ARCTIC CLIMATE CHANGES

ISSUE SUMMARY

These comments also address issues in the April 17, 2009 **Technical Support Document (TSD)** that includes many of the detailed references to science, data, and models used to justify comments in the Endangerment Finding.

EPA's responsibility under the Federal Information Quality Act (IQA) was to review the source documentation and data to make an independent judgment about the science and the data and also the comments made to both the CCSP and ANPR. As is shown below, the Administrator relied on a superficial and erroneous review of summaries and conclusions of other "studies" rather than conducting a thorough evaluation of the relevant science and data. This is a pervasive fatal flaw in the Endangerment Finding and the Technical Support Document. EPA's reliance on "studies" that fail to meet the requirements of the IQA invalidates the Endangerment Finding.

ISSUE SUMMARY

The EPA accepts the notion the arctic ice will continue to melt although it is rapid recovery mode the last two years for the same natural cycle reasons for is recent decline.

TSD ES4
Sea ice extent is projected to shrink in the Arctic under all IPCC emission scenarios.

COMMENTS:

The described changes in the Arctic are not at all unprecedented nor are they are described. Many peer review papers support interaction with the Atlantic and Pacific and other factors not greenhouse warming are the real drivers.

Changes to temperature and ice happen predictably every 60 years or so and is in fact entirely natural, related to multidecadal ocean cycles and possibly recently accentuated by major undersea volcanism and the invasion of tundra shrubs and deposition of soot from Asia.

Records of arctic ice cover extent start in 1979. Multidecadal cyclical warming was observed before in the 1800s and middle 1900s long before the industrial revolution. Also there is more recent evidence showing the idea of lubrication by melt water accelerating loss of glacial or icecap ice is not valid.

THE OCEAN MULTIDECADAL CYCLES

The natural multidecadal cycles in the Pacific (called the Pacific Decadal Oscillation or PDO) and Atlantic (called the Atlantic Multidecadal Oscillation or AMO) correlate strongly with temperatures over Greenland and the arctic.

In early May 2008, a paper appeared in Nature (Keenlyside) showing how by including long term ocean cycles in models the recent global cooling or at least lack of warming may continue to 2020. The same week, a story by NASA's Earth Observatory reported on the flip of the Pacific Decadal Oscillation to its cool mode. "This multi-year Pacific Decadal Oscillation 'cool' trend can intensify La Niña or diminish El Niño impacts around the Pacific basin," said Bill Patzert, an oceanographer and climatologist at NASA's Jet Propulsion Laboratory, Pasadena, Calif. "The persistence of this large-scale pattern tells us there is much more than an isolated La Niña occurring in the Pacific Ocean."

THE ARCTIC

Warming in the arctic has 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 Pacific through the Bering Straits and the far North Atlantic and the Norwegian Current.

Hartmann et al., 2005 showed how the rapid Great Pacific Climate Shift that was the change of the PDO from cold to warm in 1977 produced stepladder discontinuities in Alaskan temperatures.

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 3.

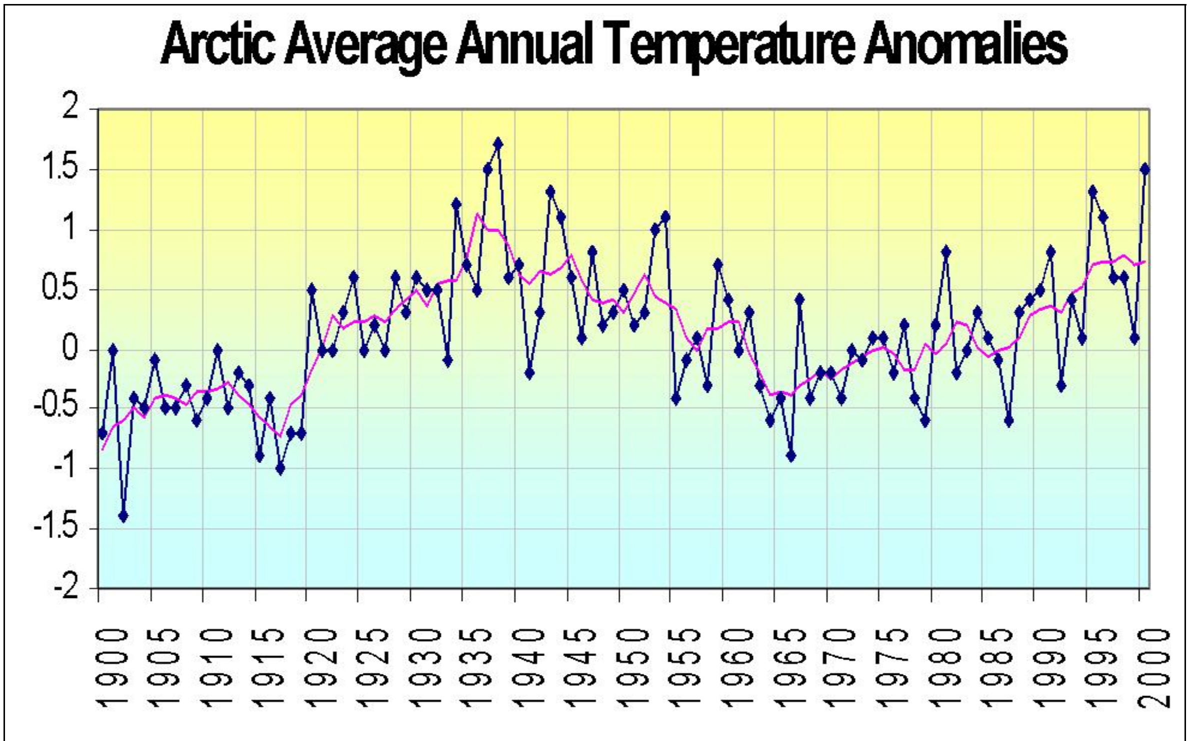


Figure 3: Arctic Basin wide temperatures (Polyakov 2003)

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."*

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

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.

