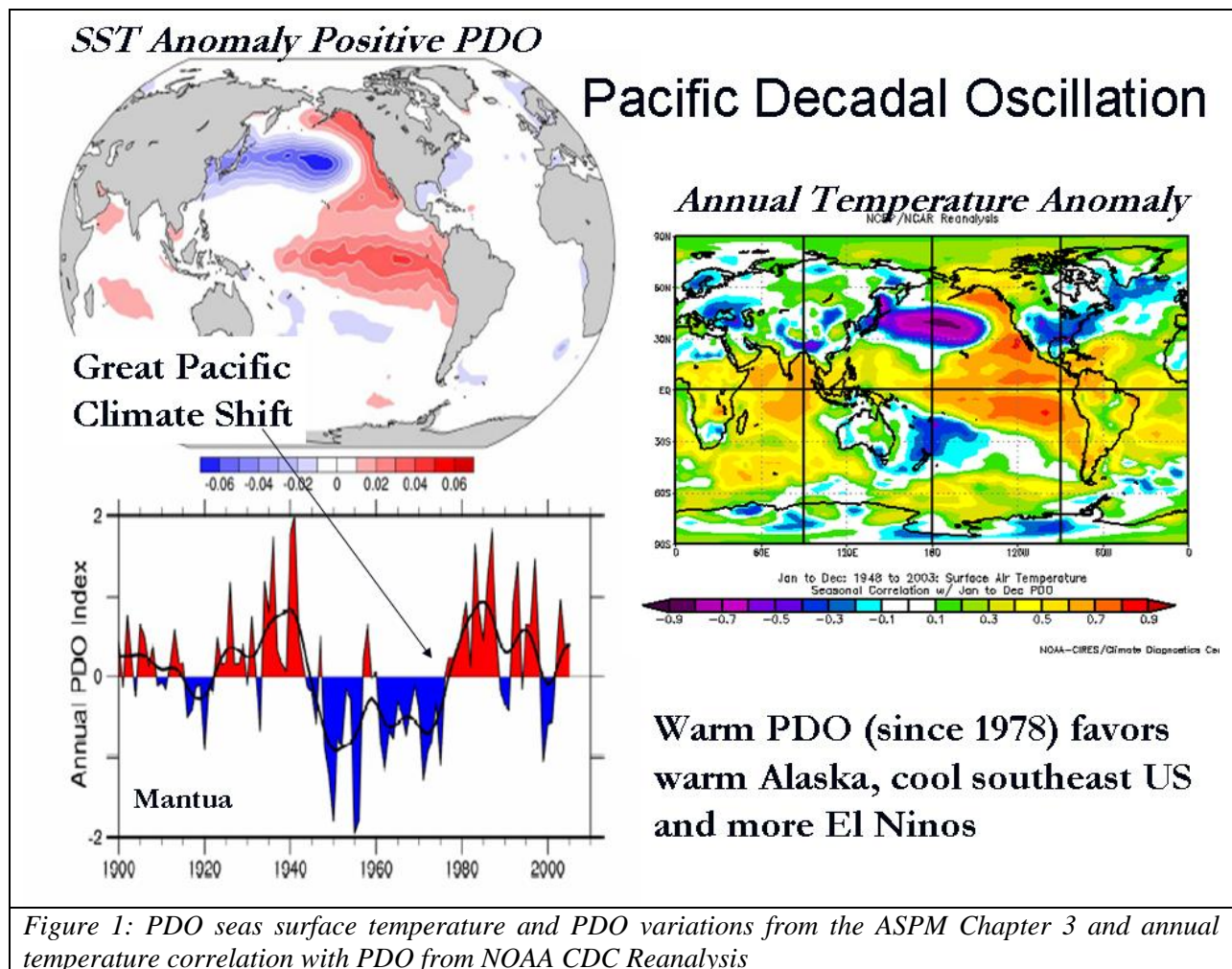


Figure 1: PDO sea surface temperature and PDO variations from the ASPM Chapter 3 and annual temperature correlation with PDO from NOAA CDC Reanalysis

In addition, as 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.

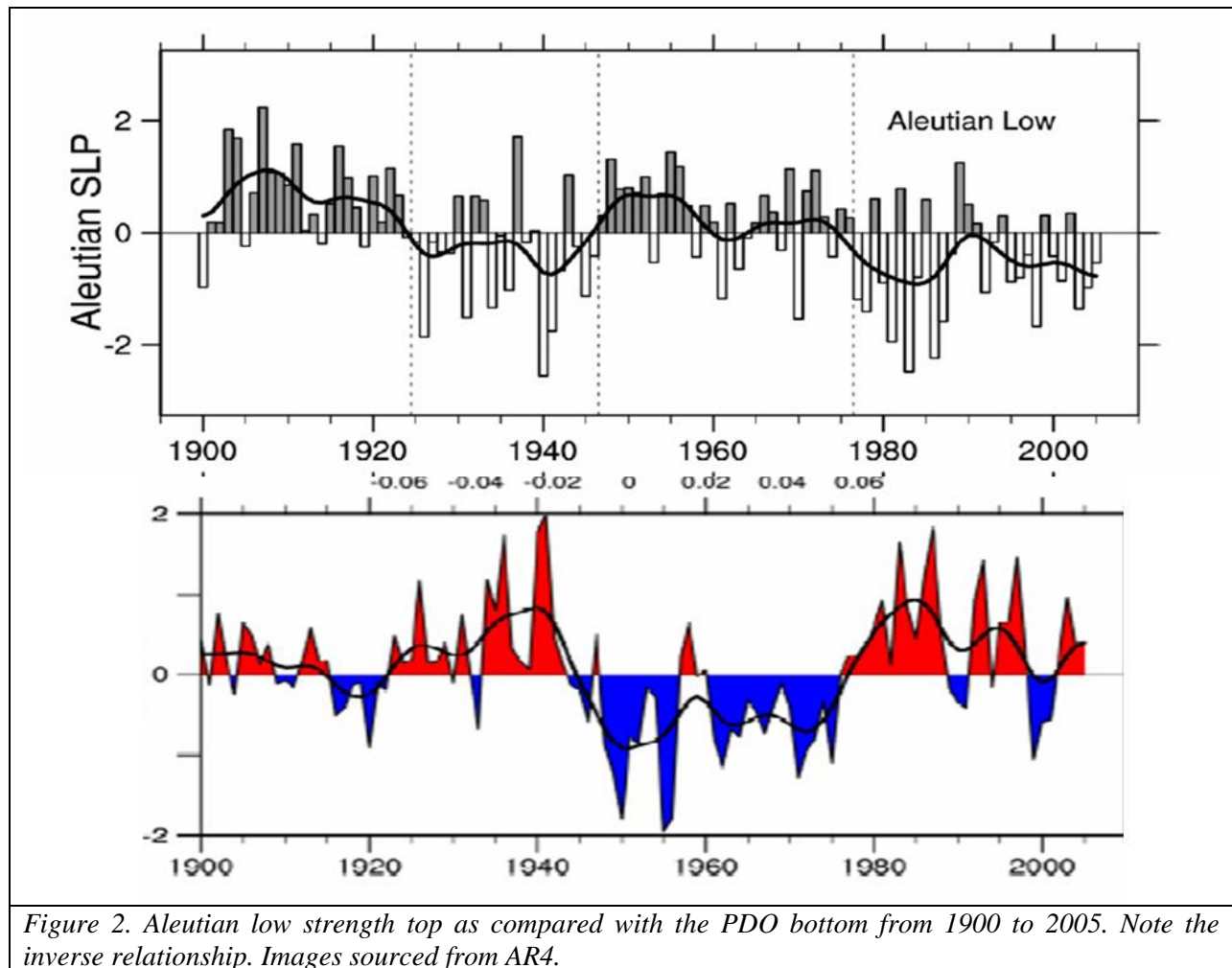


Figure 2. Aleutian low strength top as compared with the PDO bottom from 1900 to 2005. Note the inverse relationship. Images sourced from AR4.

Positive PDO and Alaska Warmth

As suggested by a stronger Aleutian low which brings southerly winds which blow across the warmer water off the coast into Alaska, it is not surprising Alaska has been in 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.

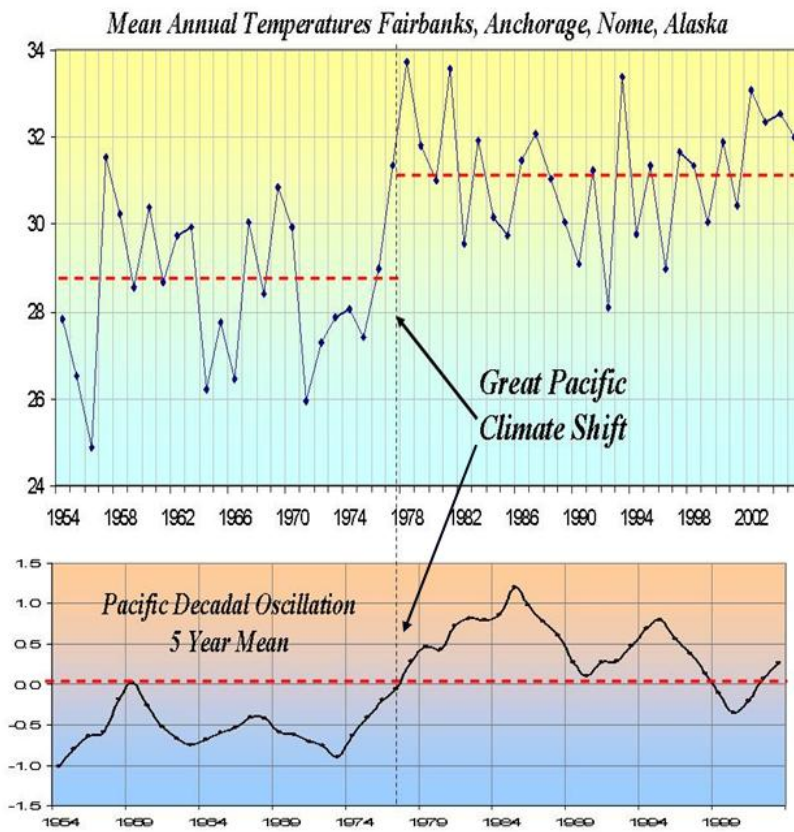
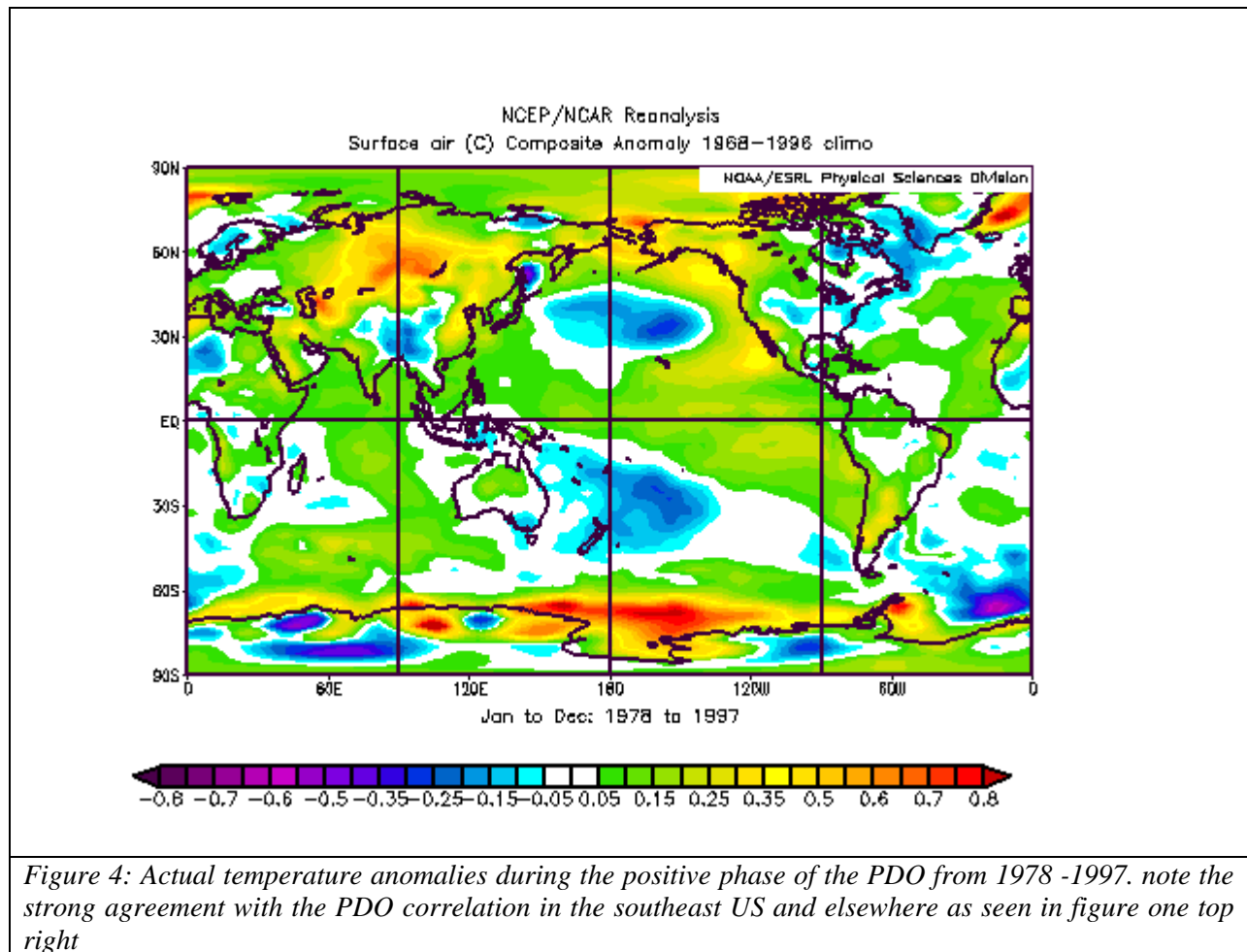


