Global Cooling About to "Kick-in"?
An Alernative View on Climate Change

INTRODUCTION

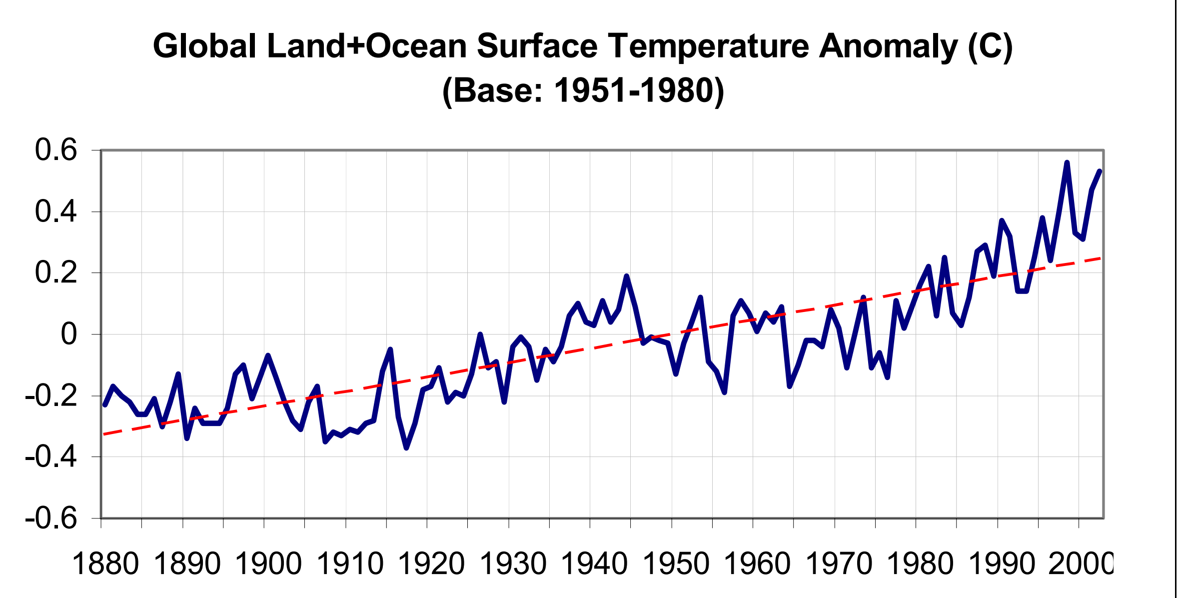
Climate change is real, inevitable. After all, the only constant in nature is change. Considerable data has been presented to us in recent years suggesting that over the last century, the earth has warmed and the warming has man's fingerprint on it. Many assume that the steady long-term increase in atmospheric carbon dioxide and other greenhouse gases is behind the apparent warming.

However, in this paper, we will present evidence that man's influence may be mostly a local one through the effect of urbanization and that the longer-term changes are smaller and cyclical in nature and instead more likely driven by large-scale oscillations in the oceans and on the sun. We will also see these oscillations appear to have all switched modes in the last few years, suggesting the start of a cooling trend.

ASSESSING LONG TERM CLIMATE CHANGE

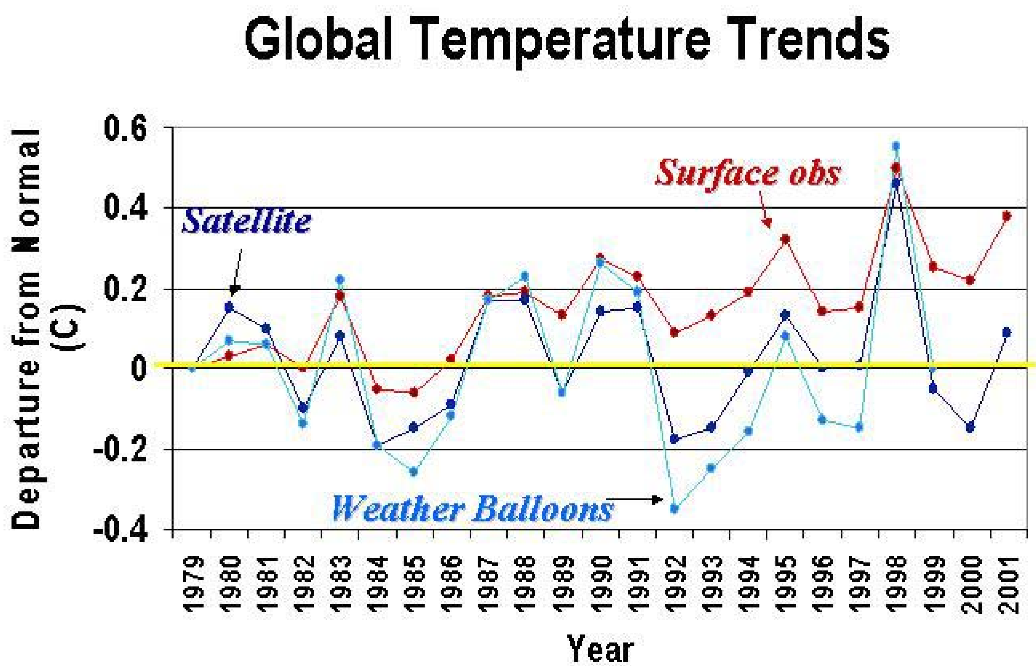
In an attempt to measure climate change, NCDC and NASA and the UK Met Office have assembled databases of historical weather observations from global surface observing stations. The mean temperatures of these stations have been used to construct the global climate state for every month roughly from the late 1880s to the current time.

The long-term average of this global station data is the primary evidence presented that the world is warming. It has shown an apparent warming of about 0.6°C since 1880.



NASA GIS Surface Temperature Anomalies for Land and Ocean Surface (°C) since 1880. Over that period an apparent warming of around 0.6°C has occurred in global mean *temperatures*

However, two other reliable sources have not shown the same warming that the weather observing station network implies. Both satellite derived and weather balloon measured temperatures show very little change in the last few decades in sharp contrast to the warming suggested by the raw global station data.



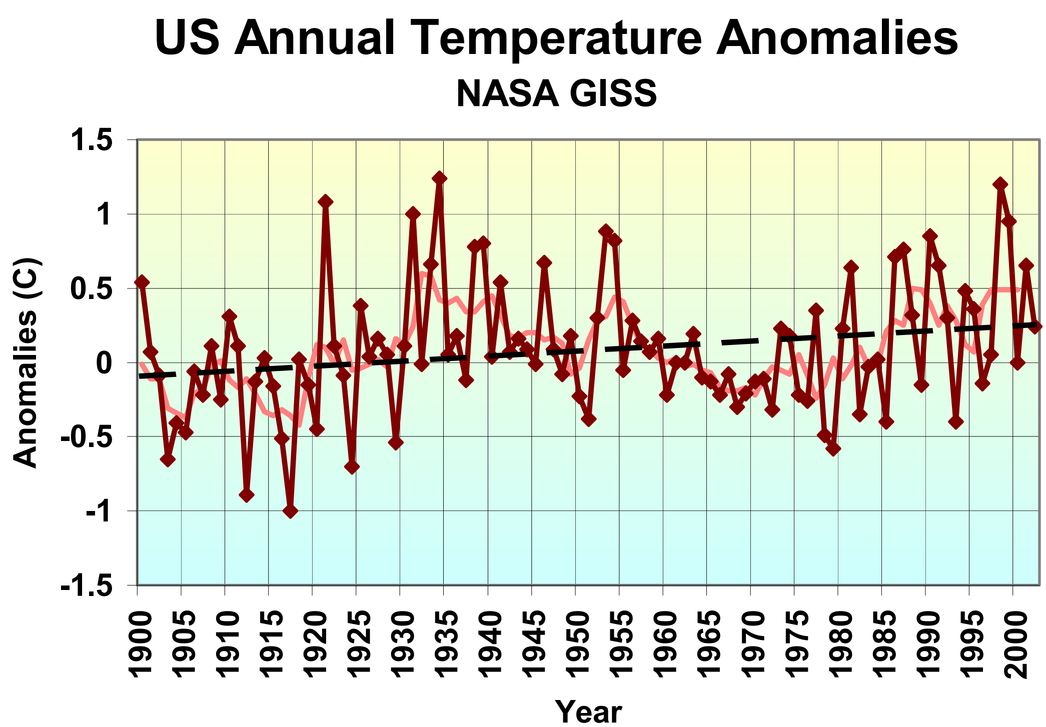
Satellite and weather balloon measurements of the lower atmospheric temperatures since 1979 has not shown the same level of warming as the station based observation data.

Part of the reason for this discrepancy may be the effect of urbanization and other local factors on temperature observations. Urbanization produces a localized warming effect concentrated in the cities, which we call the "urban heat island effect". The warming is especially evident at night, due, in part, to the trapping of the sun's heat during the day by the city's structures and a slow release at night.

Urban warming is concentrated at the earth's surface (where station observations are made) and not in the atmosphere (where weather balloons and satellites do their measuring). This could explain why the surface observation data shows a warming, while satellite and weather balloon data does not.

Further evidence that much of the station based global warming may be due to urban contamination may be seen by comparing rural temperature trends versus urban temperature trends http://www.intellicast.com/DrDewpoint/Library/1211/. If the warming was greenhouse gas induced and truly global, rural areas should be warming too (greenhouse gas should raise the bar for all locations). This is often not the case. Many truly rural locations in virtually all corners of the United States instead have long-term temperature trends that are flat or even down.

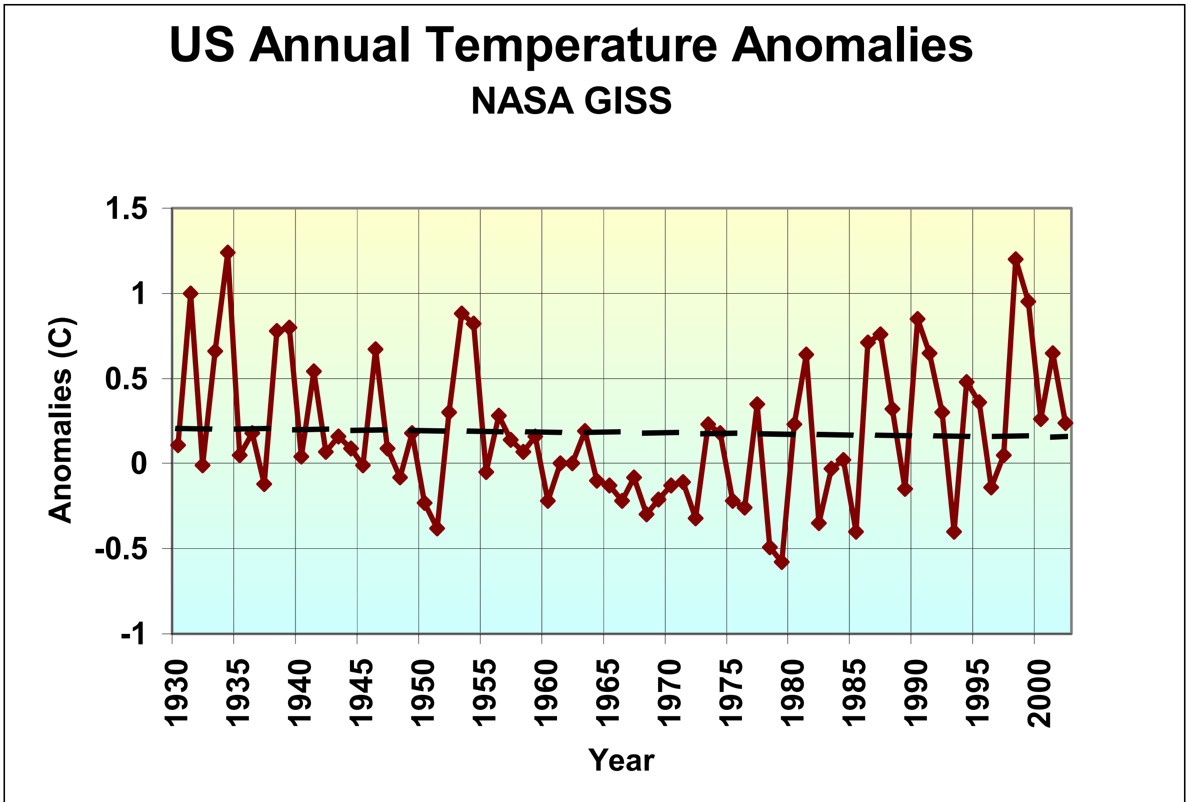
NCDC and NASA have both recognized that local factors such as urbanization can cause an upward creep in temperatures and have made urban "adjustments" to the temperature data. The result has been a smaller rise in global average temperature in the last two decades and overall.



NASA GISS United States annual mean temperature since 1900 adjusted for urban factors. There is a slight warming of about 0.3℃ apparent in this data since 1900. Also evident is a cyclical change with peak warmth in the 1930s and 1990s and overall coolness in the 1910s and 1960s.

The NASA adjustment uses the regression approach outlined by Tom Karl (1988). The adjusted data shows a relatively small warming of 0.3°C over the last century (roughly half that of most global estimates). The greatest discontinuity in the adjusted data came in the 1920s. The warming of the 1920s may have been partly influenced by changes in the measurement procedures at that time from observations at mainly fixed times to one that included daily maximums and minimums, the standard even today (Ellsaesser & MacCracken, 1986).

Indeed, if you start the plot in 1930, you find there has been no net long-term warming (even a very slight cooling) for the mean annual temperatures in the United States. You are left with what appears to be a cyclical decadal scale oscillation with a cooling from the 1950s to the 1970s, then a warming to the 1990s.