Figure 3: Temperature Data for Fairbanks, Anchorage, Nome from NOAA. PDO index from NOAA CDC Climate Indices.

Positive PDO and a Cool Southeast US

Temperatures in the southeast United States during the recent positive PDO phase also reflected the PDO correlation and were anomalously cool pool in a sea of general warmth



Positive PDO Phase and More El Ninos

In addition, as the top left map in figure 1 shows the PDO positive warm phase brings warmth in the four NINO regions and thus it is not surprising that there were 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). The MEI is based on six main observed variables over the tropical Pacific: sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C). ([Wolter, 1987](#), [Wolter and Timlin, 1993](#)).

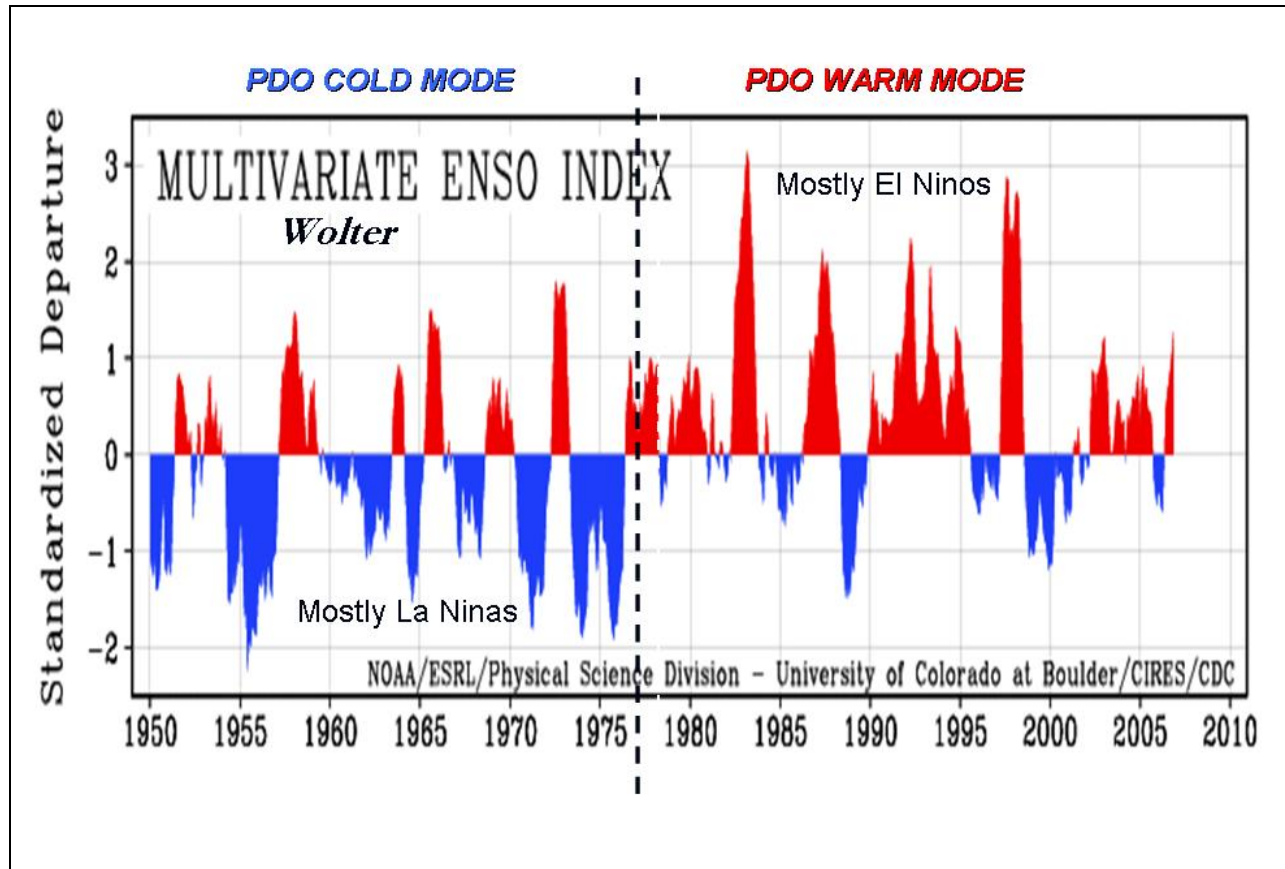
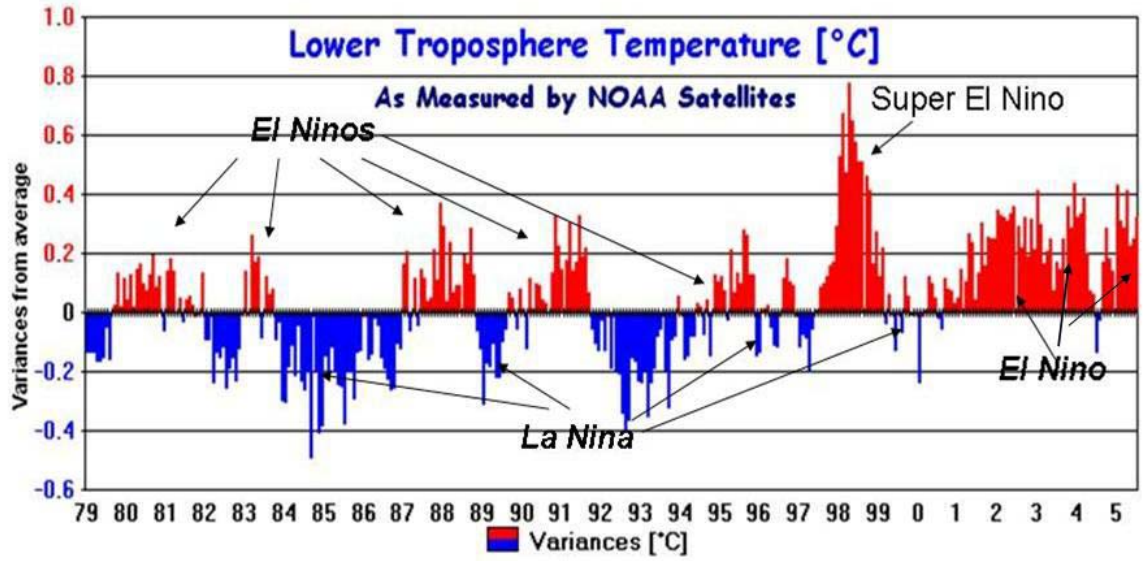


Figure 5: Wolter Multivariate ENSO Index. Positive values (generally greater than 0.50) represent warm events (El Ninos) and negative (more than -0.5) cool events (La Ninas)

In the prior cold PDO period, one would expect the opposite with a cold Alaska and western North America and a warmer southeast and more La Ninas and that too was observed in Figure 5.

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 circulation) 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 6. 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.



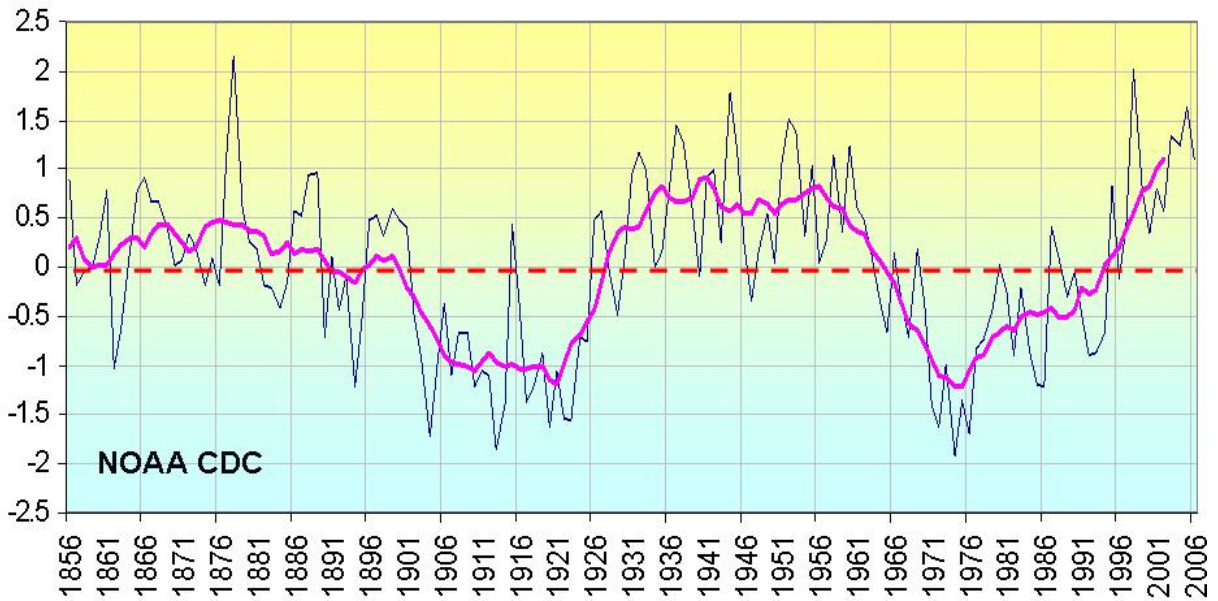
El Ninos lead to global warming and La Ninas to cooling

Figure 6: Global average lower tropospheric temperature anomalies as measured by satellite (MSU data Christy 2000, updated 2006). 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.

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 7. Both Delworth and Mann (2000) and Gray et al. (2004) showed proxy evidence of its existence at least back four centuries.

Annual Atlantic MultiDecadal Oscillation (AMO)



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

Figure 7: Atlantic Multidecadal Oscillation (NOAA CDC) – the mean ocean temperatures from 0 to 70 degrees north latitude. Note the approximate 60-70 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 8.

Atlantic Multidecadal Oscillation

Correlates with general warmth, statistically significant in places

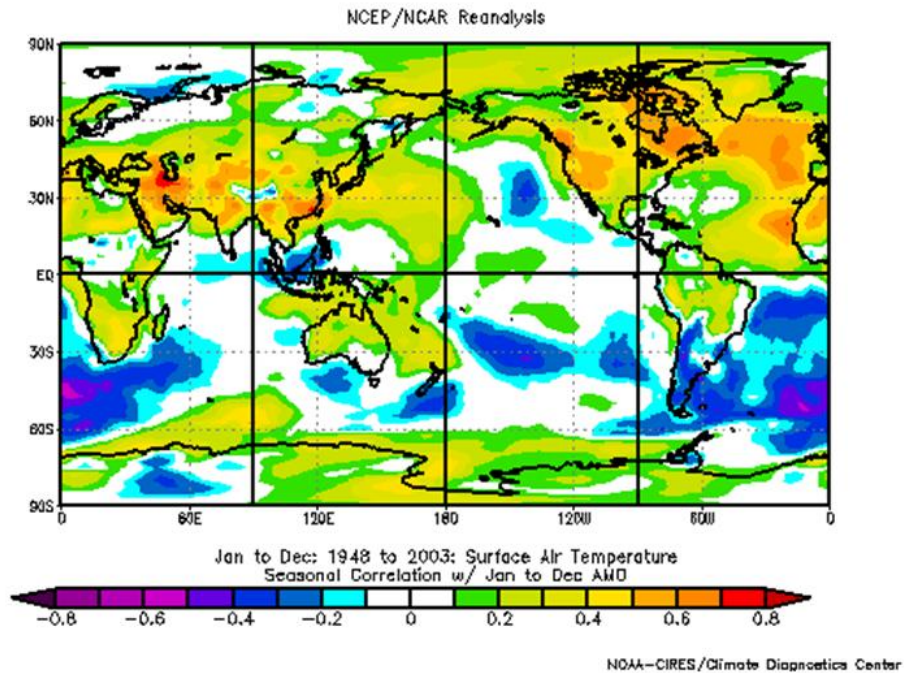


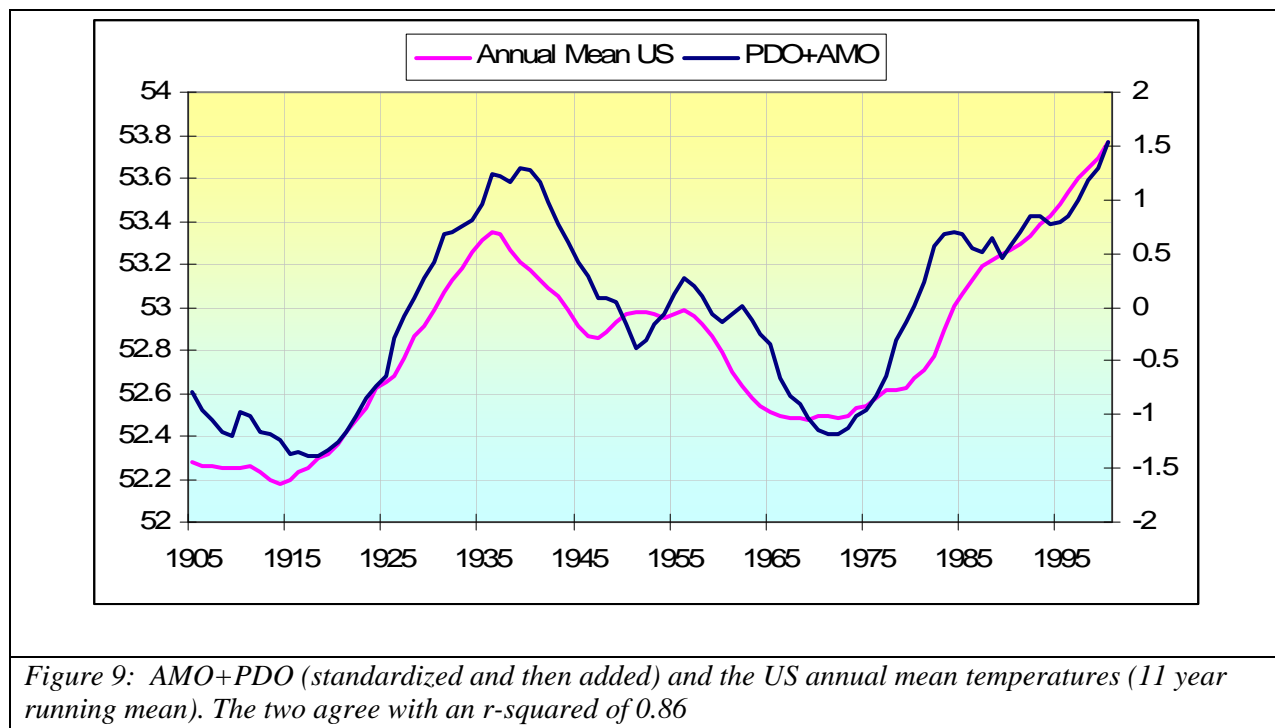
Figure 8: Annual Temperatures correlated with a positive AMO (warm Atlantic).

AMO AND PDO CYCLE OVERLAPS AND COLD AND WARM PERIODS

We have shown how the warm PDO mode is associated with more frequent El Ninos which are accompanied and followed by a global warming and 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.



This matches the NCDC USHCN time series very well (**r-squared of 0.86!**) as can be seen in figure 9.

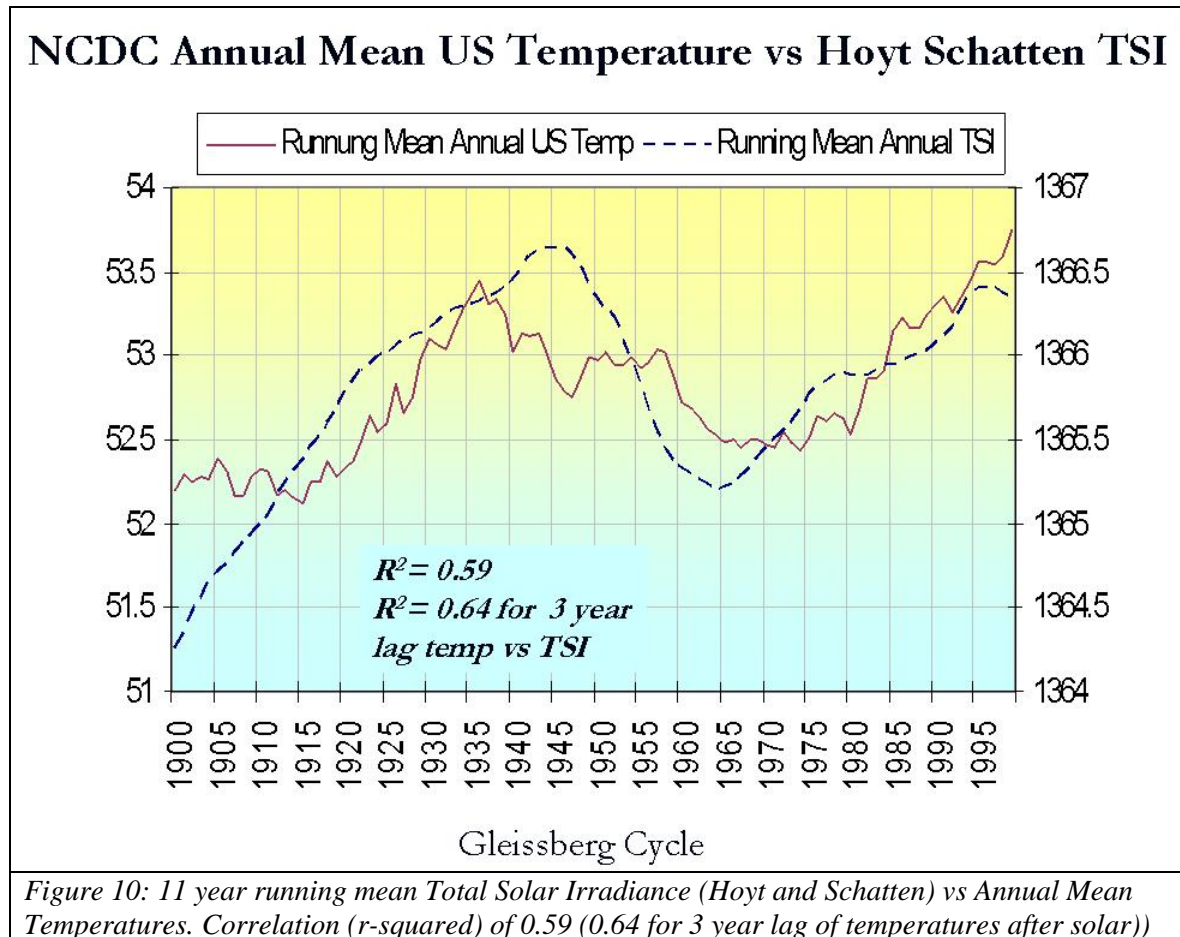
SOLAR FACTORS AND US TEMPERATURES

The sun changes on cycles of 11, 22, 80, 180 years and more. When the sun is more active there are more sunspots and solar flares and the sun is warmer. When the sun is warmer, the earth is warmer. Though the changes in brightness or irradiance the 11 year cycle are small (0.1%), when the sun is more active there is more ultraviolet radiation (6-8% for UV up to a factor of two for extremely short wavelength UV and X-rays- Baldwin and Dunkerton 2004) and there tends to be a stronger solar wind and more geomagnetic storms. Increased UV has been shown to produce warming in the high and middle atmosphere (that leads to surface warming) especially in low and mid latitudes, This is has been shown through observational measurements by Labitzke (2001) over the past 50 years and replicated in NASA models by Shindell et al. (1999).

Increased solar wind and geomagnetic activity has been shown by Svensmark (1997) and others to lead to a reduction in cosmic rays reaching the ground. Cosmic rays have a cloud enhancing property and the reduction during active solar periods leads to a reduction of up to a few percent in low clouds. Low clouds reflect solar radiation leading to cooling. Less low cloudiness means more sunshine and warmer surface temperatures. Shaviv (2005) found the cosmic ray and irradiance factors could account for up to 77% of the warming since 1900 and found the strong correlation extended back 500 million years

Though the IPCC acknowledged these indirect UV and cosmic ray effects may be important (was a source of considerable uncertainty), they latched onto the small 0.1% change in the 11 year cycle and a single paper by Lean with Wang (2005) that used a new untested model approach that suggested the sun's role longer-term was less, to cut back solar forcing by a factor of 7 from the prior assessment in 2001. This despite the slew of peer reviewed papers (see supplement on solar) that showed the sun being more important not less important.

Scafetta and West (2006) suggested the solar could account for at least half of the warming since 1950 and showed it using simple total solar irradiance, assuming it was a proxy for the total (direct and indirect) solar effect. They used the global data bases with their exaggerated warming, I repeated the effort using the US data (figure 10). You can see how well the solar activity on the 80 year time scale (Gleissberg cycle) matches the average US station annual mean temperatures (both data bases with 11 year smoothing to filter out the 11 year cycle changes). I found the best r-squared correlation of 0.64 when I lagged the temperature 3 years to the solar forcing.



Greenland and the Arctic Region

In the prior section, we showed how the ocean and solar cycles correlate with the US Annual Mean temperatures. These oscillations play a key role in the arctic and Greenland in both ice and snowcover and temperatures.

GREENLAND

Many recent studies have addressed Greenland mass balance. They yield a broad picture of slight inland thickening and strong near-coastal thinning, primarily in the south along fast-moving outlet glaciers. AR4 assessment of the data and techniques suggests overall mass balance of the Greenland Ice Sheet ranging between growth by 25 Gigatonnes per year (Gt/year) and shrinkage by 60 Gt/year for 1961-2003. This

range changes to shrinkage by 50 to 100 Gt/year for 1993-2003 and by even higher rates between 2003 and 2005.

However, interannual variability is very large, driven mainly by variability in summer melting and sudden glacier accelerations. Consequently, the short time interval covered by instrumental data is of concern in separating fluctuations from trends. But in a paper published in *Science* in February 2007, Dr Ian Howat of the University of Washington reports that two of the largest glaciers have suddenly slowed, bringing the rate of melting last year down to near the previous rate. At one glacier, Kangerdlugssuaq, "average thinning over the glacier during the summer of 2006 declined to near zero, with some apparent thickening in areas on the main trunk."

In an interview with the *New York Times*, Dr. Howat went on to add

"Greenland was about as warm or warmer in the 1930's and 40's, and many of the glaciers were smaller than they are now. This was a period of rapid glacier shrinkage world-wide, followed by at least partial re-expansion during a colder period from the 1950's to the 1980's. Of course, we don't know very much about how the glacier dynamics changed then because we didn't have satellites to observe it. However, it does suggest that large variations in ice sheet dynamics can occur from natural climate variability. The problem arises in the possibility that, due to anthropogenic warming, warm phases will become longer and more severe, so that each time the glaciers go through a period of retreat like this, they won't fully grow back and they will retreat farther the next time."