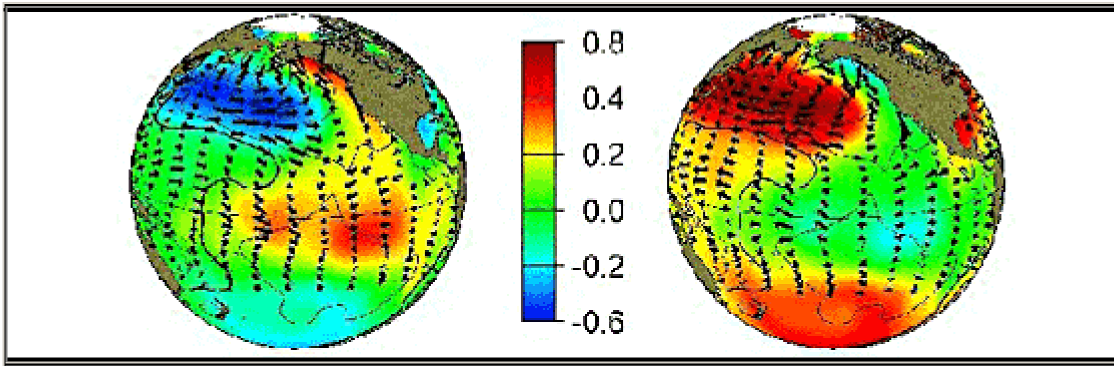
Temperature trends in the urban adjusted temperature data since 1930 show a cyclical pattern but no net warming.

This longer-term cyclical change in temperature may relate to similar long-term cyclical changes in the oceans and on the sun.

DECADAL SCALE CHANGES IN THE OCEANS

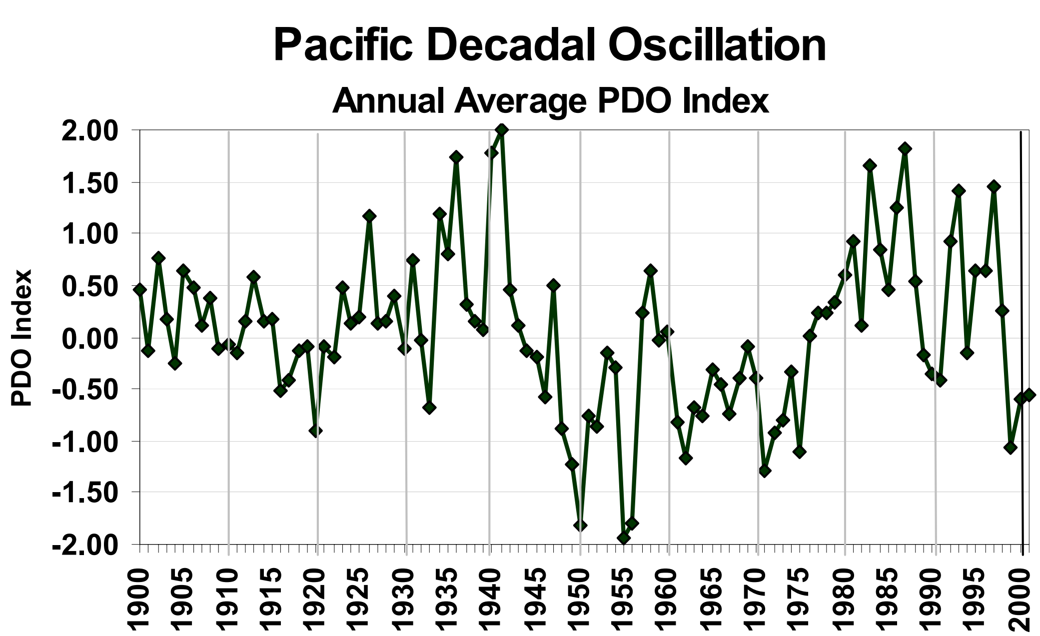
While the focus in recent years has been on the tropical Pacific where the El Nino Southern Oscillation takes place, there is a larger-scale, longer-term oscillation involving the entire Pacific Basin that is now beginning to get much more attention. Research scientists at the Jet Propulsion lab (JPL) and the University of Washington have named this oscillation the Pacific Decadal Oscillation.

Their analysis of long-term ocean temperature patterns showed a tendency for the Pacific Basin Ocean temperatures to take on one of two configurations. In what they termed the warm phase, colder than normal water was found in the Northwest Pacific, and warmer than normal water along the North American West coast and along the equator. In what they termed the cool phase, the opposite configuration tended to dominate, with warmer than normal waters in the Northwest Pacific and cooler than normal waters near the west coast of North America and along the equator.



Mean oceanic maps for the positive (left) and negative (right) phases of the PDO. Sea surface temperature anomalies are shown (red for above normal, blue for below normal). The ocean temperature pattern in the northern and central Pacific generally resembles either of these two modes. In the positive phase, cold water is predominant in the North Pacific with warm water along the North American west coast and in the tropical Pacific. In the negative phase, we find warm water to the north with cool water off the west coast and in the tropics. Maps courtesy of University of Washington's Joint Institute for the Study of the Atmosphere and Oceans.

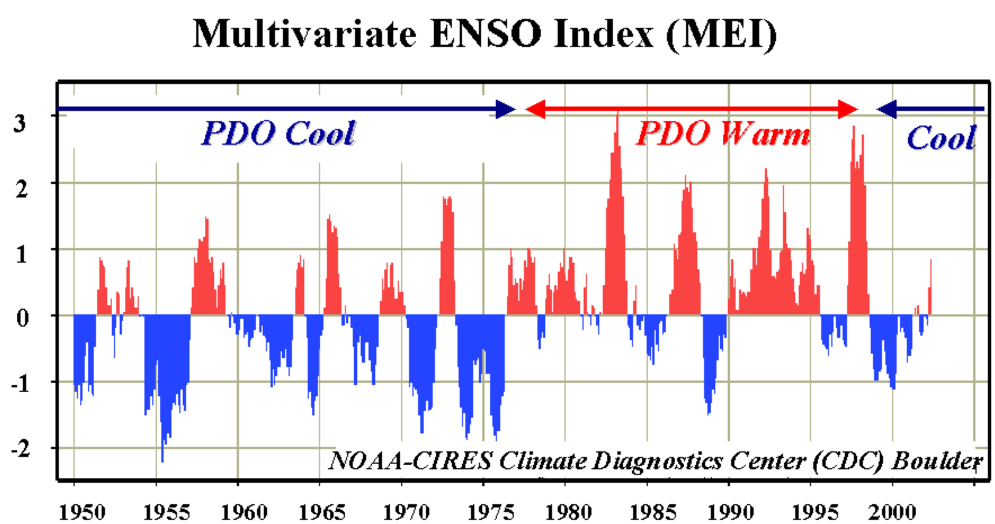
Unlike El Nino and La Nina events which usually only last 12-18 months, the phases of the PDO tend to persist for 20-30 years (see figure below).



The PDO index shows a strong tendency for decadal persistence. The index was predominantly positive from the mid-1920s to the late 1940s and again from the late 1970s to the late 1990s. It was negative from the late 1940s to late 1970s. The PDO *has been generally in a negative phase since the end of the last El Nino in 1997/98.*

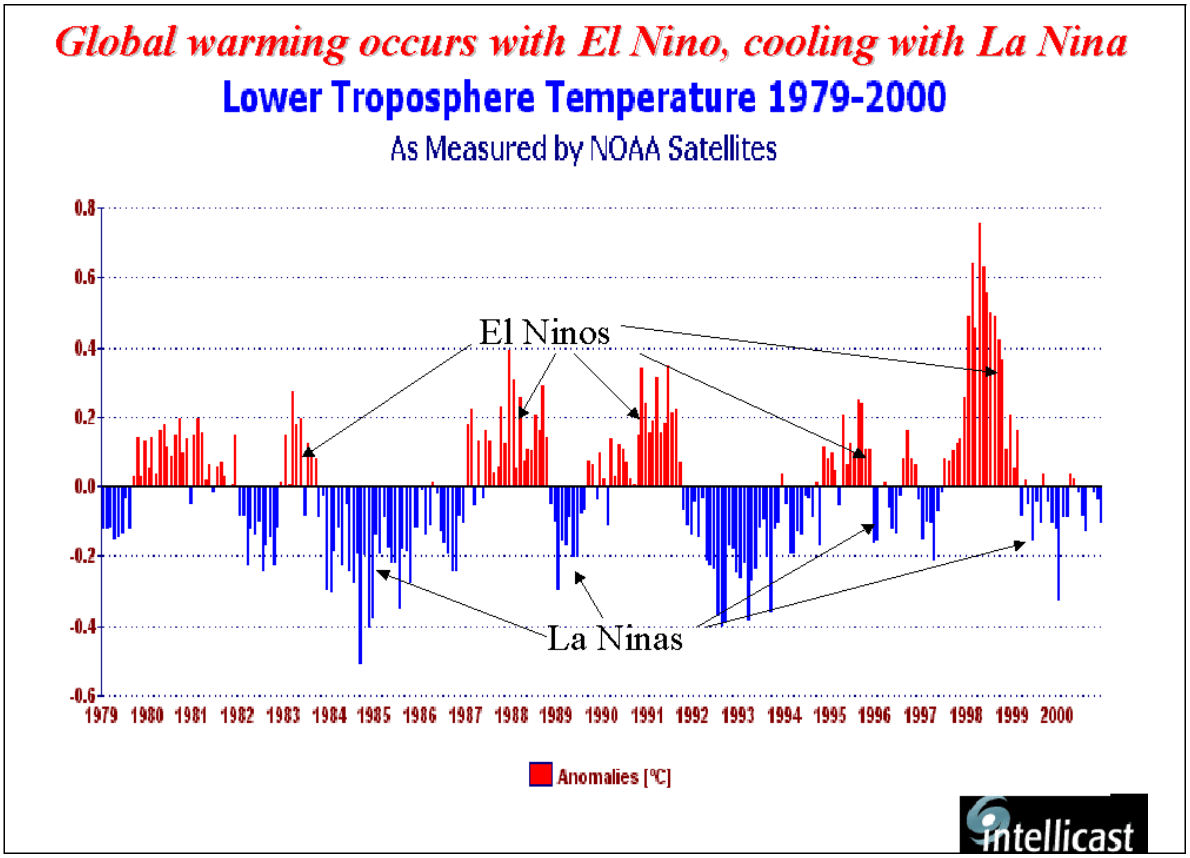
The El Nino/La Nina cycle is effectively a higher-frequency oscillation within the low-frequency PDO. Because the positive phase of the PDO favors warm water in the tropical Pacific, El Nino events are typically stronger and longer and La Nina events are weaker and briefer. Conversely, during the negative phase, cooler water is favored in the tropical Pacific, which should result in stronger and longer La Nina events and weaker and briefer El Nino events.

This is what is observed as illustrated by the time series of the Multivariate ENSO Index or MEI during the last half-century (below). This index developed by Wolter, etal at CDC measures the atmospheric and oceanic variables that typically change with the two phases of the ENSO cycle. The red spikes represent El Nino events and the blue spikes represent La Nina events.



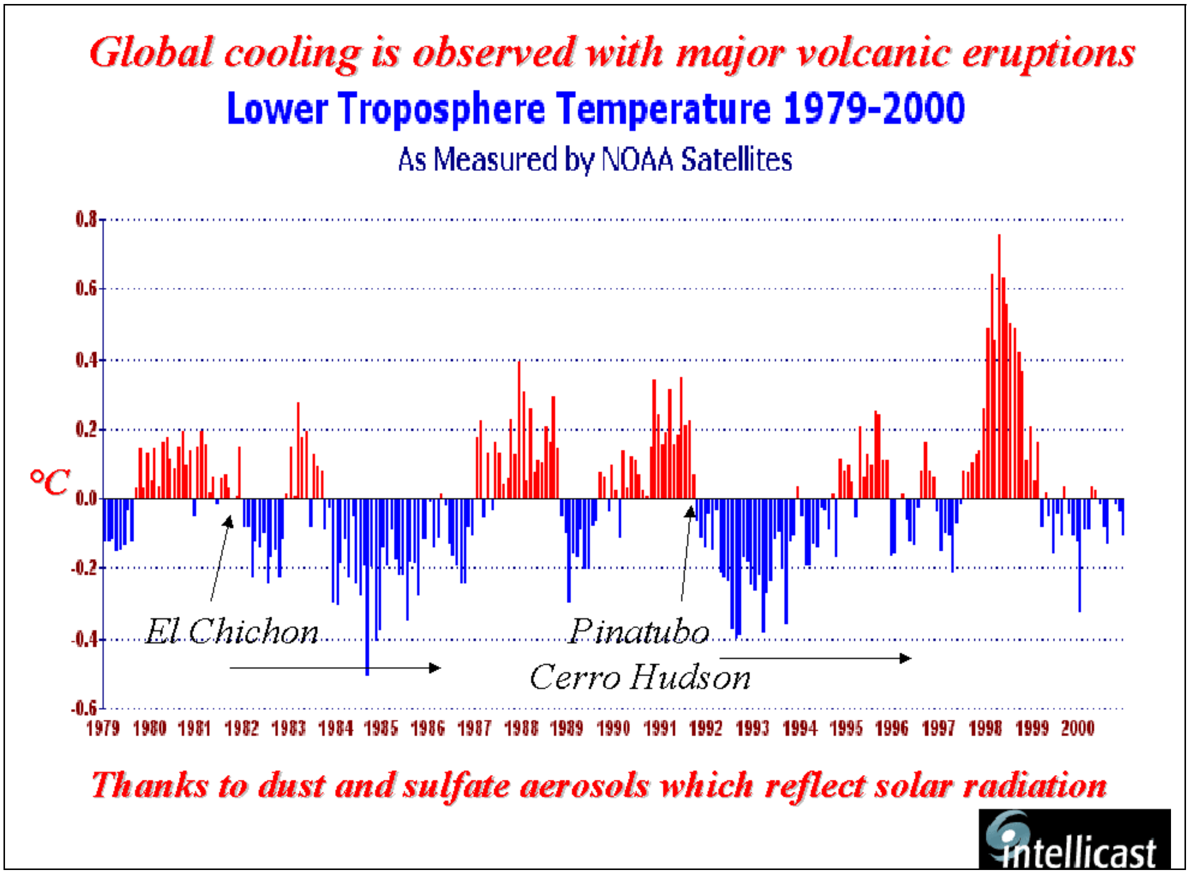
The MEI illustrates the tendency for more frequent, stronger and longer La Ninas and fewer, weaker, and briefer El Ninos during the negative (cool) phase of the PDO and more frequent, stronger and longer El Ninos and fewer, briefer, usually weaker La Ninas during the positive (warm) phase.