The last sentence is of course presumptive and the unnecessary conjecture we find in too many papers which look at data objectively and don't find what they expect. The author does at least acknowledge that we may not be as warm as in the 1930s and 1940s. Thomas, et al. (2000) showed great variance in mass balance of the Greenland ice sheet with highly variable thickening and thinning depending on location.

Temperatures indeed were warmer in the 1930s and 1940s in Greenland. They cooled back to the levels of the 1880s by the 1980s and 1990s. In a GRL paper in 2003, Hanna and Cappelen showed a significant cooling trend for eight stations in coastal southern Greenland from 1958 to 2001 (-1.29°C for the 44 years). The temperature trend represented a strong negative correlation with increasing CO₂ levels.

Shown below in figure 11, the temperature plot for Godthab Nuuk in southwest Greenland. Note how closely the temperatures track with the AMO (which is a measure of the Atlantic temperatures 0 to 70N). It shows that cooling from the late 1950s to the late 1990s even as Greenhouse gases rose steadily, a negative correlation over almost 5 decades. The rise after the middle 1990s was due to the flip of the AMO into its warm phase. They have not yet reached the level of the 1930s and 1940s.

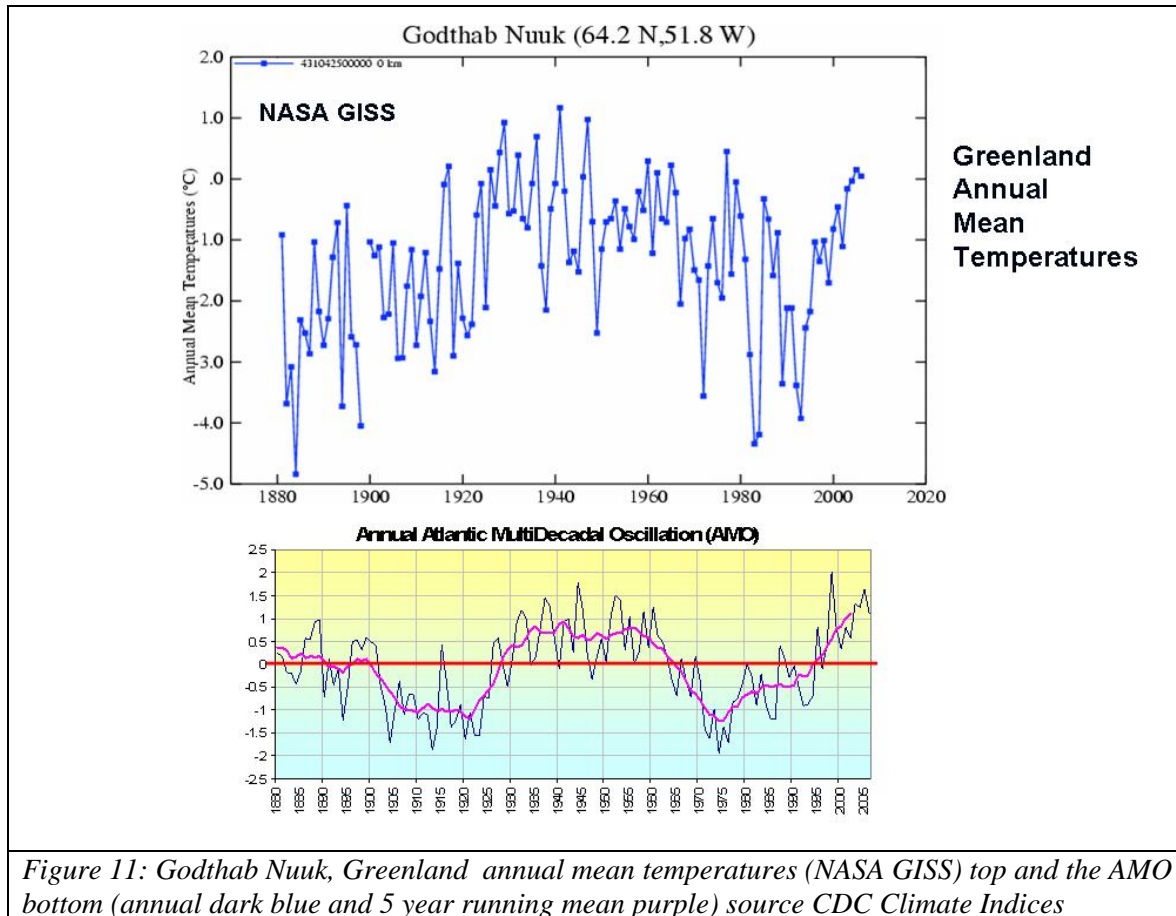
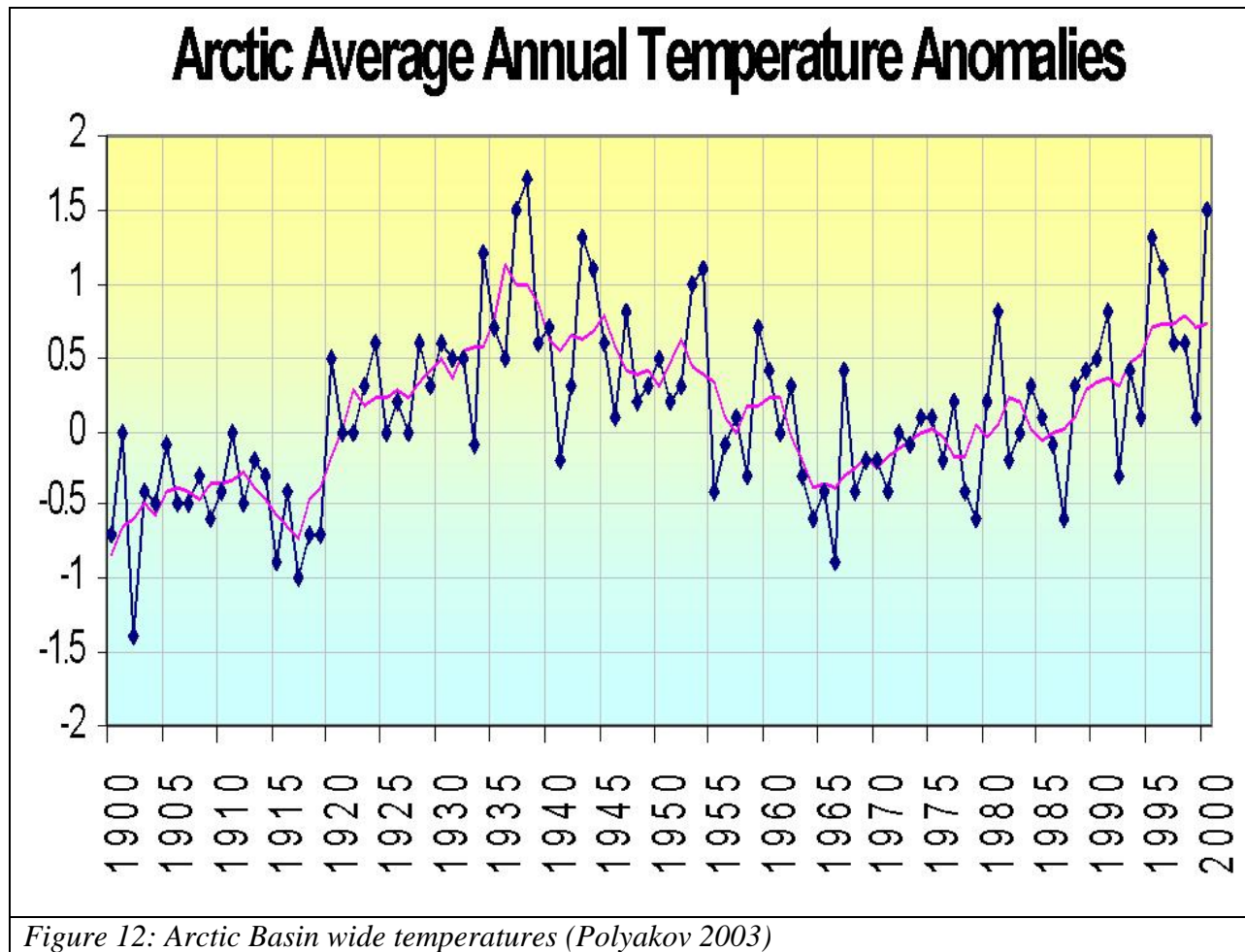


Figure 11: Godthab Nuuk, Greenland annual mean temperatures (NASA GISS) top and the AMO bottom (annual dark blue and 5 year running mean purple) source CDC Climate Indices

A SIMILAR STORY IN THE ARCTIC

Warming in the arctic is likewise shown to be cyclical in nature. This was acknowledged in the AR4 which mentioned the prior warming and ice reduction in the 1930s and 1940s. Warming results in part from the reduction of arctic ice extent because of flows of the warm water associated with the warm phases of the PDO and AMO into the arctic from the Bering Straits and the far North Atlantic.

Polyakov et al (2002) created a temperature record using stations north of 62 degrees N. The late 1930s-early 1940s were clearly the warmest of the last century. In addition, the numbers of available observations in the late 1930s-early 1940s (slightly more than 50) is comparable to recent decades. The annual temperatures are plotted in figure 12.



Pryzbylak (2000) says:

“There exists an agreement in estimating temperature tendencies prior to 1950. Practically all (old and new) of the papers which cover this time period concentrate on the analysis of the significant warming which occurred in the Arctic from 1920 to about 1940. Estimates of the areal average Arctic temperature trend in the second half of the 20th century are inconsistent.

“The second phase of contemporary global warming in the Arctic [since 1970] is either very weakly marked or even not seen at all. For example, the mean rate of warming in the last 5-year period in the Arctic was 2–3 times lower than for the globe as a whole.

“In the Arctic, the highest temperatures since the beginning of instrumental observation occurred clearly in the 1930s. Moreover, it has been shown that even in the 1950s the temperature was higher than in the last 10 years.”

Though papers such as Wadhams and Davis (2000) and Rothrock et al (1999) and Johannessen et al. (1999) showed the ice had thinned in the arctic in the decades leading into the middle 1990s, Winsor (2001) showed the arctic sea ice thickness remained constant in the 1990s. In Vinnikov, et al (1999), the authors use the warming in recent decades as supposed verification of the GFDL and Hadley Center models. They acknowledge a lack of data in the 1940s. Polyakov (2003) showed ice extent time series with a combination of decadal and multidecadal tendencies, with lower values prior to the 1920s, in the

late 1930s to 1940s and in recent decades. They showed higher values in the 1920s to early 1930s and 1960s-1970s, similar to variability in temperature records. It is impossible to find a consistent long term trend in the data plots