El Ninos tend to produce a global warming effect while La Ninas produce a net global cooling. This is very evident from the satellite-derived temperatures in the last two decades.

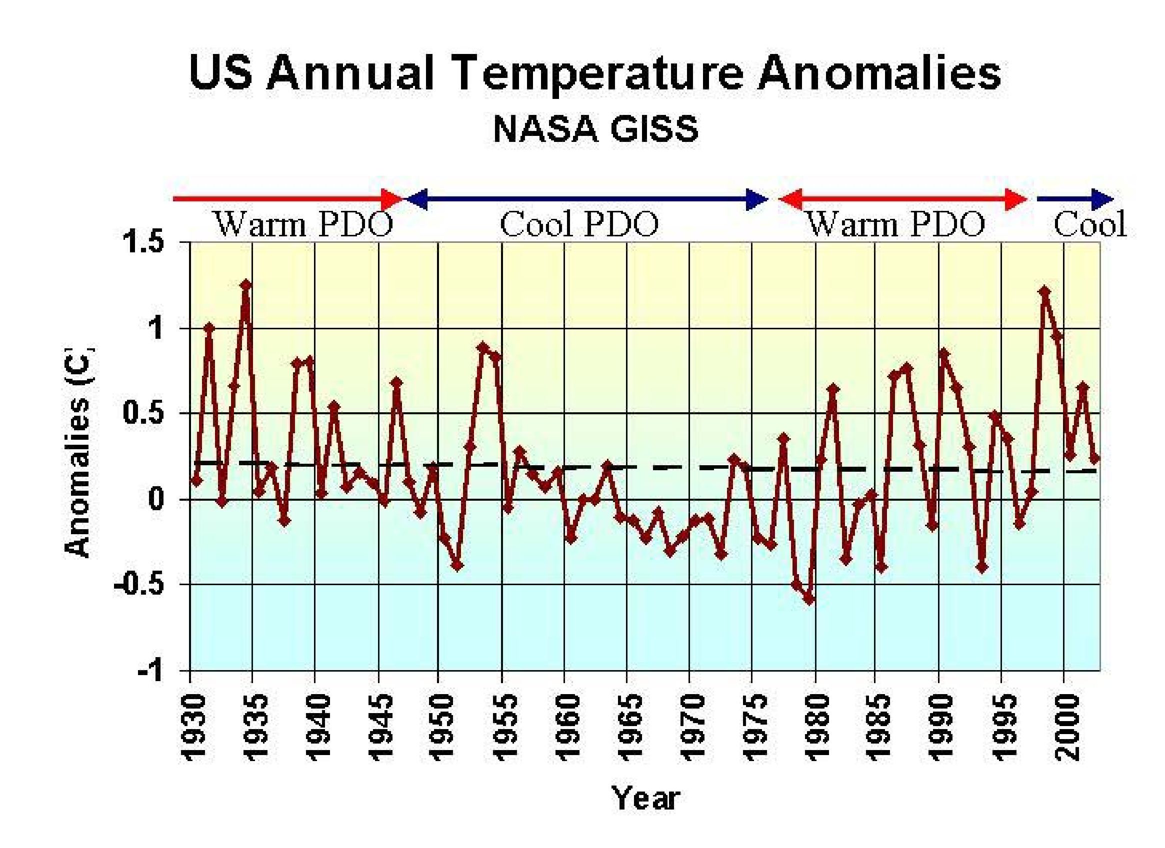


Global warming occurs with El Nino, cooling with La Nina
Lower Troposphere Temperature 1979-2000
As Measured by NOAA Satellites
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
El Ninos
La Ninas
1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Anomalies [°C]
intellicast

Also evident is the shorter term (2-4 year) cooling trends following major volcanic eruptions. Note how in the early 1980s, El Chichon reduced the warming from the super El Nino of 1982/83 and in the early 1990s, Pinatubo and Cerro Hudson swamped the warming from the multi-year El Nino (1991-1995).



Well you might thus expect that during the warm PDO periods when El Ninos are favored (more frequent and stronger), a net global warming might occur. Conversely, during the decades when the cool PDO favors La Nina, we might expect a global cooling. Again, that is exactly what is observed in the data.

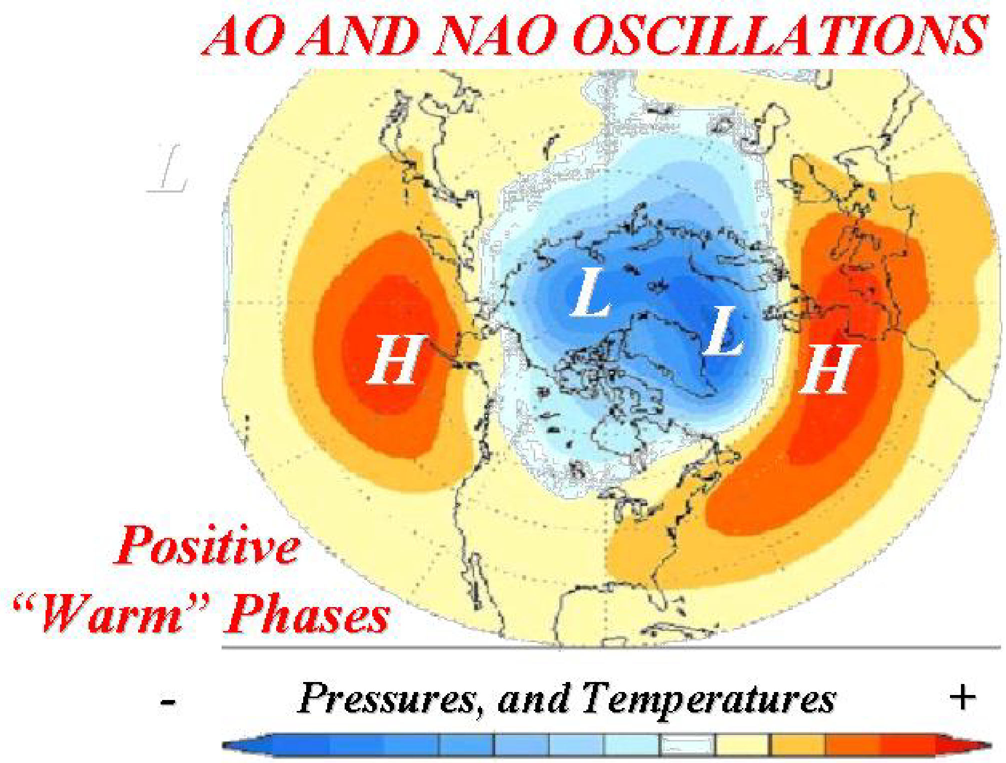


U.S. Annual temperatures tended to drop below long term average during the cool PDOs and warm to above average during the warm PDO phases

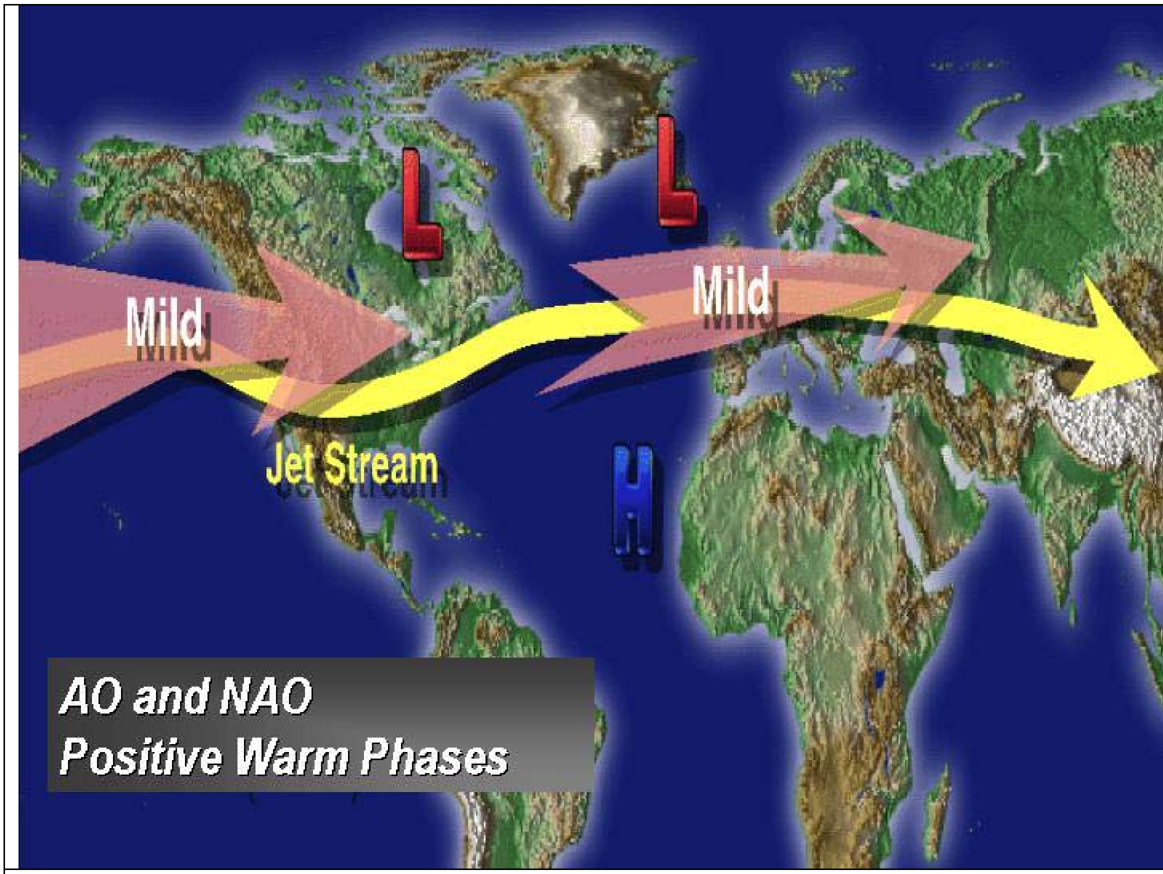
THE NORTH ATLANTIC AND ARCTIC OSCILLATIONS

As we observe in the Pacific, pressure and temperature patterns in the Arctic and Atlantic also tend to oscillate on a decadal scale between “cold” and “warm” modes. There are two oscillations that have been viewed here, the North Atlantic Oscillation or NAO and the Arctic Oscillation or AO. Usually these two indices change in unison, as the North Atlantic Oscillation features are a major component of the larger Arctic oscillation.

During the warm (positive) phases of the NAO and AO, pressures and temperatures tend to be below normal in the Polar Regions and above normal in middle latitudes. The westerly winds that blow between the polar lows and middle latitude highs tend to keep the polar air trapped in higher latitudes and allow milder maritime air to dominate over Northern Hemisphere landmasses.

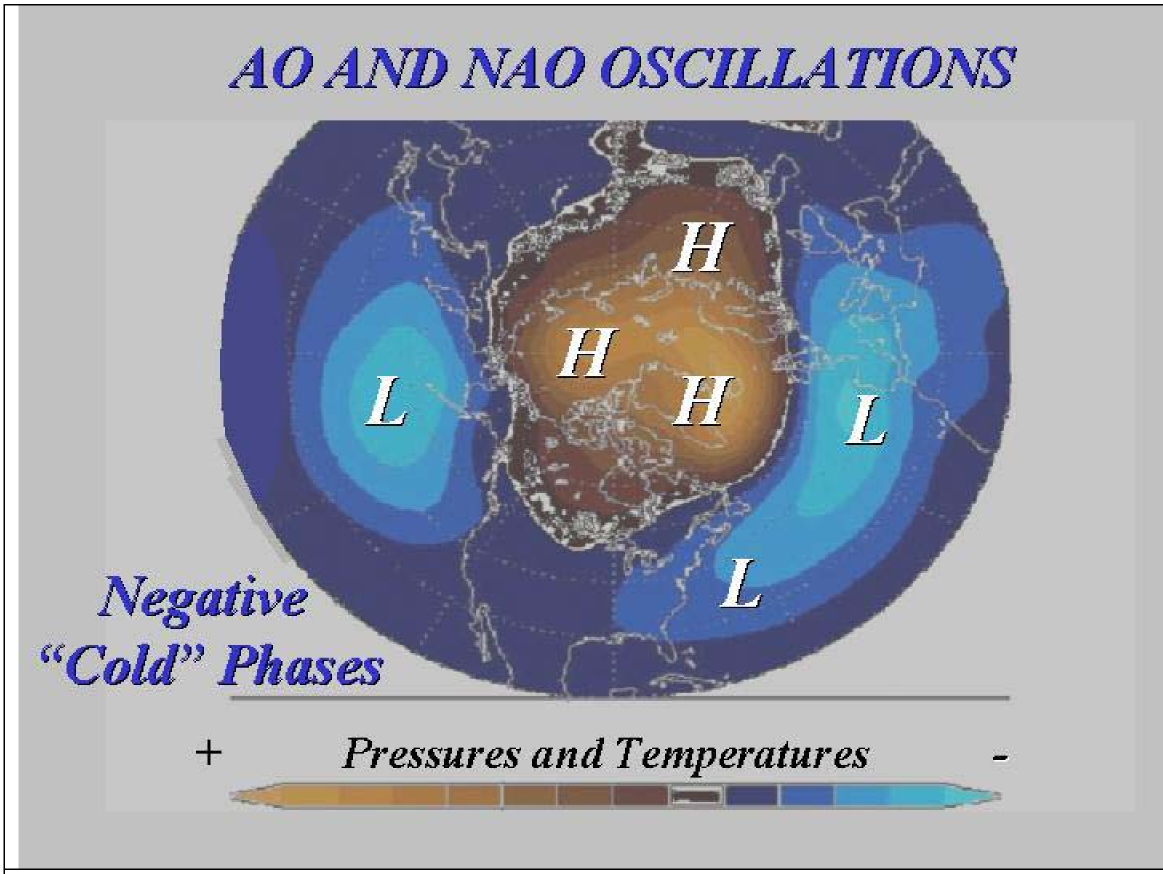


During the + (warm) phase of the Arctic and North Atlantic Oscillations, lower than normal pressures and temperatures are found in the higher (polar) latitudes and above normal pressures and temperatures in the middle latitude oceans and adjoining land masses

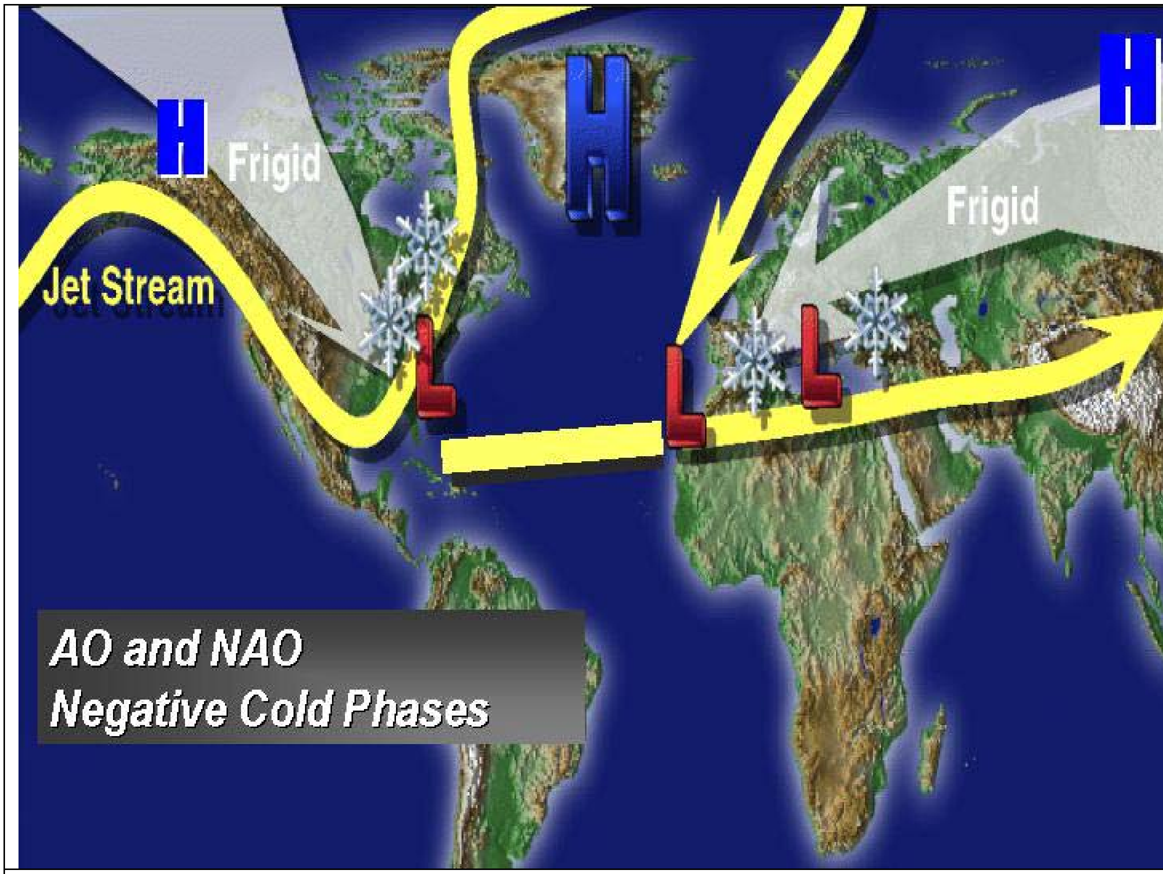


During the positive AO and NAO phases, enhanced westerly winds between the polar low pressures and the mid latitude high pressure belts cause cold air to be trapped in higher latitudes and for milder ocean air to more often dominate over the mid latitude land areas.

During the cold (negative) phases of the NAO and AO, higher than normal pressure (high latitude blocking highs) tend to be found in the Polar Regions. This favors larger polar and arctic high-pressure systems, which depress the polar front and storm tracks. The result is colder air in middle latitudes and more storminess (often more snow).

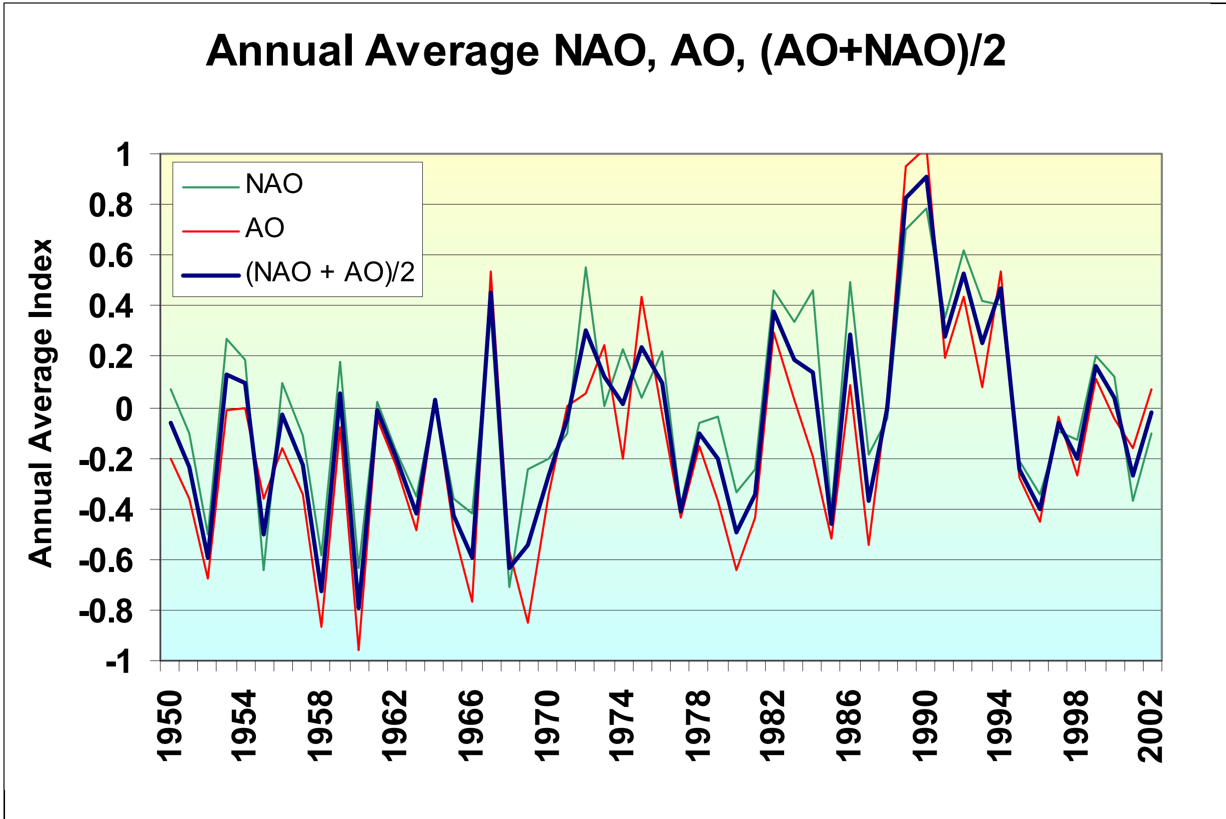


During the – (cold) phase of the Arctic and North Atlantic Oscillations, higher than normal pressures are found in the higher (polar) latitudes and below normal pressures and temperatures in the middle latitude oceans and adjoining land masses



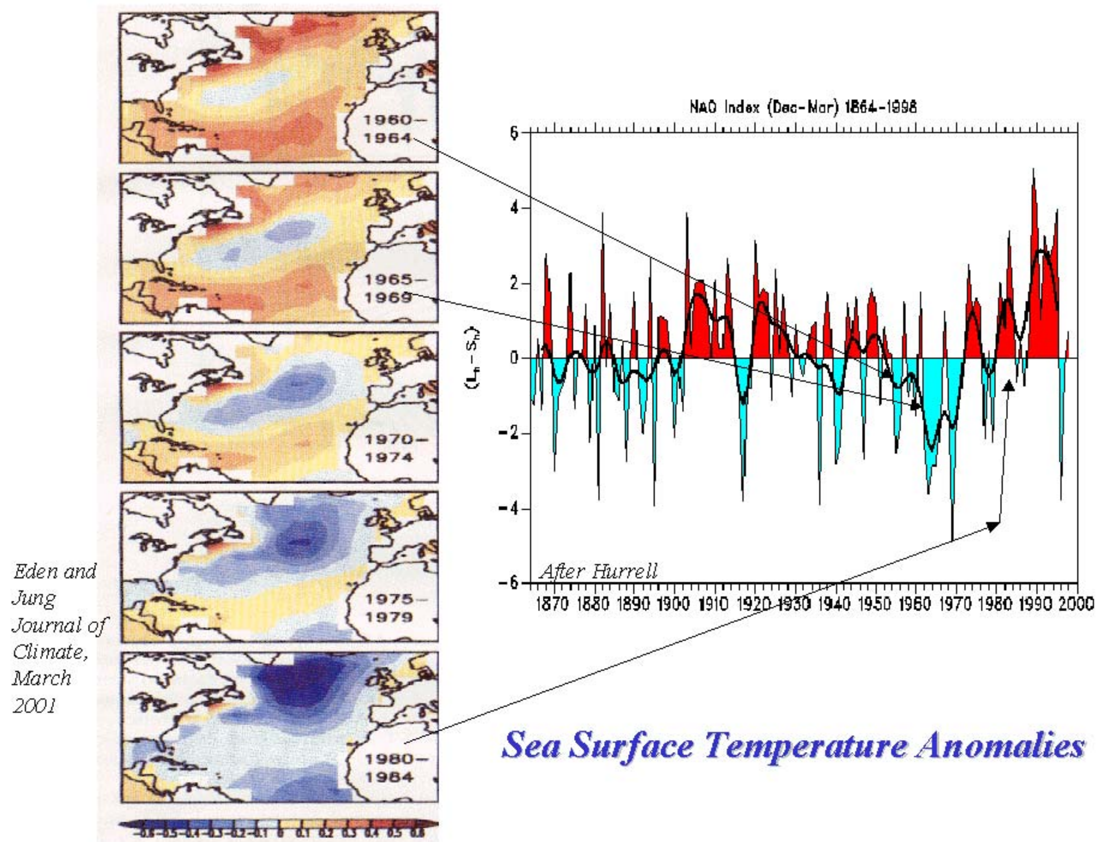
During the negative AO and NAO phases, the high latitude blocking highs produce large arctic and polar outbreaks into middle latitude continental areas. They suppress the polar front and storm tracks. The result is colder than normal temperatures and above normal snows for many heavily populated areas especially in eastern North America and western Europe.

The NAO and AO tend, like the PDO to be predominantly positive for some decades and negative during others.



The North Atlantic and Arctic Oscillations have tended to be predominantly negative (cold) during some periods (1950s to 1960s and again the late 1990s to 2000s) and predominantly positive (warm) during other periods (1980s and 1990s).

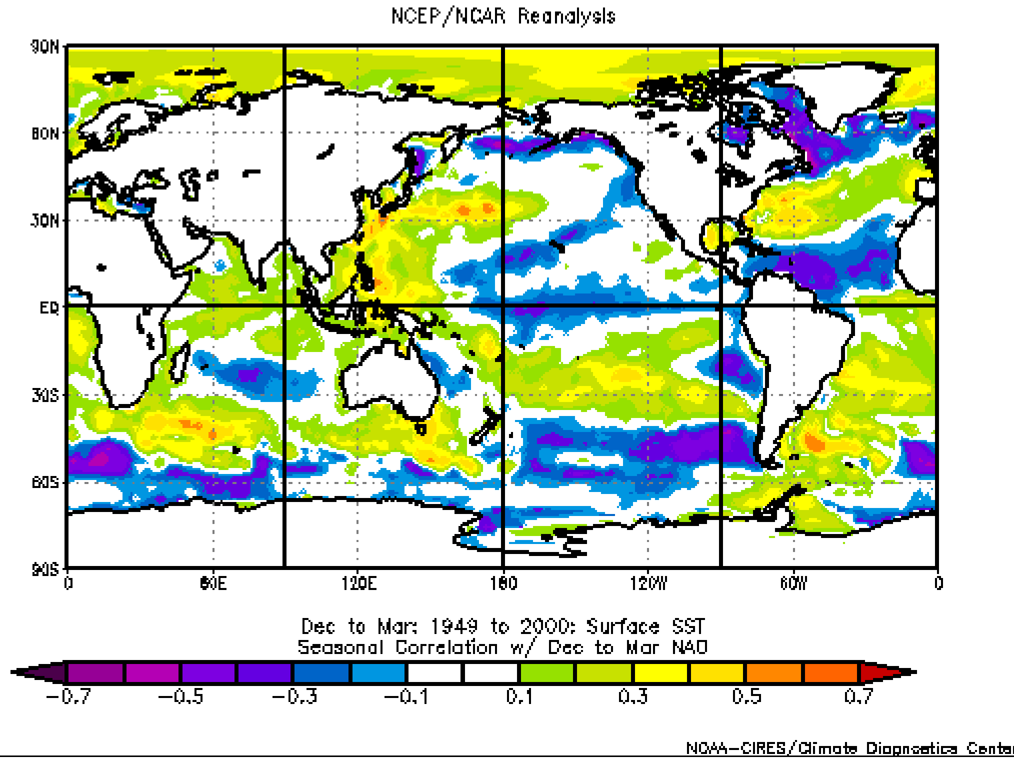
As is the case for the phases of the PDO, these longer-term tendencies may be related to the development of warm and cold pools of ocean water.