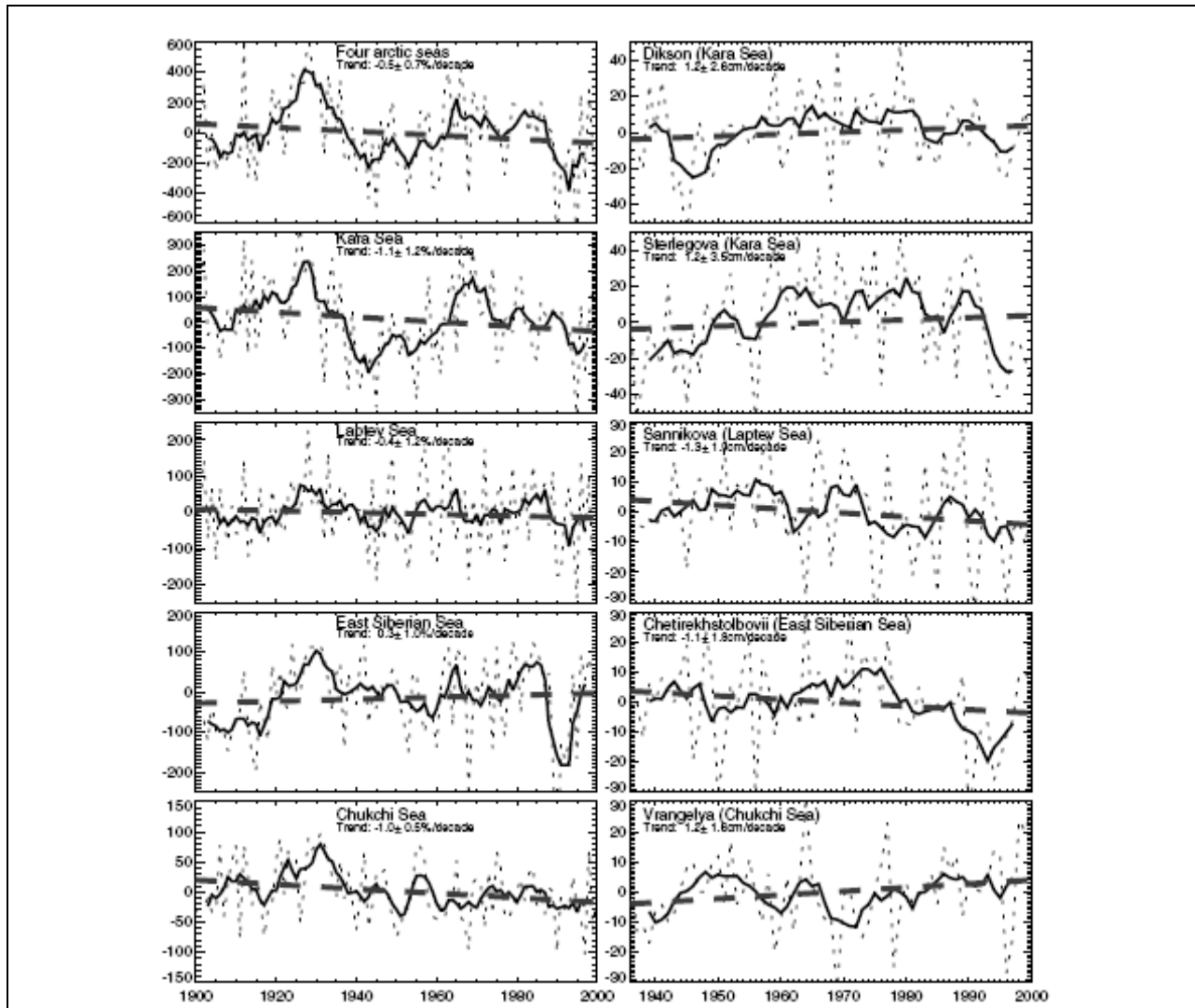


Figure 13: (Left) Time series of August ice-extent anomalies (1000 km²) in four arctic seas. (Right) Time series of annual maximum fast-ice thickness anomalies (cm) at five locations. The plot shows annual means (dotted), six-year running means (solid), and linear trends at the quoted 95% level (dashed).

The Japan Agency for Marine-Earth Science and Technology in Yokosuka, Kanagawa Prefecture observed in a [story](#) in Yahoo Asia News in 2005 an ice shrinkage in the western Arctic Ocean from 1997 to 1998 that they attributed to "... by the flow to the area of warm water from the Pacific Ocean, not by atmospheric impact as previously thought". This was related to the super El Nino of 1997/98. JAMSTEC's Koji Shimada, the group's sub-leader, said the shrinkage was particularly severe in the Pacific side of the Arctic Ocean. The ocean's ratio of area covered with ice during the summer stood at about 60-80 percent from the 1980s to mid-1990s, but it went down to 15-30 percent after 1998, he said. Trenberth (1999) also has acknowledged this warming effect of El Nino on the arctic.

The changes are due to large scale circulation changes in the Atlantic and Pacific. Hass and Eicken (2001) and Proshutinsky and Johnson (1997) showed how arctic circulations vary from cyclonic to anticyclonic depending on strength and position of Icelandic low and Siberian highs. The latter paper noting the tendencies for the regimes to last 5-7 years and help explain the basin scale changes in arctic temperatures and the variability of ice conditions in the Arctic Ocean. Vennegas and Mysak (2000) found four dominant signals, with periods of about 6–7, 9–10, 16–20, and 30–50 yr. These signals account for about 60%–70% of the variance in their respective frequency bands. All of them appear in the monthly (year-round) data. They noted penetration of Atlantic waters into the arctic is affected by the North Atlantic Oscillation and multidecadal changes in the Norwegian Current.

Of the two oceans, for the larger arctic basin, the Atlantic may be more important. Przybylak (2000) noted that

“For arctic temperature, the most important factor is a change in the atmospheric circulation over the North Atlantic” The influence of the atmospheric circulation changes over the Pacific (both in the northern end and in the tropical parts) is significantly lower”

Rigor, et al (2002) suggest that the Arctic Oscillation (AO) affects surface air temperatures and sea ice thickness over the Arctic in a profound way. Ice thickness responds primarily to surface winds changes caused by the AO, whose long-term trends are shown below. Positive AO values (as have been observed in recent years) correspond to higher wind speeds (and generally thinner ice).

The North Atlantic Oscillation and the Arctic Oscillation (also referred to as the NAM) are related to the AMO.

The North Atlantic Oscillation (NAO) and Arctic Oscillations (AO), which generally operate in tandem, have significant control over the weather patterns in mid and high latitudes of the Northern Hemisphere.

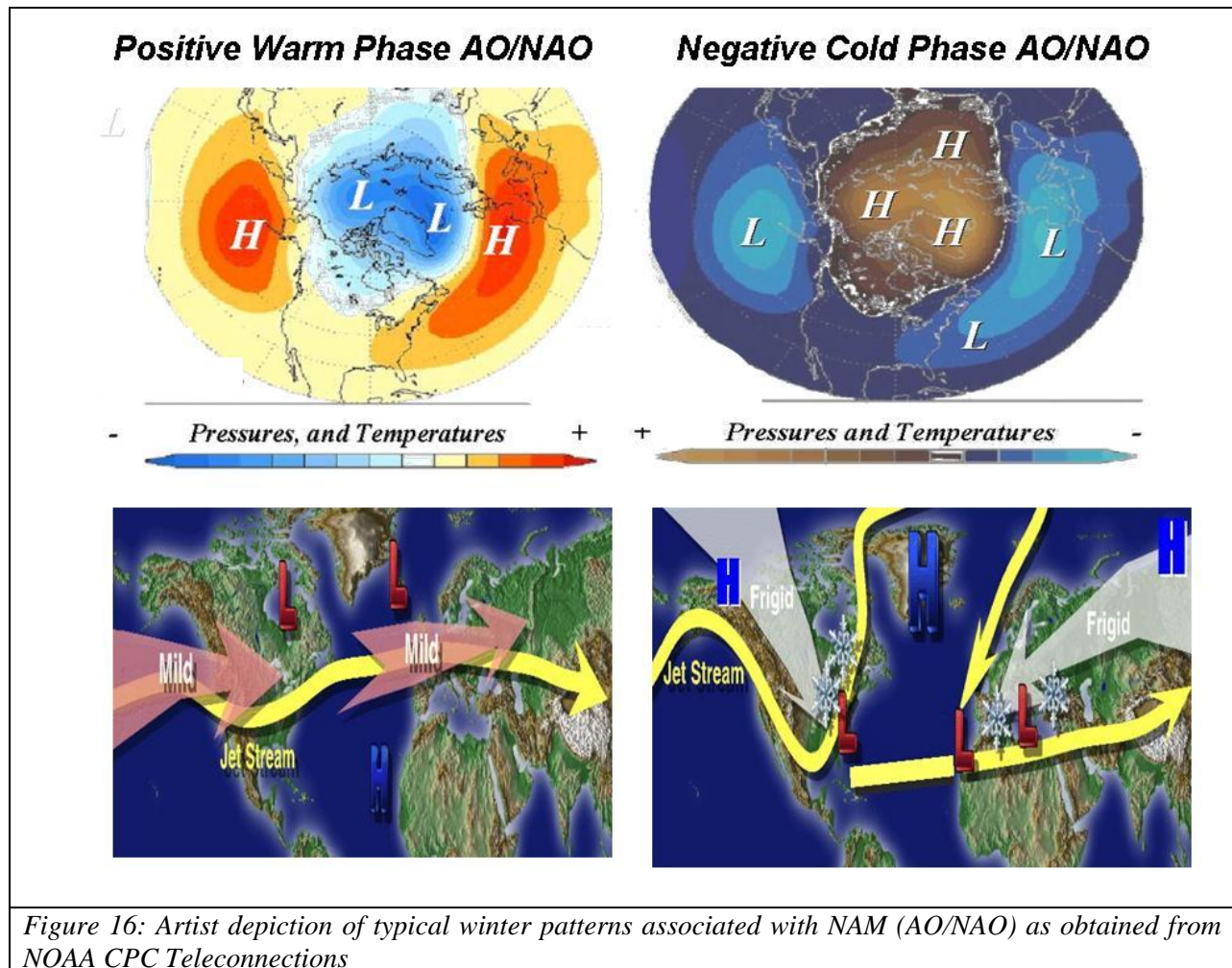


Figure 16: Artist depiction of typical winter patterns associated with NAM (AO/NAO) as obtained from NOAA CPC Teleconnections

Like the PDO, the NAO and AO tend to be predominantly in one mode or in the other for decades at a time. There is a relationship between the AMO and these NAO/AO decadal tendencies. When the Atlantic is cold (AMO negative), the AO and NAO tend more often to the positive state, when the Atlantic is warm on the other hand, the NAO/AO tend to be more often negative. The AMO tripole of warmth in the 1960s below was associated with a predominantly negative NAO and AO while the cold phase was associated with a distinctly positive NAO and AO in the 1980s and early 1990s as can be seen in both figures 17 and 18.

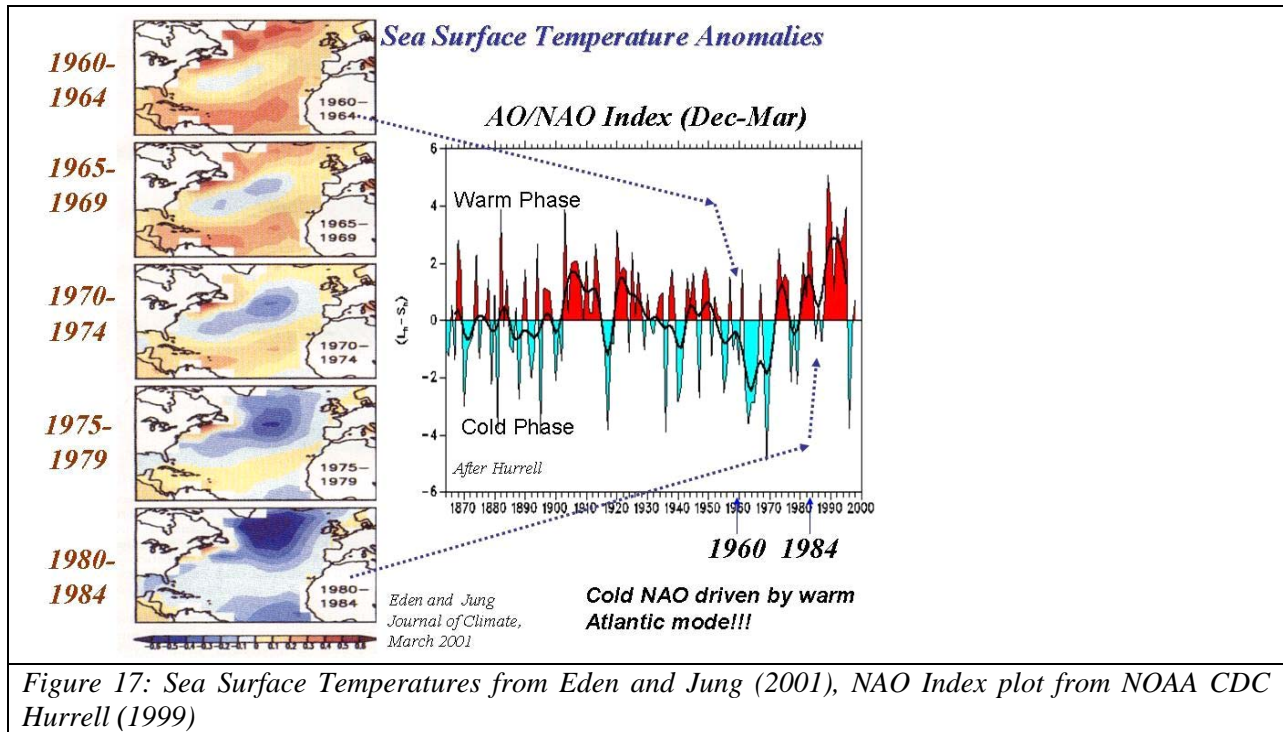


Figure 17: Sea Surface Temperatures from Eden and Jung (2001), NAO Index plot from NOAA CDC Hurrell (1999)

As noted in the AR4 and seen in figure 18, the relationship is a little more robust for the cold (negative AMO) phase than with the warm (positive) AMO. There tends to be considerable intraseasonal variability of these indices that relate to other factors (stratospheric warming and cooling events that are correlated with the Quasi-Biennial Oscillation or QBO for example).