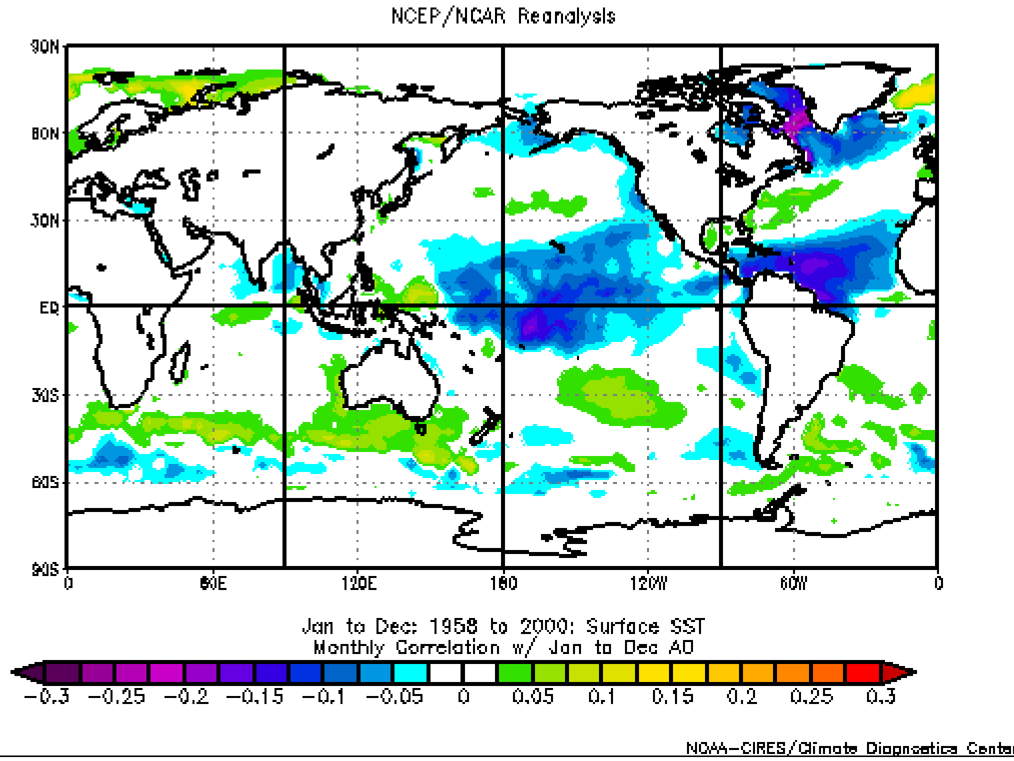
A "tripole" of sea surface temperature anomalies appears typical in the North Atlantic. When waters are warmer than normal in the far north, they tend to be colder than normal in the central areas and warmer than normal in the subtropics and tropics and vice versa. When the waters were warm in the north and near the equator in the 1950s and 1960s, the NAO was strongly negative. When it was cold in the north and in the tropics as in the 1980s and early 1990s, the NAO was strongly positive.

In the part of the cycle when waters were warmer than normal in the far North Atlantic and tropics and cooler than normal in between, the NAO (and AO) were predominantly negative. In the part of the cycle when water was colder than normal in the far Northern Atlantic and the tropics and warmer than normal in between, the NAO and AO were predominantly positive.

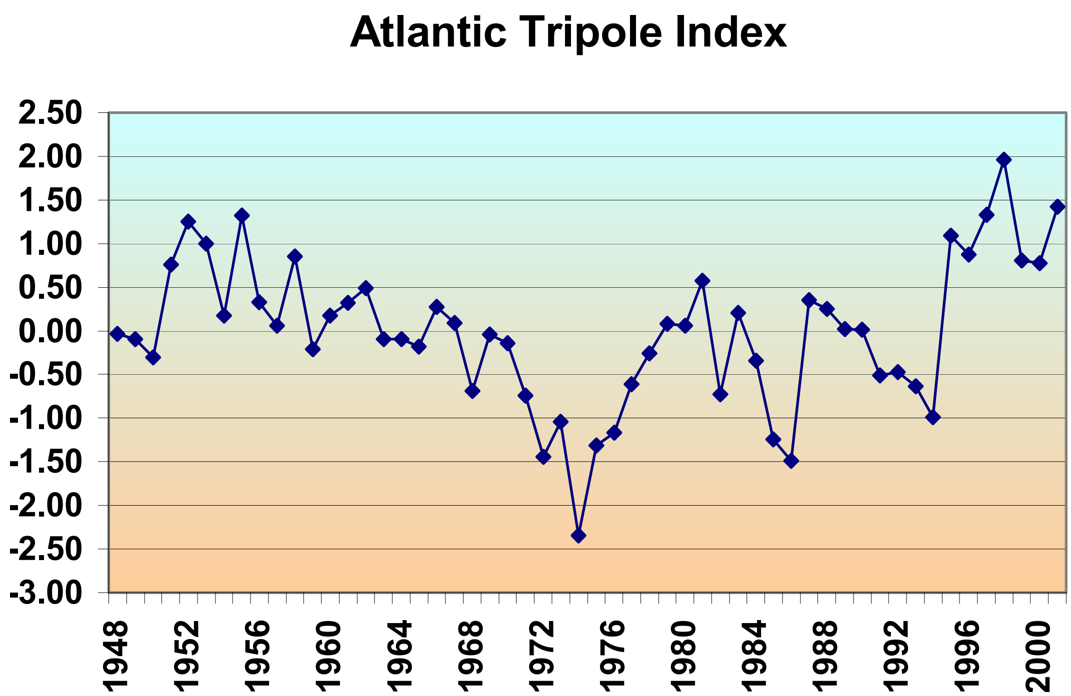
This three level arrangement of sea surface temperature anomaly pools in the Atlantic is called the Atlantic Tripole. Correlation maps from NCEP relating sea surface temperature anomalies with both the NAO and AO show this tripole.



Correlation of sea surface temperatures with the North Atlantic Oscillation. Note the tripole pattern with a negative (blue) correlation in the North Atlantic (off Canada and Greenland) and in tropics (Africa to the Caribbean) but a positive correlation in between (east coast of US to Europe). This means when waters are cold in the north and tropical areas and warmer than normal in between, the NAO tends to be positive. When waters are warmer than normal in the north and tropical areas and colder than normal in between, the NAO tends to be negative.



Similarly, correlation maps of seas surface temperature anomalies with the AO show this same tripole tendency.

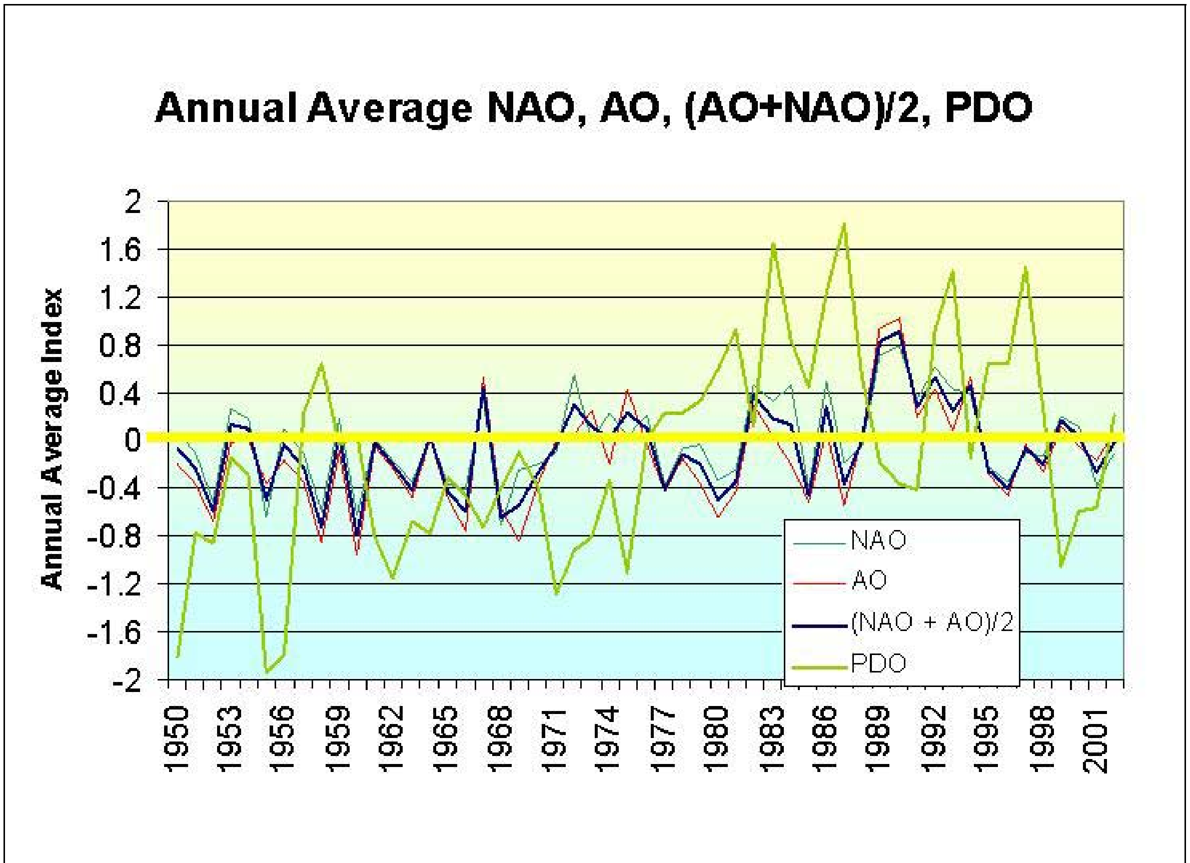


The Atlantic Tripole Index (CDC) shows the slow changing (decadal scale) of the ocean pools. Note the recent return to the state of the 1950s and 1960s.

In the late 1990s, ocean temperatures in the Atlantic returned to the state they were in the 1950s and 1960s. The AO and NAO indices have reverted to predominant neutral to negative states in response.

PDO, AO, NAO AND THE THERMOHALINE CIRCULATION

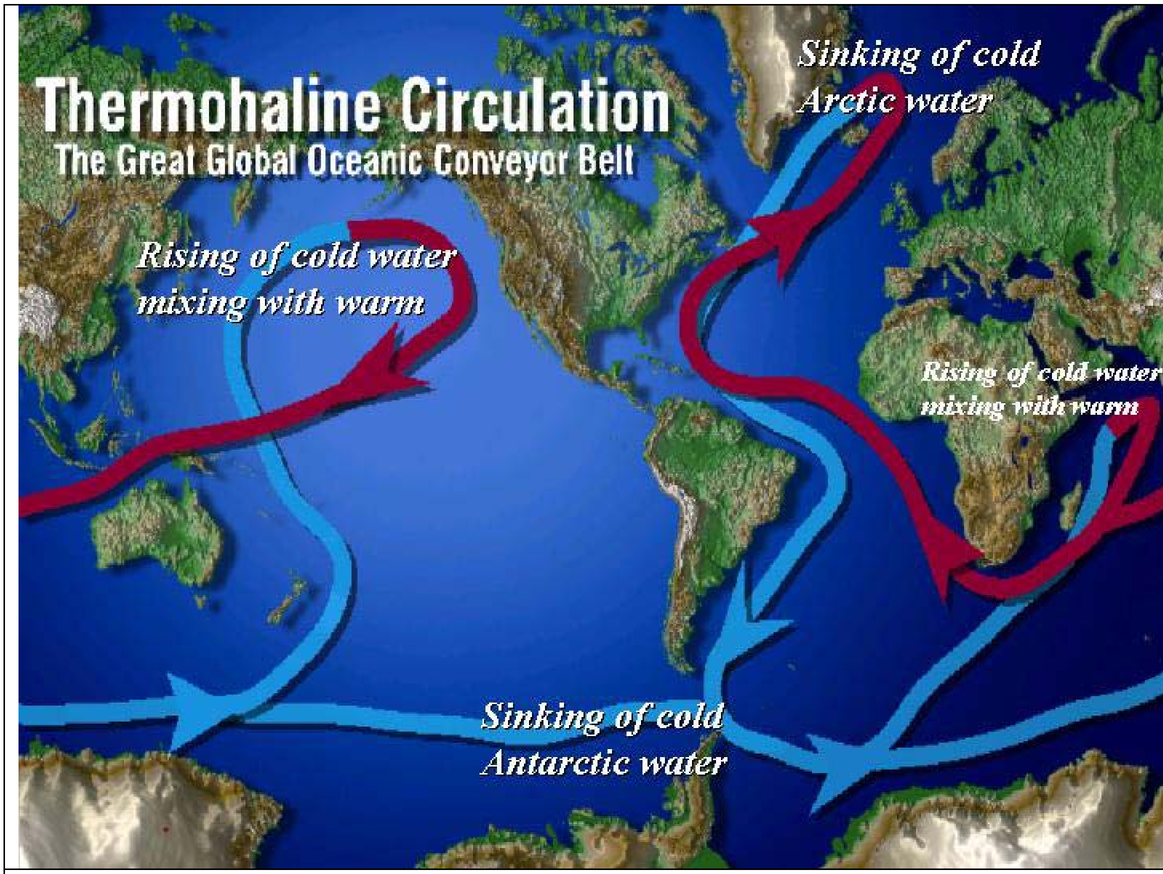
You may have noticed that these three ocean cycles tend to undergo cycles that were very similar in timing.



The NAO, AO and PDO cycles superimposed. Note the general tendency for these cycles to be negative during the 1950s and 1960s and positive during the 1980s and the early 1990s.

Could they be related? Well many oceanographers and climatologists including [Dr Bill Gray] believe these cycles are driven by changes in the large-scale global ocean conveyor belt known as the Thermohaline Circulation.