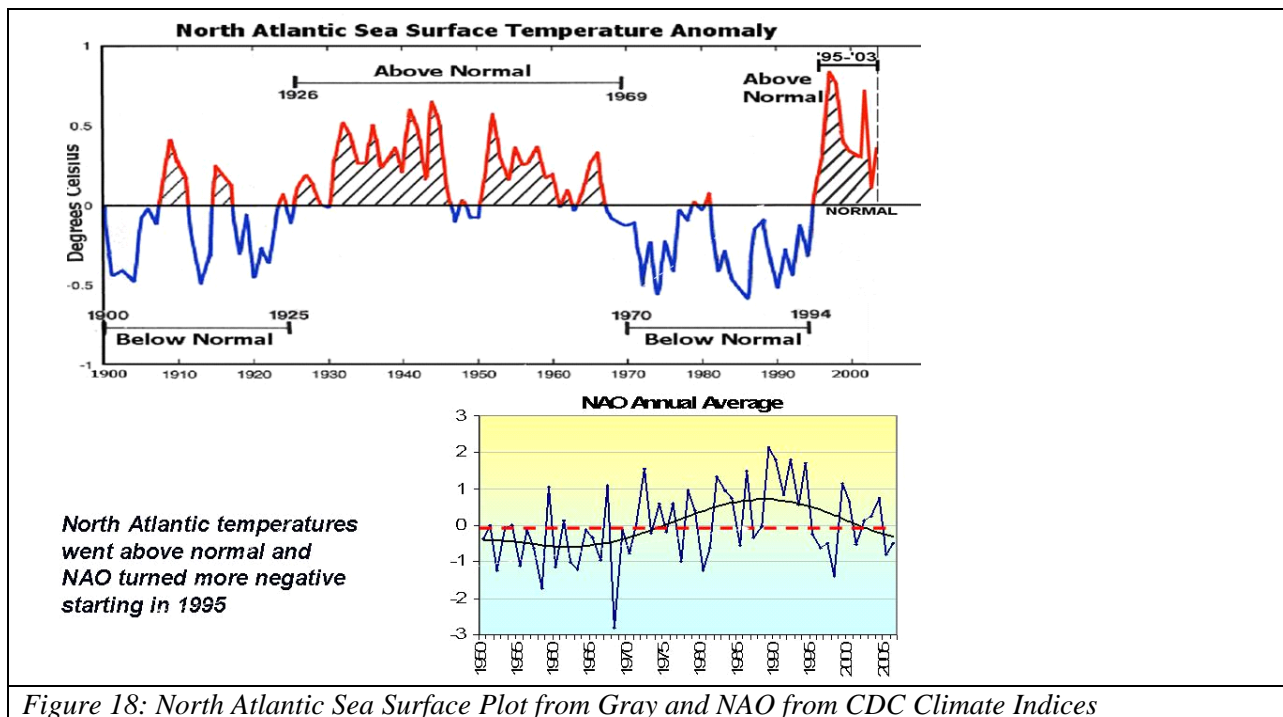


Figure 18: North Atlantic Sea Surface Plot from Gray and NAO from CDC Climate Indices

Indeed, Dmitrenko and Polyakov (2003) observed that warm Atlantic water in the early 2000s from the warm AMO that developed in the middle 1990s had made its way under the ice to off of the arctic coast of Siberia where it thinned the ice by 30% much as it did when it happened in the last warm AMO period from the 1880s to 1930s. Polyakov had previously concluded (2002)

“Arctic and northern hemispheric air-temperature trends during the 20th century (when multi-decadal variability had little net effect on computed trends) are similar, and do not support the predicted polar amplification of global warming. The possible moderating role of sea ice cannot be conclusively identified with existing data. If long-term trends are accepted as a valid measure of climate change, then the SAT and ice data do not support the proposed polar amplification of global warming.”

As was the case for US temperatures, the combination of the PDO and AMO Indexes (PDO+AMO) again has considerable explanatory power for Arctic average temperature, yielding an r-squared of 0.73.

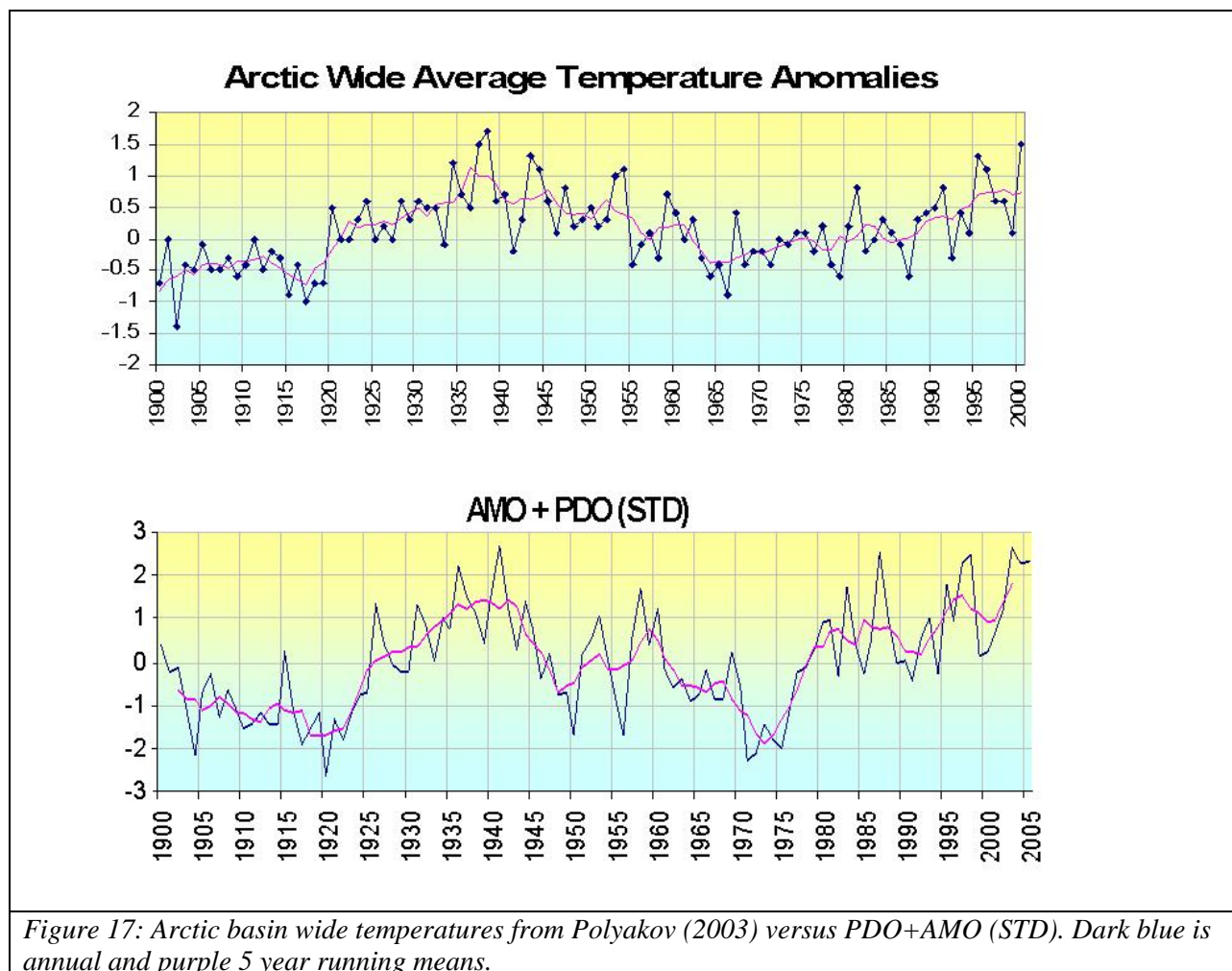


Figure 17: Arctic basin wide temperatures from Polyakov (2003) versus PDO+AMO (STD). Dark blue is annual and purple 5 year running means.

The cycles reported by Polyakov and Przybylak was supported in numerous other peer-reviewed papers. Karlen (2005) reported on historical temperatures in Svalbard (Lufthavn, at 78 deg N latitude), claiming that the area represents a large portion of the Arctic. It is reported that the “mean annual temperature increased rapidly from the 1910s to the late 1930s.” Later,

temperatures dropped, “and a minimum was reached around 1970.” Once again, “Svalbard thereafter became warmer, but the mean temperature in the late 1990s was still slightly cooler than it was in the late 1930s.”

Karlen goes on to say that similar trends (warm 1930s, cooling until about 1970, minor warming since) have occurred in Arctic areas of the North Atlantic, in northern Siberia, and in Alaska. At Stockholm, where records go back 250 years, “changes of the same magnitude as in the 1900s occurred between 1770 and 1800, and distinct but smaller fluctuations occurred around 1825.”

Finally, in view of the fact that “during the 50 years in which the atmospheric concentration of CO₂ has increased considerably, the temperature has decreased,” Karlen concludes that “the Arctic temperature data do not support the models predicting that there will be a critical future warming of the climate because of an increased concentration of CO₂ in the atmosphere.”

Hanna, et al (2006) estimated Sea Surface Temperatures (SSTs) near Iceland over a 119-year period based on measurements made at ten coastal stations located between latitudes 63°N and 67°N. They concluded that there had been “generally cold conditions during the late nineteenth and early twentieth centuries; strong warming in the 1920s, with peak SSTs typically being attained around 1940; and cooling thereafter until the 1970s, followed once again by warming - but not generally back up to the level of the 1930s/1940s warm period.”

Jennifer Francis of Rutgers University detailed in a recent issue of the journal *Geophysical Research Letters* that the warming waters in the Barents Sea—which have risen about 3 degrees Celsius since 1980—are to blame for the reduction in winter ice cover. “Two factors contribute to the warming of the Barents Sea: warming Atlantic waters funneled in by the Gulf Stream and solar heating of the open ocean as ice melts in the summer, both of which make it harder for new ice to form in the winter.

The latter factor, known as the ice-albedo (reflectance) feedback works like this: As ice melts in the summer, the open ocean warms up as it absorbs the solar radiation that the ice would normally reflect back to space; as global temperatures rise, more ice melts, so the ocean absorbs more heat, and less ice re-forms the next winter, which just keeps the cycle going.”

This research supports the notion that the natural cyclical warming Atlantic is partially responsible for the ice loss. How did that warm water get to the Barent’s sea? Well it was the natural thermohaline circulation cycling that warmed it in the last decade after cooling down the area for the previous 3 decades. In other words, the Atlantic Multidecadal Oscillation. And Jennifer is exactly right, once the ice melts there is some positive feedback through that albedo effect.

Drinkwater (2006) reviewed changes in marine ecosystems of the northern North Atlantic over the last century. In particular, Drinkwater looked for evidence of “regime shifts,” defined as “a persistent radical shift in typical levels of abundance or productivity of multiple important components of the marine biological community structure, occurring at multiple trophic levels and on a geographical scale that is at least regional in extent.”

Drinkwater concluded that “in the 1920s and 1930s, there was a dramatic warming of the air and ocean temperatures in the northern North Atlantic and the high Arctic, with the largest changes occurring north of 60°N,” which “led to reduced ice cover in the Arctic and subarctic regions and

higher sea temperatures." This was "the most significant regime shift experienced in the North Atlantic in the 20th century."

During the late 1920s, "average air temperatures began to rise rapidly and continued to do so through the 1930s." In this period, "mean annual air temperatures increased by approximately 0.5-1°C and the cumulative sums of anomalies varied from 1.5 to 6°C between 1920 and 1940 with the higher values occurring in West Greenland and Iceland." Later, "through the 1940s and 1950s air temperatures in the northernmost regions varied but generally remained relatively high." Temperatures declined in the late 1960s in the northwest Atlantic and somewhat earlier in the northeast Atlantic.

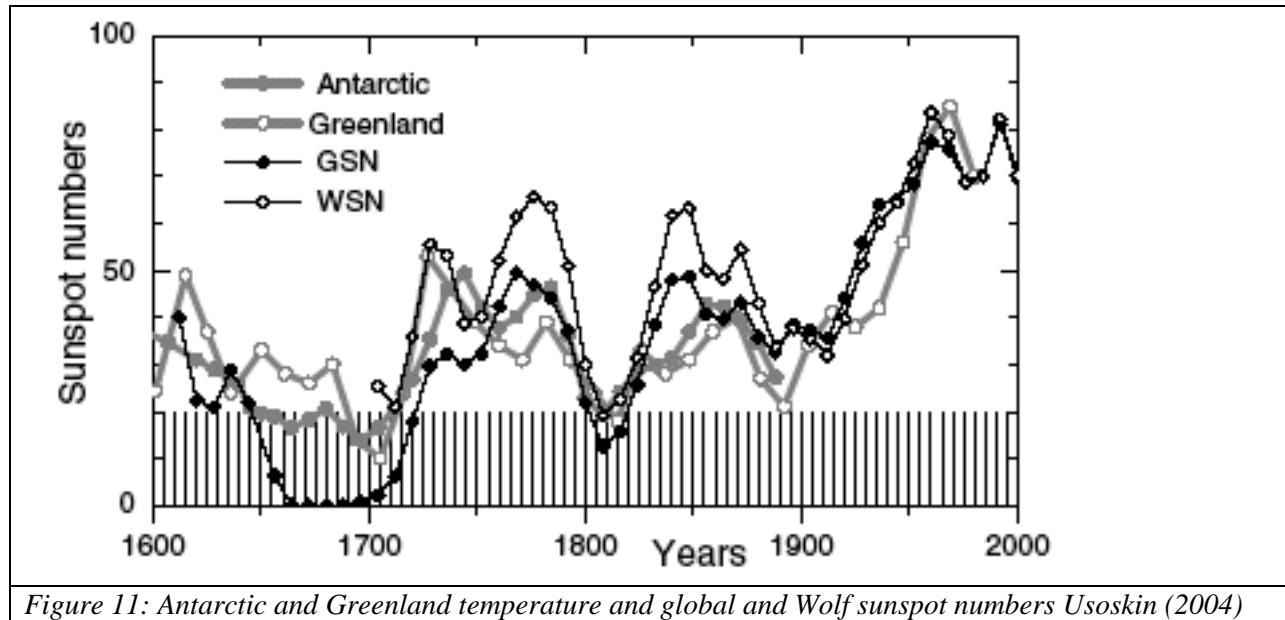
Biologically, the earlier warm was beneficial to ecosystems, for the warmer waters "contributed to higher primary and secondary production," and "with the reduced extent of ice-covered waters, more open water allow[ed] for higher production than in the colder periods." Cod populations spread approximately 1200 km northward along West Greenland," and 'warmer water' species emerged as well. In fact, "some southern species of fish that were unknown in northern areas prior to the warming event became occasional, and in some cases, frequent visitors."

Humlum, et al (2005) studied the Archipelago of Svalbard, focusing on Spitsbergen (the Archipelago's main island) and the Longyearbreen glacier located in its relatively dry central region at 78°13'N latitude. They reported that "a marked warming around 1920 changed the mean annual air temperature (MAAT) at sea level within only 5 years from about -9.5°C to -4.0°C." This "represents the most pronounced increase in MAAT documented anywhere in the world during the instrumental period." Later, "from 1957 to 1968, MAAT dropped about 4°C, followed by a more gradual increase towards the end of the twentieth century."

The Longyearbreen glacier "has increased in length from about 3 km to its present size of about 5 km during the last c. 1100 years." This is representative of "development towards cooler conditions in the Arctic." This "may explain why the Little Ice Age glacier advance in Svalbard usually represents the Holocene maximum glacier extension."

THE SUN'S ROLE IN GREENLAND AND THE ARCTIC.

Usoskin, et al (2004) show solar radiation changes (from sunspot data) and how they correlate very well with Greenland and Antarctic temperatures over the last several centuries



Soon (2006) attempted to determine the relative effects of rising atmospheric CO₂ concentrations or variations in solar irradiance on Arctic temperatures. Soon examined surface air temperature (SAT) variations, particularly over decadal- and longer-term periods. The results indicated a much stronger statistical relationship between SATs and Total Solar Irradiance (again Hoyt and Schatten), compared with SATs and CO₂ mixing ratios. Solar forcing was estimated to explain more than 79% of the variance in decadally-averaged Arctic temperatures, whereas CO₂ forcing explained 22%.

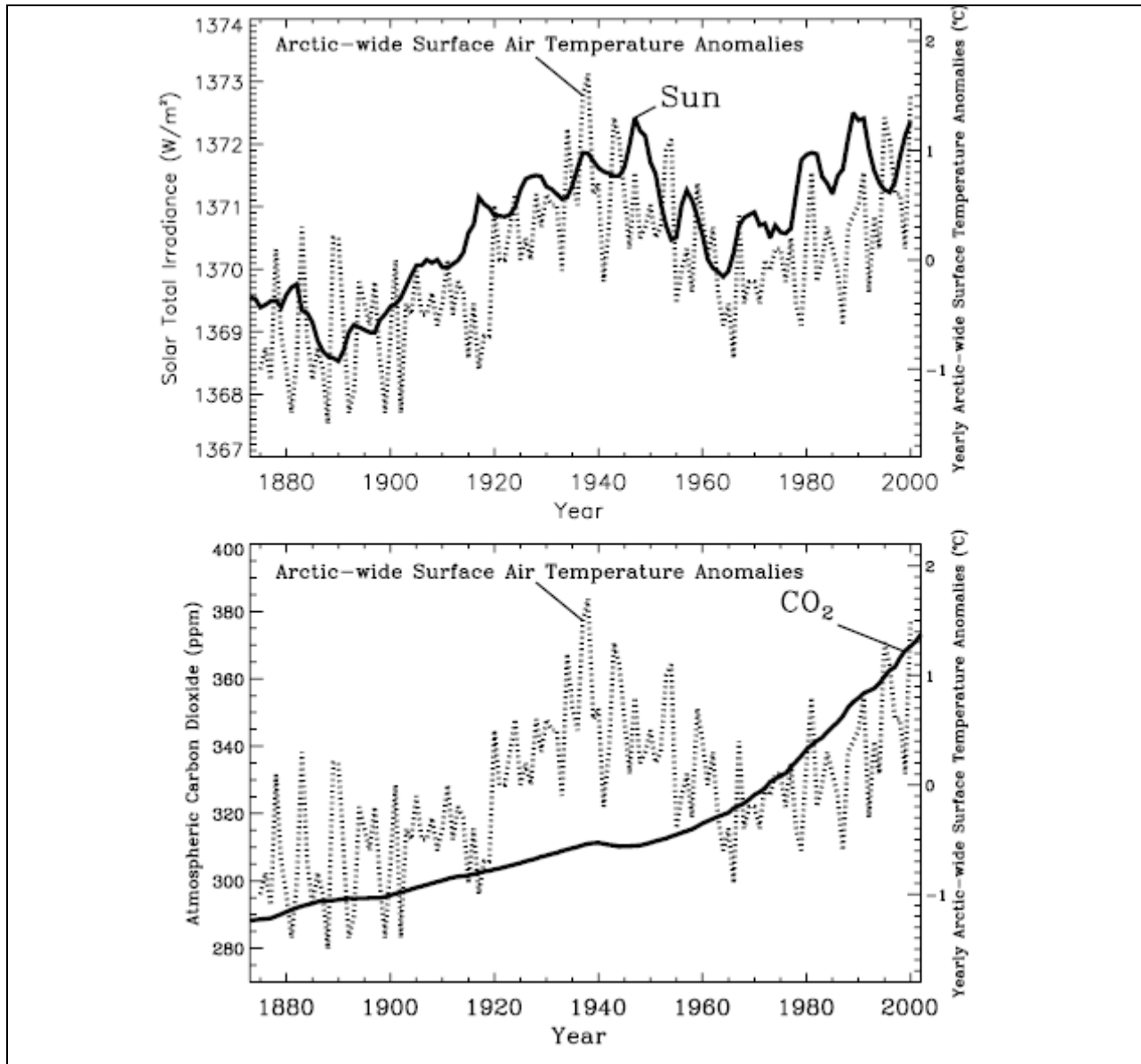


Figure 12: Soon (2006) plot of Total Solar Irradiance (Hoyt and Schatten) versus arctic basin wide average surface temperatures Polyakov (2003) and with annual CO2

These relationships common to the United States, Greenland and the arctic imply a possible role of the sun in the ocean cycles. The ocean cycles seem to be in phase with the solar cycles and there is Pearson correlation of 0.725 and a r-squared of 0.54 between the 11 years smoothed TSI and comparably smoothed PDO+AMO (ocean warmth index).

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 including Greenland and the arctic.

When you combine the two effects, you can explain much of the temperature variances of the past 110 years for the United States, Greenland and the arctic.

Similarly solar cycle changes also correlate well with temperature changes in the United States and the arctic.

Though correlation does not always imply causation, the strength of these relationships suggest the oceans and sun play a far more important role in climate change than the IPCC admits to.

References:

AMS Glossary of Meteorology, Second Edition, 2000

Arctic Climate Assessment (ACIA), 2004. Impacts of a warming Arctic. Cambridge University Press, Cambridge, UK

Baldwin, M.P., Dunkerton, T.J.. (2004). The solar cycle and stratospheric-tropospheric dynamical coupling JAS 2004

Barnston, A.G., Livezey, R.: A Closer Look at the Effect of the 11 year Solar Cycle and QBO on Northern Hemispheric 700mb Height and Extratropical North American Surface Temperature;, Journal of Climate, November 1989, 1295-1313

Barnston, A., Livesey, R., Halpert, M.: Modulation of Southern Oscillation - Northern Hemisphere Mid-Winter Climate Relationships by the QBO; Journal of Climate, February 1991, 203-217

Barnston, A., Livesey, R., (1991) Statistical Prediction of the January-February Mean Northern Hemisphere Lower Tropospheric Climate from the 11 Year Solar Cycle and the Southern Oscillation for West and East QBO Phases; Journal of Climate, February 1991, 249-262

Bunkers, M., Miller, D., DeGaetana, D.: 1996: An Examination of the El Nino/La Nina Relative Precipitation and Temperature Anomalies across the Northern Plains;, Journal of Climate, January 1996, 147-160

Changnon, S., Winstanley, D.: 2004: Insights to Key Questions about Climate Change, Illinois State Water Survey, <http://www.sws.uiuc.edu/pubdoc/IEM/ISWSIEM2004-01.pdf>

Christy, J.R., R.W. Spencer and W.D. Braswell, 2000: MSU tropospheric temperatures: Dataset construction and radiosonde comparisons. J. Atmos. Oceanic Tech., 17, 1153-1170.

Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change National Assessment Synthesis Team USGRCP, June 2000

Delworth, T.L. ,and M.E. Mann, 2000: Observed and simulated multidecadal variability in the Northern Hemisphere. Climate Dyn., 16, 661-676.

Drinkwater, K.F. 2006. The regime shift of the 1920s and 1930s in the North Atlantic. Progress in Oceanography 68: 134-151.