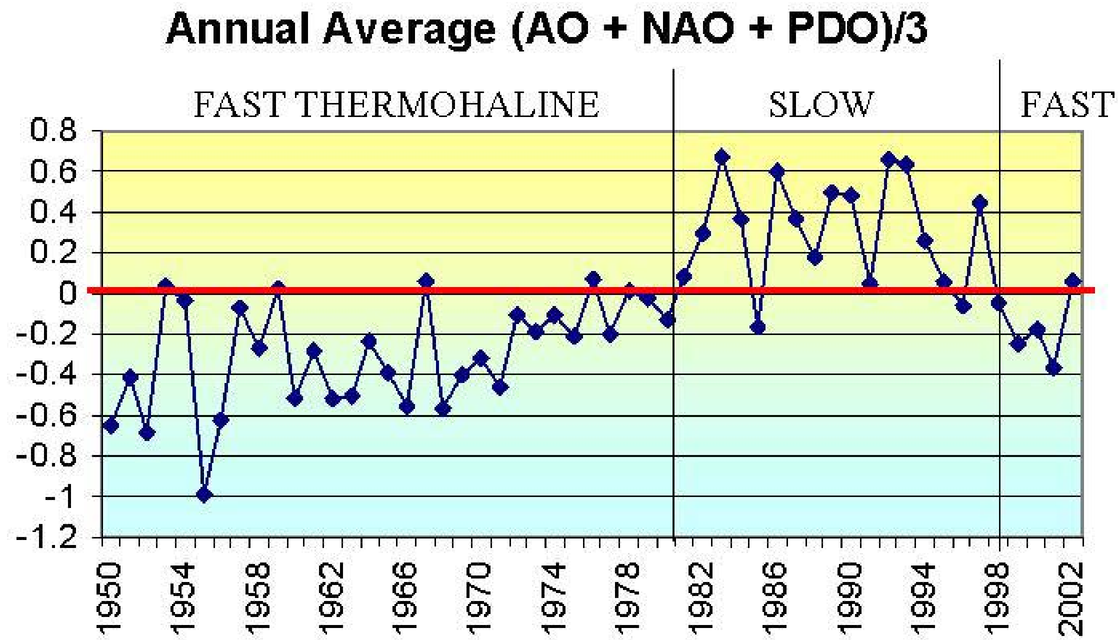
This thermohaline circulation is driven by differences in salinity and temperature in the ocean. Salty and colder water has a higher density and is more likely to sink than warmer fresher water. Water tends to sink near the Antarctic icecap where the freezing of the water leaves behind increased salt content in the surface water beneath the ice. In the North Atlantic, the water also tends to sink as the water cools, and the salinity tends to be higher as the planetary winds cause increased evaporation.



The Thermohaline Circulation is an integral component of the global ocean current system. The speed of the circulation changes on a decadal scale, which influences the tendency for warm and cool pools in key locations. This may be the driver for the PDO and AO/NAO decadal tendencies.

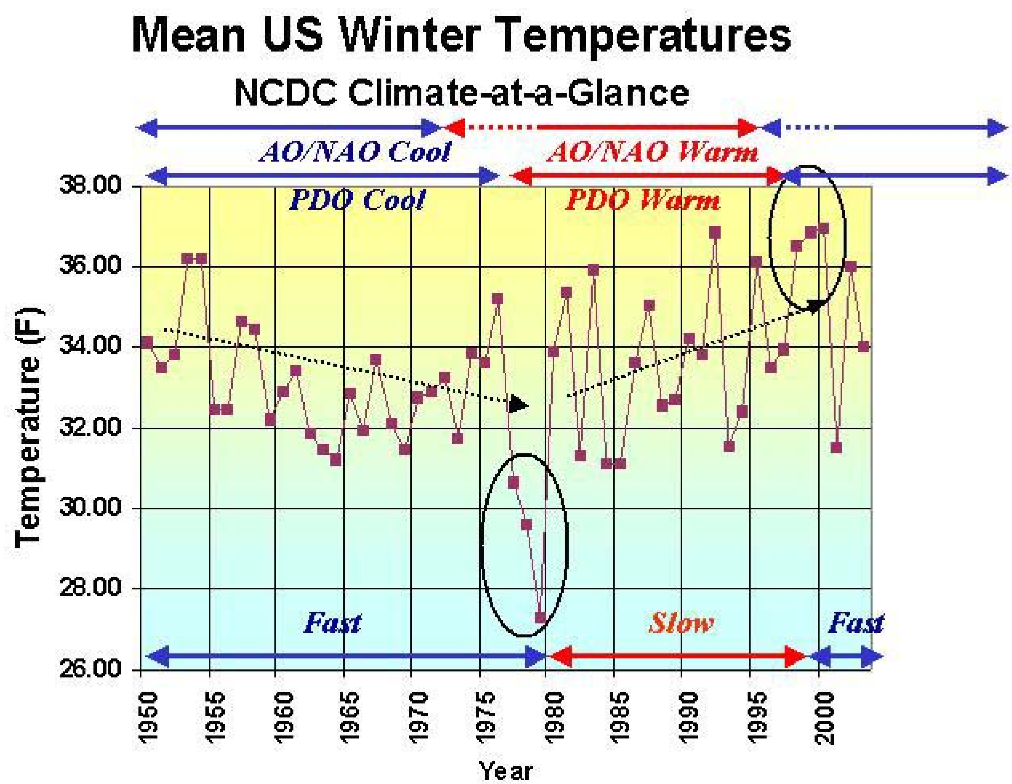
The Thermohaline circulation over times varies in the speed at which the conveyor belt flows. There were long periods when the conveyor belt was observed to accelerate (the 1950s and 1960s) and other periods when it is said to have slowed (1980s to 1990s). This matches the changes in the PDO, NAO and AO we have discussed. The connection is likely through the ocean temperature patterns that result from the circulation changes.

In the faster Thermohaline Circulation mode, warmer than normal water is favored in the Northwest Pacific and colder than normal in the eastern most Pacific including the tropics and warmer than normal water is also favored in the North and Tropical Atlantic with cooler water in between. These ocean temperature patterns favor the negative cool phases of the PDO, NAO, and AO. The opposite patterns occur when the circulation slows down.



The average of the AO, NAO and PDO may be a surrogate measure of the speed of the speed of the Thermohaline Circulation. The circulation appears to have increased during the period of the 1950s and 1960s, slowed during the 1980s and 1990s and increased again in the late 1990s. See *http://www.aoml.noaa.gov/phod/acvp/gray.htm*

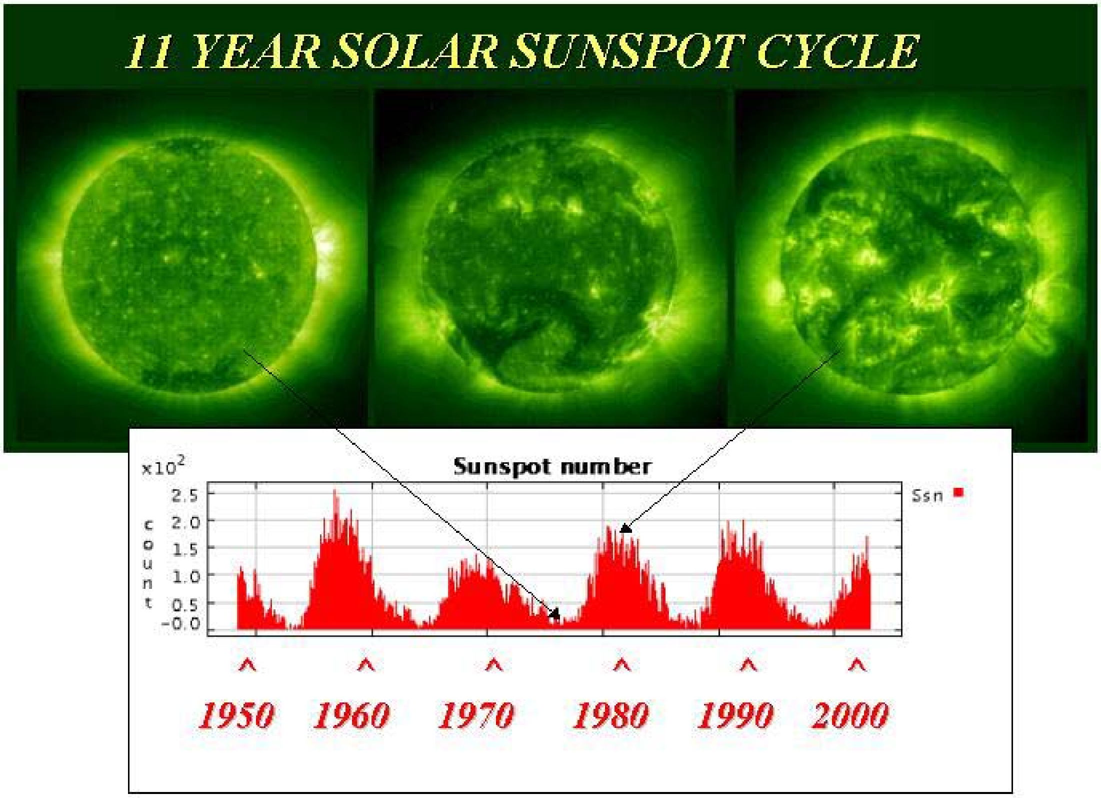
The changes in the circulation and the favored mode have an effect on temperatures and the effects tend to be cumulative over the favored periods.



Mean U.S. Winter Temperatures can be seen to vary with the Thermohaline Circulation and the induced phases of the PDO, AO and NAO. When the THC was fast and the PDO, AO and NAO were predominantly cold (negative), the mean winter temperatures declined with a grand finale in the late 1970s. When the THC slowed and the PDO, NAO and AO were predominantly warm (positive), the mean winter temperatures rose ending a grand finale in the late 1990s. The THC and PDO, AO and NAO have turned cold (negative) again in the last few years, perhaps signaling the start of a cooling leg.

THE SUN AS A FACTOR

The sun we know goes through an 11-year cycle of activity during which the sun goes from inactive (little or no sunspots and flares) to very active (numerous sunspots and flares). An active sun is a slightly brighter and hotter sun (0.22%) than a quiet one. The direct effect of this increased output is small. The changes though over the cycle induce other feedback effects that many now believe is much greater.

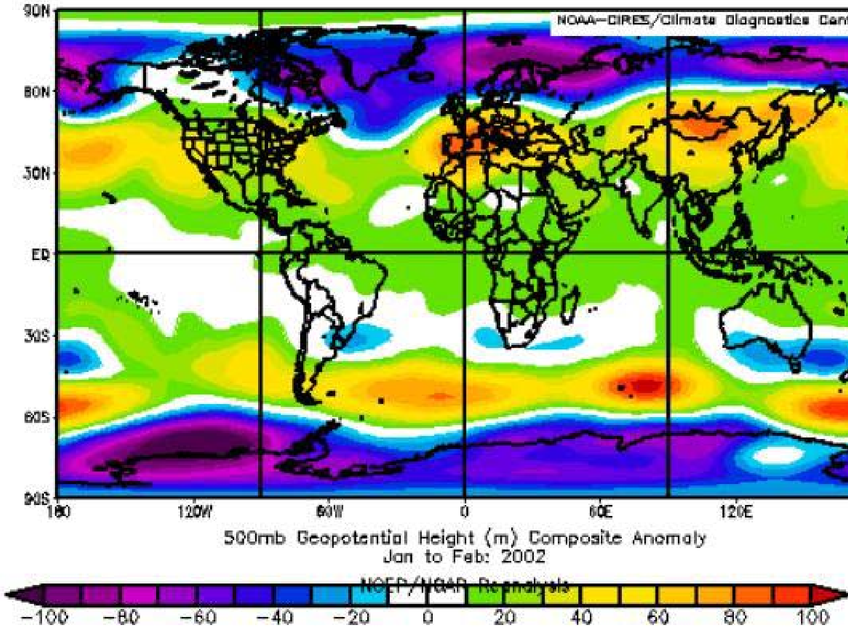


The 11-year solar cycle since 1950. Note the tendency for the sun to be active then quiet then active again with a period that averages about 11 years. .

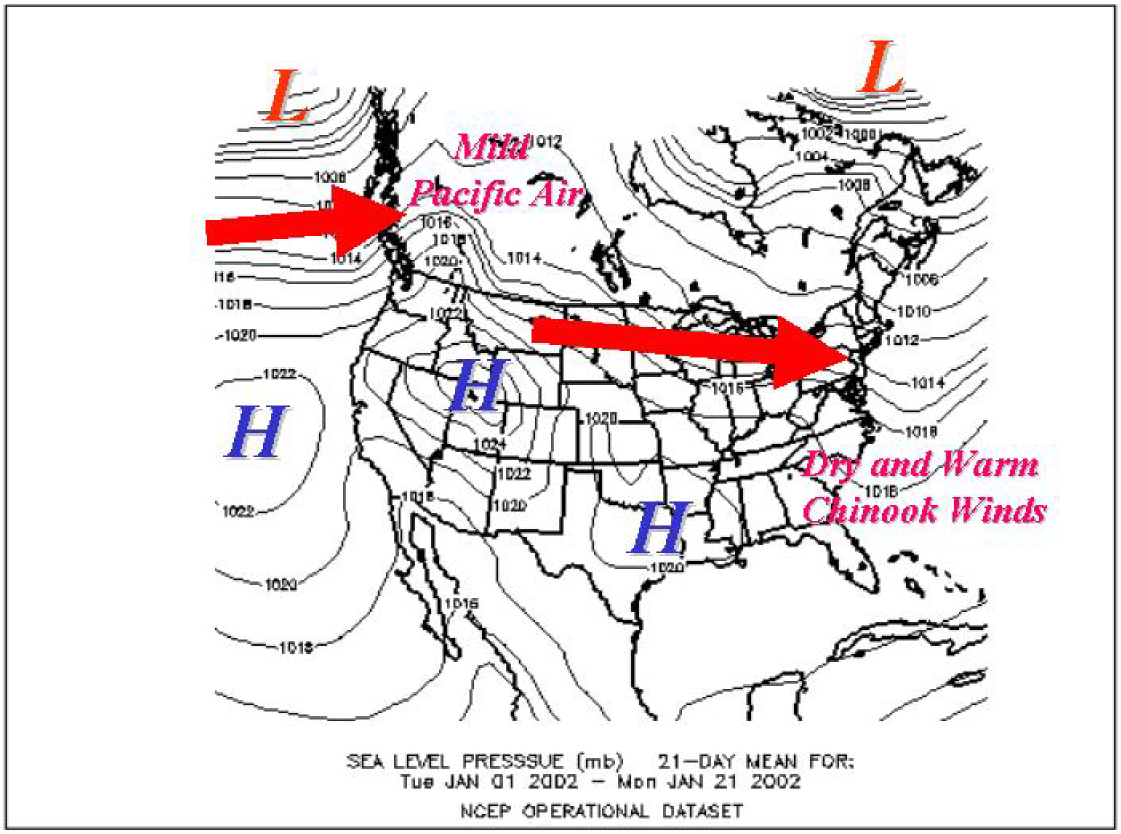
Drew Shindell, a climate researcher from NASA's Goddard Institute for Space Studies reported in a paper in (Science, 1999) that major climate changes occurred during the solar maximum relating to increases in high atmospheric ozone and subsequent warming.