- Francis, J. A., & Hunter, E. (2007). Drivers of declining sea ice in the Arctic winter: A tale of two seas. *Geophys. Res. Lett.* 34: L17503.
- Gray, S.T., et al., 2004: A tree-ring based reconstruction of the Atlantic Multidecadal Oscillation since 1567 A.D. *Geophys. Res. Lett.*, 31, L12205, doi:10.1029/2004GL019932.
- Hanna, E. and Cappelen, J. (2003). Recent cooling in coastal southern Greenland and relation with the North Atlantic Oscillation. *Geophysical Research Letters* 30(3): doi: 10.1029/2002GL015797. issn: 0094-8276.
- Hanna, E., Jonsson, T., Olafsson, J. and Valdimarsson, H. 2006. Icelandic coastal sea surface temperature records constructed: Putting the pulse on air-sea-climate interactions in the Northern North Atlantic. Part I: Comparison with HadISST1 open-ocean surface temperatures and preliminary analysis of long-term patterns and anomalies of SSTs around Iceland. *Journal of Climate* 19: 5652-5666.
- Hansen, J., R. Ruedy, J. Glascoe, and Mki. Sato, 1999: GISS analysis of surface temperature change. *J. Geophys. Res.*, 104, 30997-31022, doi:10.1029/1999JD900835.
- Hass, C., Eicken, H., 2001: Interannual Variability of Summer Se Ice thickness in the Siberian and central Arctic under Different Atmospheric Circulation Regiomes, *JGR*, 106, 4449-4462
- Humlum, O., Elberling, B., Hormes, A., Fjordheim, K., Hansen, O.H. and Heinemeier, J. 2005. Late-Holocene glacier growth in Svalbard, documented by subglacial relict vegetation and living soil microbes. *The Holocene* 15: 396-407\
- IPCC Fourth Assessment 2007
- Johannessewn, O.M., Shalina, E.V., Miles, M. W., (1999): Satellite Evidence for an Arctic Sea Ice Cover in Transformation, *Science*, 286, 1937-1939
- Karlen, W. 2005. Recent global warming: An artifact of a too-short temperature record? *Ambio* 34: 263-264.
- Kerr, R. A., A North Atlantic climate pacemaker for the centuries, *Science*, 288 (5473), 984-1986, 2000.
- Kunkel, K.E., Liang, X.-Z., Zhu, J. and Lin, Y. 2006. Can CGCMs simulate the twentieth-century "warming hole" in the central United States? *Journal of Climate* 19: 4137-4153.
- Labitzke, k., Van Loon, H.: Association Between the 11 Year Solar Cycle , the QBO and the Atmosphere, Part III, Aspects of the Association; *Journal of Climate*, June 1989, 554-565
- Labitzke, K., 2001: The global signal of the 11-year sunspot cycle in the stratosphere. Differences between solar maxima and minima, *Meteorol. Zeitschrift*, 10, 83-90.

- Latif, M. and T.P. Barnett, 1994: Causes of decadal climate variability over the North Pacific and North America. *Science* 266, 634-637.
- Lockwood, M., and R. Stamper, 1999: Long-term drift of the coronal source magnetic flux and the total solar irradiance. *Geophys. Res. Lett.*, 26, 2461-2464.
- Mantua, N.J., Hare, S.R., Zhang, Y., Wallace, J.M., Francis, R.C., 1997, A Pacific interdecadal climate oscillation with impacts on salmon production, *BAMS*, 78, 1069-1079
- Miller, A.J., D.R. Cayan, T.P. Barnett, N.E. Graham and J.M. Oberhuber, 1994: The 1976-77 climate shift of the Pacific Ocean. *Oceanography* 7, 21-26.
- Minobe, S. 1997: A 50-70 year climatic oscillation over the North Pacific and North America. *Geophysical Research Letters*, Vol 24, pp 683-686.
- Minobe, S. Resonance in bidecadal and pentadecadal climate oscillations over the North Pacific: Role in climatic regime shifts. *Geophys. Res. Lett.* 26: 855-858.
- Polyakov, I., Walsh, D., Dmitrenko, I., Colony, R.L. and Timokhov, L.A. 2003a. Arctic Ocean variability derived from historical observations. *Geophysical Research Letters* 30: 10.1029/2002GL016441.
- Polyakov, I., Alekseev, G.V., Timokhov, L.A., Bhatt, U.S., Colony, R.L., Simmons, H.L., Walsh, D., Walsh, J.E. and Zakharov, V.F., 2004. Variability of the Intermediate Atlantic Water of the Arctic Ocean over the Last 100 Years. *Journal of Climate* 17: 4485-4497.
- Proshutinsky, A.Y., Johnson, M.A., 1997: Two Circulation Regimes of the Wind Driven Arctic, *JGR*, 102, 12493-12514
- Przybylak, R., 2000, Temporal And Spatial Variation Of Surface Air Temperature Over The Period Of Instrumental Observations In The Arctic, *Intl Journal of Climatology*, 20: 587-614
- Rigor, I.G., Wallace, J.M. and Colony, R.L., 2002. Response of Sea Ice to the Arctic Oscillation. *Journal of Climate* 15: 2648-2663.
- Rothrock, D.A., Yu, Y., Maykut, G.A., 1999: Thinning of the Arctic Sea-Ice Cover, *GRL*, 26, no23 3469-3472
- Scafetta, N., West, B.J. (2006). Phenomenological Solar Signature in 400 years of Reconstructed Northern Hemisphere Temperature Record", *GRL*.
- Shindell, D.T., D. Rind, N. Balachandran, J. Lean, and P. Lonergan, (1999). Solar cycle variability, ozone, and climate, *Science*, 284, 305-308
- Shaviv, N. J., (2005). "On Climate Response to Changes in the Cosmic Ray Flux and Radiative Budget", *JGR-Space*, vol. 110, A08105.'

Soon, W., (2006). "Variable Solar Irradiance as a Plausible Agent for Multidecadal Variations in the Arctic-Wide Surface Air Temperature Record of the Past 130 years " *GRL*, vol 32

Solanki, S.K., M. Schüssler, and M. Fligge, 2002: Secular variation of the sun's magnetic flux. *Astronomy and Astrophysics*, 383, 706-712.

Solanki, S.K., I.G. Usoskin, B. Kromer, M. Schüssler, and J. Beer, 2004: Unusual activity of the Sun during recent decades compared to the previous 11,000 years. *Nature*, 431, 1084-1087.

Soon, W. W.-H. 2005. Variable solar irradiance as a plausible agent for multidecadal variations in the Arctic-wide surface air temperature record of the past 130 years. *Geophysical Research Letters* 32 L16712, doi:10.1029/2005GL023429.

Svenmark, H, Friis-Christensen, E.. (1997). Variation of cosmic ray flux and global cloud cover—a missing link in solar -climate relationships, *Journal of Atmospheric and Solar-Terrestrial Physics*, 59, pp 1125-32

Thomas, R., Akins, T., Csatho, B., Fahenstock, M., Goglneni, P., Kim, C., Sonntag, J., (2000): Mass Balance of the Greenland Ice Sheet at High Elevations, *Science*, 289, 427

Trenberth, K.E., and J.W. Hurrell, 1994: Decadal atmosphere-ocean variations in the Pacific. *Clim. Dyn.*, 9, 303-319.

Usoskin, I. G., Mursula, K., Solanki, S. K., Schüssler, M. & Alanko, K. Reconstruction of solar activity for the last millenium using 10Be data. *Astron. Astrophys.* 413, 745–751 (2004).

Van Loon, H.: Association Between the 11 Year Solar Cycle, the QBO and the Atmosphere, Part II, Surface and 700 mb in the Northern Hemisphere Winter, *Journal of Climate*, September 1988, 905-920

Venegas, S.A., Mysak, L.A., 2000: Is There a Dominant Timescale of Natural Climate Variability in the Arctic, *Journal of Climate*, October 2000, 13, 3412-3424

Venne, D., Dartt, D.: An Examination of Possible Solar Cycle/QBO Effects on the Northern Hemisphere Troposphere; *Journal of Climate*, February 1990, 272-281

Wadhams, P., Davis, N.R., 2000: Further Evidence of Ice thinning in the Arctic Ocean, *GRL*, 27, 3973-3975

Wang, Y.M., J.L. Lean, and N.R. Sheeley, 2005: Modeling the sun's magnetic field and irradiance since 1713. *Astrophysical Journal*, 625, 522-538.

Winsor, P., (2001) Arctic Sea ice Thickness Remained Constant During the 1990s: *GRL* 28, no6 1039-1041

Wolter, K., 1987: *The Southern Oscillation in surface circulation and climate over the tropical Atlantic, Eastern Pacific, and Indian Oceans as captured by cluster analysis*. *J. Climate Appl. Meteor.*, **26**, 540-558.

Wolter, K., and M.S. Timlin, 1993: *Monitoring ENSO in COADS with a seasonally adjusted principal component index*. *Proc. of the 17th Climate Diagnostics Workshop, Norman, OK, NOAA/N MC/CAC, NSSL, Oklahoma Clim. Survey, CIMMS and the School of Meteor., Univ. of Oklahoma*, 52-57.

Wolter, K., and M.S. Timlin, 1998: *Measuring the strength of ENSO - how does 1997/98 rank?* *Weather*, **53**, 315-324

DEFINITIONS OF TERMS

Some items adapted from AR4 Chapter 3 (Defining the Circulation Indices)

An atmospheric teleconnection is made up of a fixed spatial pattern with an associated index time series showing the evolution of its amplitude and phase. Teleconnections are best defined by values over a grid, but it has generally been convenient to devise simplified indices based on key station values. Using gridded fields to define indices provides a fuller picture of the true magnitude of fluctuations in a teleconnection pattern and reduces short term “noise”. However, an index defined in this way is more complicated to calculate, and relies on the existence of gridded data fields. A number of teleconnections have historically been defined from either station data (NAO and MEI) or upper air data (QBO) or from gridded fields (NAM) of surface pressure or ocean temperatures (PDO, AMO):

North Atlantic Oscillation (NAO) Index. The difference of normalized MSLP anomalies between Lisbon, Portugal and Stykkisholmur, Iceland has become the widest used NAO index and extends back in time to 1864 (Hurrell, 1995), and to 1821 if Reykjavik is used instead of Stykkisholmur and Gibraltar instead of Lisbon (Jones et al., 1997). When originally defined in the 1930s, Ponta Delgada, Azores and Stykkisholmur, Iceland were used and the series extended back to 1865, but this series is less easily updatable in real time.

Northern Annular Mode (NAM) Index. The amplitude of the pattern defined by the leading empirical orthogonal function of winter monthly mean NH MSLP anomalies poleward of 20°N (Thompson and Wallace, 1998, 2000). The NAM has also been known as the Arctic Oscillation (AO), and is closely related to the NAO.

Pacific Decadal Oscillation (PDO) Index

The PDO is defined as the pattern and time series of the first empirical orthogonal function of SST over the North Pacific north of 20°N (Mantua et al., 1997), see also Deser et al. (2004).

Atlantic Multi-decadal Oscillation (AMO) (3.6.6.1 pages 51-52)

Over the instrumental period (since the 1850s) North Atlantic SSTs show a 65–75 year variation (0.4°C range), with apparent warm phases at roughly 1860–1880 and 1930–1960 and cool phases during 1905–1925 and 1970–1990 (Schlesinger and Ramankutty, 1994), and this feature has been termed the AMO (Kerr, 2000). The cycle appears to have returned to a warm phase beginning in the mid-1990s and tropical Atlantic SSTs were at record high levels in 2005. Instrumental observations capture only two full cycles of the AMO, so the robustness of the signal has been addressed using

proxies. Similar oscillations in a 60–110 year band are seen in North Atlantic paleoclimatic reconstructions through the last four centuries (Delworth and Mann, 2000; Gray et al., 2004).

Multivariate ENSO Index

Multivariate ENSO Index (MEI) is based on the six main observed variables over the tropical Pacific. These six variables are: sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C). After spatially filtering the individual fields into clusters ([Wolter, 1987](#)), the MEI is calculated as the first unrotated Principal Component (PC) of all six observed fields combined. This is accomplished by normalizing the total variance of each field first, and then performing the extraction of the first PC on the co-variance matrix of the combined fields ([Wolter and Timlin, 1993](#)). In order to keep the MEI comparable, all seasonal values are standardized with respect to each season and to the 1950-93 reference period.

Quasi Biennial Oscillation (QBO)

The QBO is an oscillation in the zonal winds of the equatorial stratosphere having a period that fluctuates between about 24 and 30 months. This oscillation is a manifestation of a downward propagation of winds with alternating sign