"When we added the upper atmosphere's chemistry into our climate model, we found that during a solar maximum major climate changes occur in North America." The changes, according to Shindell, are caused by stronger westerly winds. Changes also occur in wind speeds and directions all over the Earth's surface.

This enhanced westerly flow was very evident during the winter of 2001/02 over North America. This resulted in a very "European Winter". Europe's climate is strongly influenced by the Atlantic and is relatively mild. In 2001/02 our climate was strongly influenced by the Pacific.



January to February 2002 500mb height anomalies (temperature anomalies are virtually the same). Note the cold air trapped in the polar regions and the warm air that dominated in the middle and lower latitudes thanks to the enhanced solar-induced zonal flow.



Mid winter pattern during the solar warmed winter of 2001/02. Note the polar low pressure and the large ocean-based highs helping to produce warm westerly winds that made it one of the warmest and driest winters in recent memory in the lower 48 states.

Increased Solar Flux Decreases Low Cloud Cover Leading to More Surface Warming

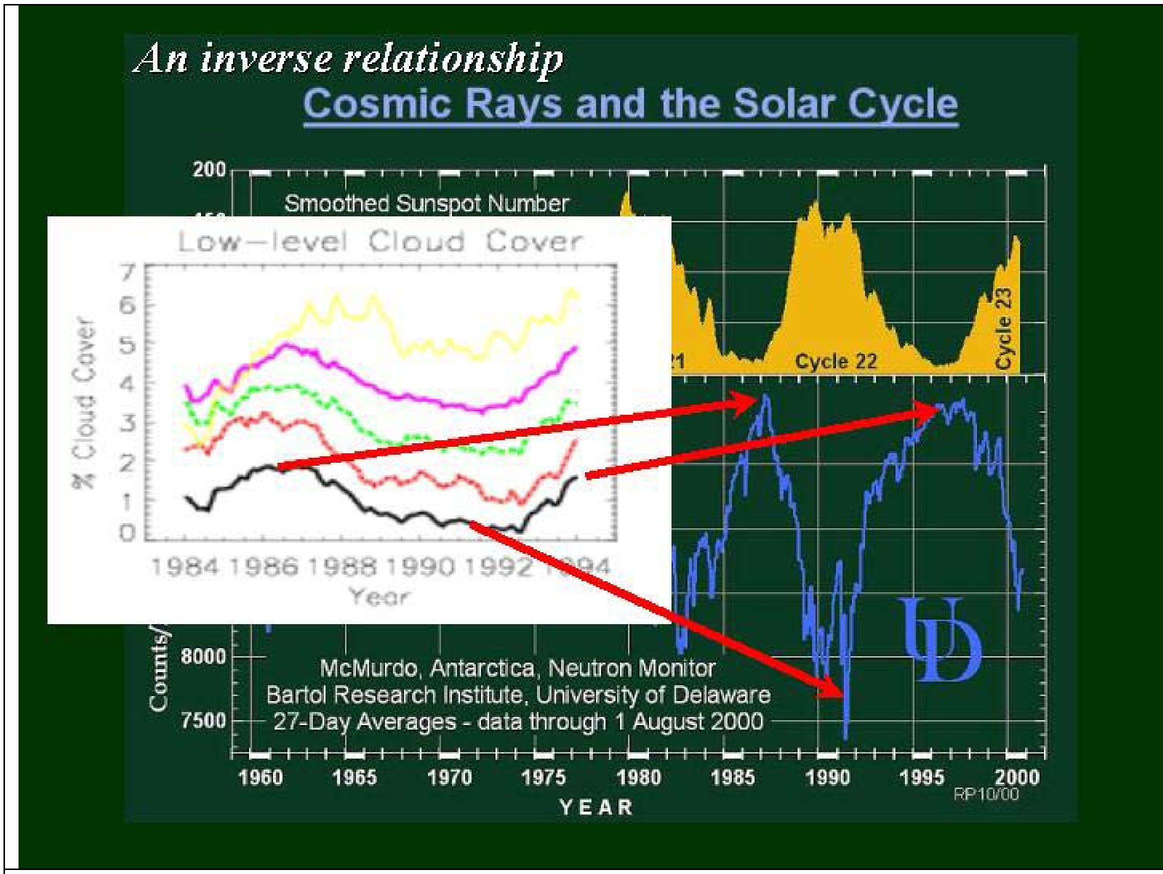
High solar flux also impacts the climate through the effect on clouds. This has been a hotly debated subject in the last few years in climate circles. In the landmark 1997 paper, *"Variations of Cosmic Ray Flux and Global Cloud Coverage: A Missing link in Solar-climate Relationships,"* Friis-Christensen and Svensmark of the Danish Meteorological Institute, showed an apparent inverse relationship of cloud cover (especially mid-latitude ocean areas) and the solar cycle. In other words, more clouds during quiet sun times and less during active sun years. They related it to the inverse relationship of cosmic rays to solar activity. These cosmic rays have a cloud enhancing effect by ionizing molecules, which can act as nuclei for water droplets. Their initial analysis showed a variation of 3 percent or so of cloud cover from the solar min to solar max (a decrease in cloud cover at the solar max as the number of cosmic rays and thus ionized molecules declined).

The cloud data used in the study was over a portion of an 11-year solar cycle (1984-1991). Some researchers looking at more recent data found the apparent relationship broke down after 1991, calling into question the original proposed connection.

However in a more recent paper *"The Influence of Cosmic Rays on Terrestrial Clouds and Global Warming"* (http://star.arm.ac.uk/~epb/paper1.html) appearing in the August 2000 issue of Astronomy and Geophysics, Armaugh Observatory scientists Bago and Butler used the new NASA Langley D2 cloud data established by the ISCCP (International Satellite Cloud Climatology Project) to show that the cloud- solar cycle relationship is real. They found some surprising new results (a good read for those interested in this possible solar connection and global warming!).

In their paper, they found that although the data confirmed the breakdown of the relationships with total cloud coverage after 1991, *a strong correlation remained for low clouds (below 3.2 km)*. They found *the low cloud correlation to be widespread across the globe including the tropics, mid-latitudes and the oceans,* but little change in low clouds was observed in Polar Regions.

There were two surprises. One, it had been assumed in prior studies that the enhancing effect of cosmic rays on clouds would be greater for higher clouds because that is the part of the atmosphere where the cosmic rays are most effective at ionizing molecules. In their study, Bago and Butler found that the low clouds responded to solar changes best. They varied 1 to 1.5% over the solar cycle (least at the max, most at the min). In their study they also found that the enhancement was strongest for water droplet clouds, which explained why there was little change observed in higher clouds and in the low cloud cover over the Polar Regions. In both cases, the clouds were usually composed of ice and not water droplets.

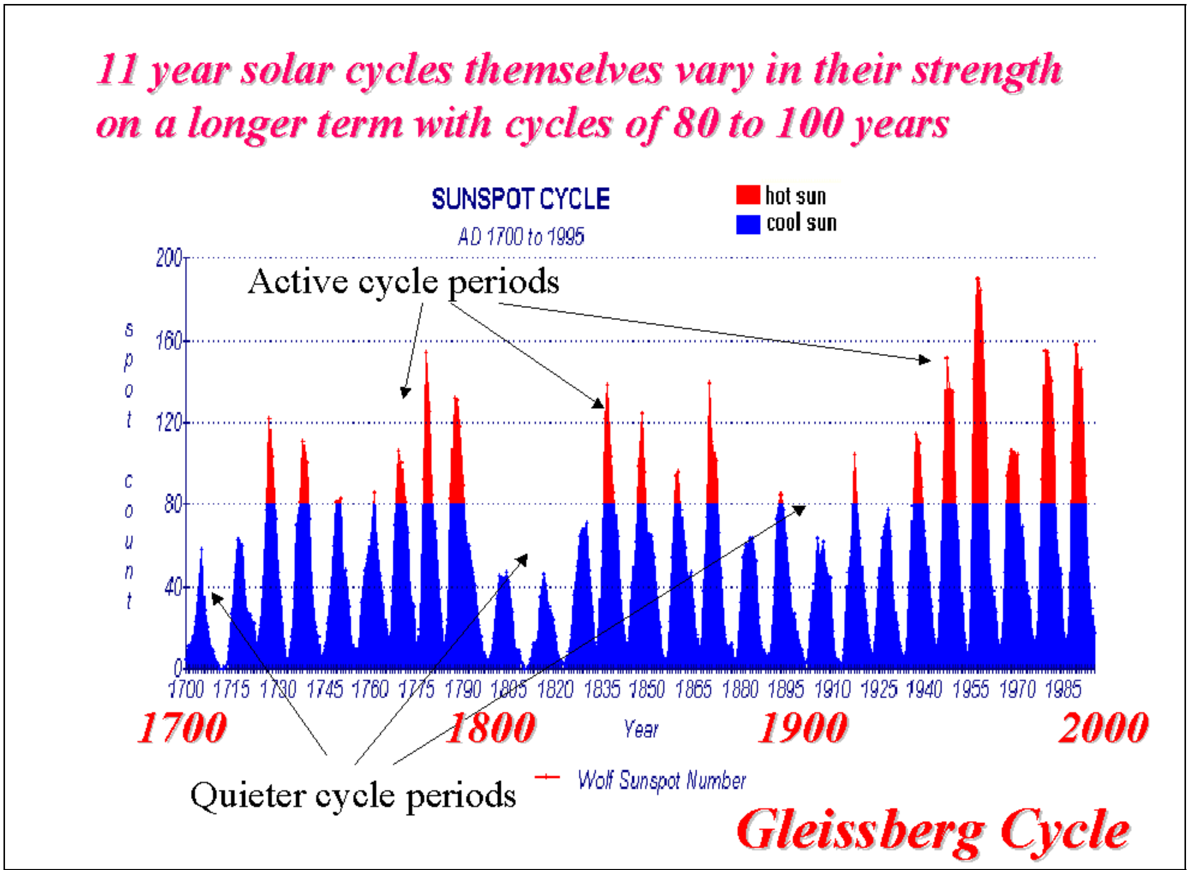


Bago and Butler cloud analysis (colors representing different global belts) compared to the solar cycle induced variations in the cosmic rays reaching the atmosphere. Note the tendency for reduced cosmic rays and fewer low clouds during the solar max years and enhanced cosmic rays with more low cloudiness during the quiet sun phase.

Clouds vary in their effect on surface temperatures. Although clear skies maximize nighttime cooling, extensive low clouds reduce daytime warming. Low clouds tend to produce a net cooling. High clouds enable some radiation through but tend to block the escape of heat given off by the earth, thus producing a net warming. Less low cloudiness means warmer temperatures.

The active sun effect on climate is relatively short-lived. The way the sun may play a role in longer-term climate change is through variations in the 11-year solar cycles - solar cycles are not all the same. Some cycles are much more active (and shorter in length), others are quieter (and linger longer). These quiet or active cycles cluster in what appear to be cycles of 80 to 100 years. It may be that when a number of active (warmer sun) cycles are strung together, a cumulative effect occurs. Slightly higher solar output and less cloudiness perhaps may lead to a global warming during the active periods. And when quiet (cool) sun cycles cluster for several decades, slightly lower solar output and more cloudiness may cause global temperatures to respond increasingly downward.

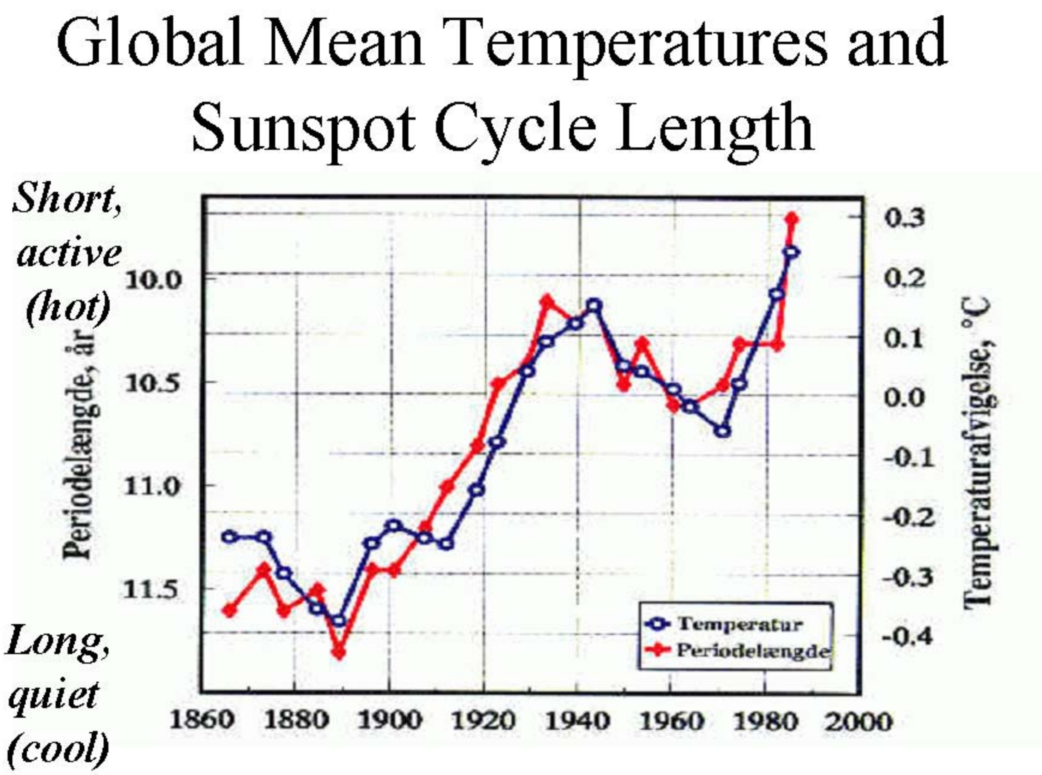
The sun was quiet for many successive cycles in the 1600s and early 1700s, in the early 1800s, and again just before 1900. Each period was marked by a turn to colder global temperatures. The long stretch of very quiet sun cycles called the Maunder Minimum from the 1600s into the early 1700s was referred to as "The Little Ice Age".



The solar cycles since 1700. Note the 11-year cycles are not all equal. At times the maximums are very large at other times, much less so. Periods with active cycles are warmer and those with quieter, longer cycles are colder.

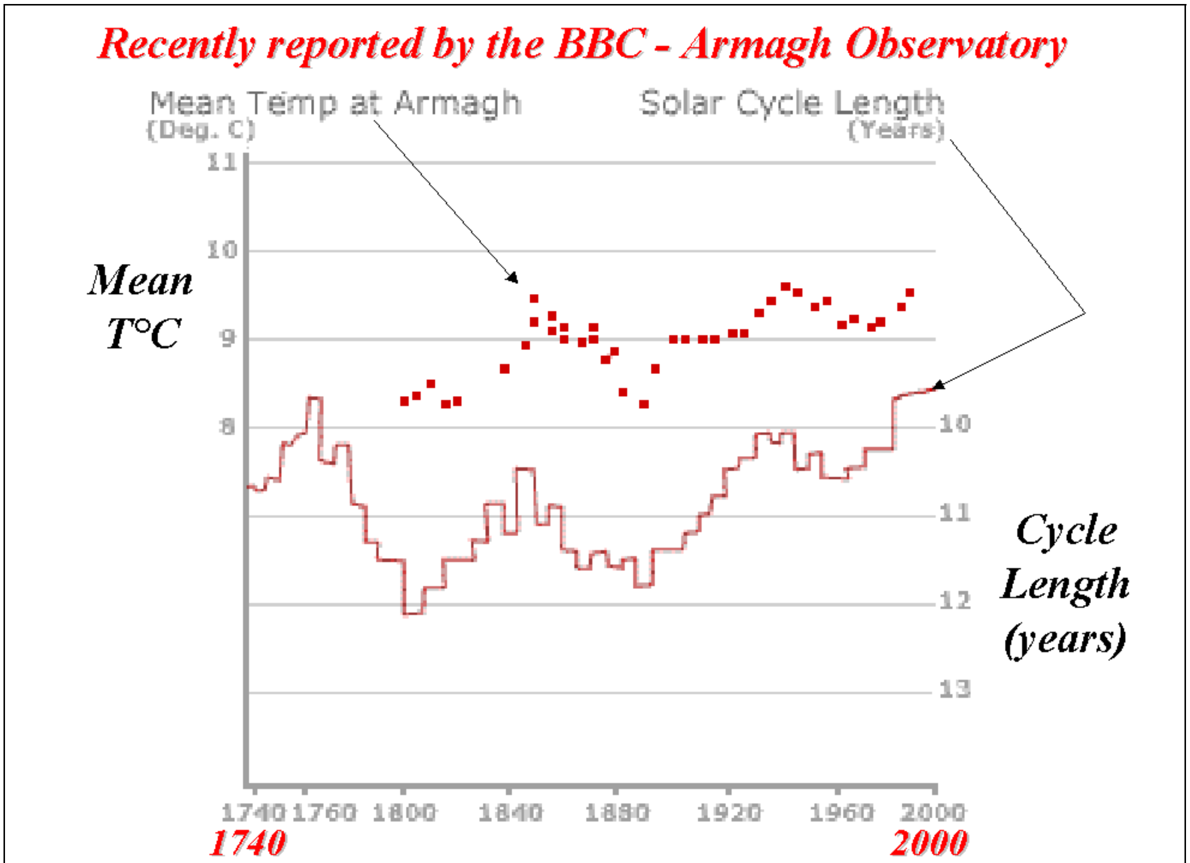
On the other hand during stretches of an active sun in the middle years of the 18th, 19th and 20th centuries the globe experienced warmer temperatures.

Global temperatures have been shown to change in virtual lock step with the length and strength of these solar cycles going back at least 200 years (Svensmark).



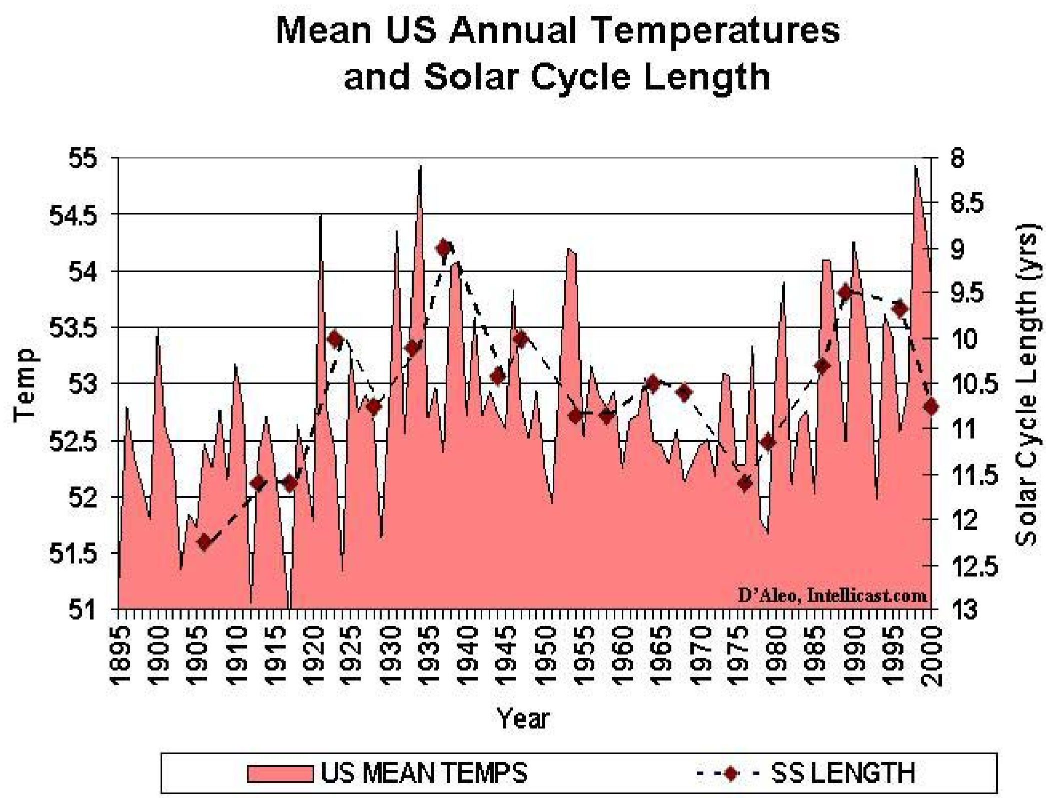
Danish Meteorological Institute correlation of solar cycle length (strength) with global temperatures. Temperatures changed in virtual lock step with solar cycle length and strength over the past 140 years.

Researchers at the Armaugh Observatory in the UK showed a similar result with their long-term temperature database.



Armaugh Observatory data showed a similar lock-step agreement of temperatures with long-term solar cycle behavior.
http://news.bbc.co.uk/hi/english/sci/tech/newsid_1045000/1045327.stm

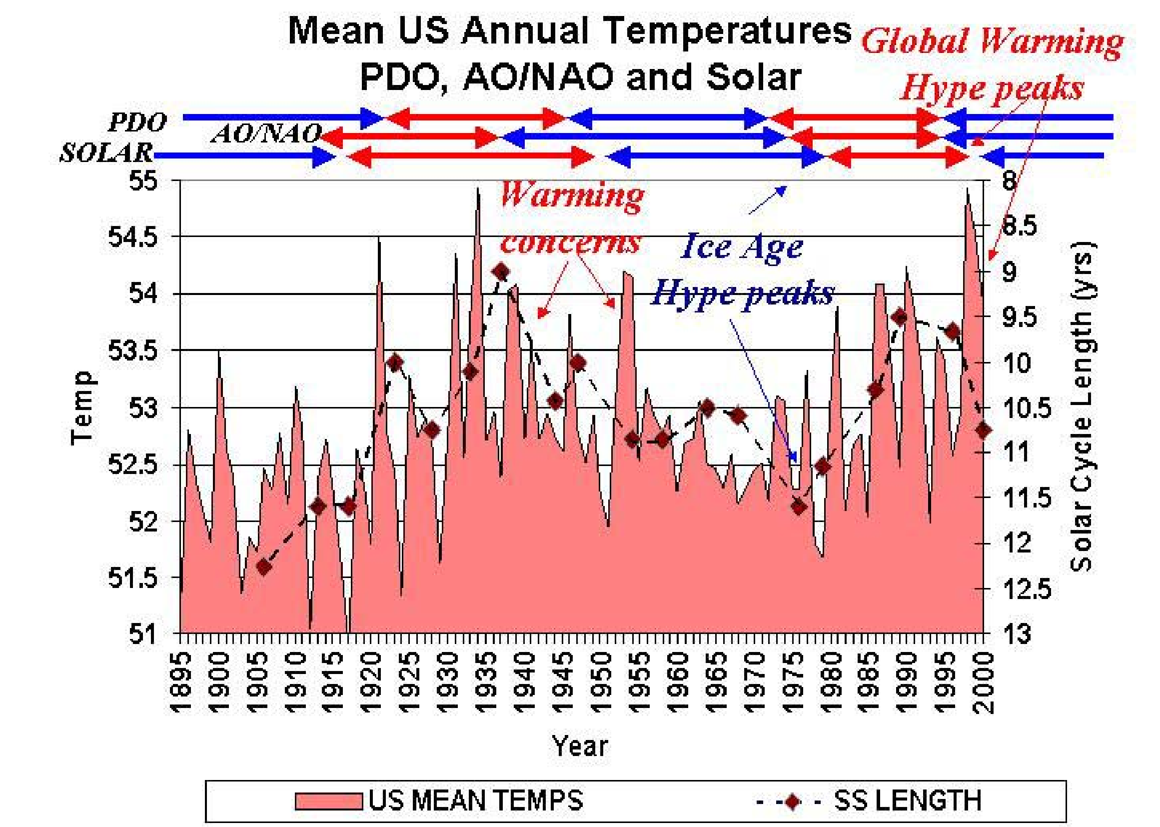
I also plotted the annual mean U.S. annual temperatures with the solar cycle lengths (max to max and min to min). It also seemed to follow the solar changes closely.



Mean annual temperatures (light rose) with plots (purple dots showing solar cycle length (max-to-max and min-to-min). Note the tendency for warming temperatures during eras when solar cycles are more active and shorter in length

Summary

Temperatures over the United States when adjusted for urban factors show little net change over the past 70 years. A decadal scale cycle is however evident in the data. Multi decadal scale changes in the ocean (possibly related to changes in the speed of the Thermohaline Circulation) and on the sun may play a key role in producing these decadal scale changes in temperatures. When they combined in modes that favored cooling in the 1950s into the 1960s, temperatures declined. When they combined in modes favoring warming as they did in the 1920s into the 1930s and again in the 1980s into the 1990s, temperatures rose.



The ocean oscillations (PDO, NAO and AO positive are shown warm and negative cool) and solar factors (solar cycle length greater than 10.5 years shown cool, less than 10.5 years warm) compared with U.S. Mean Annual temperature. When the factors all align warm or cool, temperatures trend up or down.

Finally and importantly, it should be noted that the factors appear to have recently changed to modes favoring a cooling. If so, the recent winters of 2000/01 (coldest ever November and December for the United States) and 2002/03 (one of the coldest in the eastern states in many decades) could be sign of things to come.

References:

Bago, E.P., Bulter, C.J, Influence of Cosmic Rays on Terrestrial Clouds and Global Warming, Astronomy & Geophysics, August 2000. Vol 41, Issue 4, pp 18-22.

Broecker, W. S. 1991. The Great Ocean Conveyor. Oceanography, 4: pp.79-89

Deser, Clara, Michael S. Timlin, 1997: Atmosphere-Ocean Interaction on Weekly Timescales in the North Atlantic and Pacific. Journal of Climate: Vol. 10, No. 3, pp.393-408

Ellsaesser, H.W., M.C. MacCracken, J.J. Walton, and S.L. Grotch.
1986. Global climatic trends as revealed by the recorded data. Reviews

of Geophysics 24(4):745-792

Gray, W., Role of the Ocean Conveyor Belt as a Cause of Global Multidecadal Climate, *http://www.aoml.noaa.gov/phod/acvp/gray.htm*

Karl, T.R., Urbanization: Its Detection and Effect in the United States Climate Record", 1988, Journal of Climate 1: pp.1099-1123.

Mantua, N.J. and S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis 1997: A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society, 78, pp. 1069-1079.

Shindell, D., D. Rind, N. Balachandran, J. Lean, AND P. Lonergan 1999. Solar cycle variability, ozone, and climate. *Science* **284**, 305-308.

Svensmark H., "Influence of Cosmic Rays on Earth's Climate", Physical Review Letters, v.81, no.22, p.5027, 30 Nov 1998

Svensmark, H., and Friis-Christensen, E., 1997. Variation of cosmic ray flux and global cloud coverage - a missing link in solar-climate relationships, *J. Atmos. & Solar-Terr. Phys.*, 59, 1225-1232