THE IMPORTANCE OF THE ATLANTIC

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. 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 as we reported on in the last post here.

As noted in the AR4, 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).

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 year. 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.

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 4).

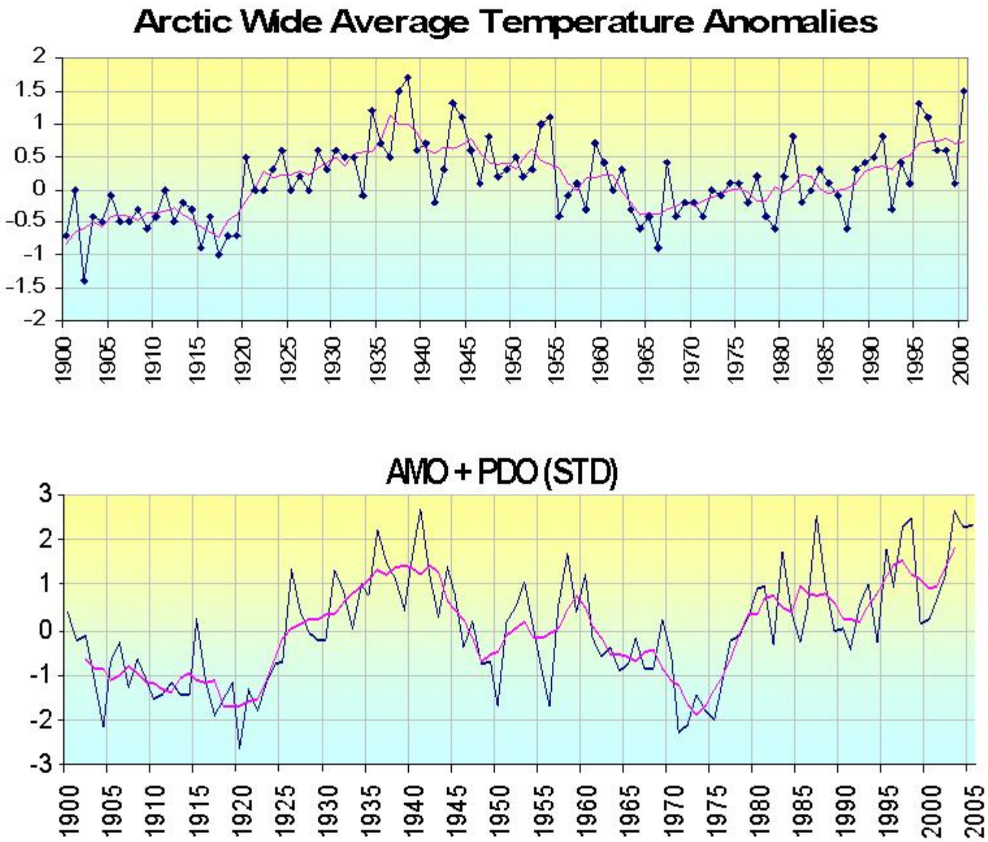


Figure 4: Arctic basin wide temperatures from Polyakov (2003) versus PDO+AMO (STD). Dark blue is annual and purple 5 year running means.

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 CO_2 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 CO_2 in the atmosphere."

Drinkwater (2006) 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.

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."

An excellent paper by Chylek et al.(2009) documents the major role of regional atmospheric/ocean circulation pattern changes on regional multi-decadal climate variability. This paper supports the finding that long term variations in atmospheric/ocean circulations (such as the Atlantic Multidecadal Oscillation, the Pacific Decadal Oscillation, ENSO, etc) cause regional changes in temperatures over this time period, and that these changes have a significant natural cause. The abstract reads:

"Understanding Arctic temperature variability is essential for assessing possible future melting of the Greenland ice sheet, Arctic sea ice and Arctic permafrost. Temperature trend reversals in 1940 and 1970 separate two Arctic warming periods (1910-1940 and 1970-2008) by a significant 1940-1970 cooling period. Analyzing temperature records of the Arctic meteorological stations we find that (a) the Arctic amplification (ratio of the Arctic to global temperature trends) is not a constant but varies in time on a multi-decadal time scale, (b) the Arctic warming from 1910-1940 proceeded at a significantly faster rate than the current 1970-2008 warming, and (c) the Arctic temperature changes are highly correlated with the Atlantic Multi-decadal Oscillation (AMO) suggesting the Atlantic Ocean thermohaline circulation is linked to the Arctic temperature variability on a multi decadal time scale."

Text in this paper includes: "In the following analysis we confirm that the Arctic has indeed warmed during the 1970-2008 period by a factor of two to three faster than the global mean in agreement with model predictions but the reasons may not be entirely anthropogenic. We find that the ratio of the Arctic to global temperature change was much larger during the years 1910-1970." "We consequently propose that the AMO is a major factor affecting inter-decadal variations of Arctic temperature and explaining [the] high value of the Arctic to global temperature trend ratio during the cooling period of 1940-1970."

"Our analysis suggests that the ratio of the Arctic to global temperature change varies on [a] multi-decadal time scale. The commonly held assumption of a factor of 2-3 for the Arctic amplification has been valid only for the current warming period 1970-2008. The Arctic region did warm considerably faster during the 1910-1940 warming compared to the current 1970-2008 warming rate. During the cooling from 1940-1970 the Arctic amplification was extremely high, between 9 and 13. The Atlantic Ocean thermohaline circulation multi-decadal variability is suggested as a major cause of Arctic temperature variation. Further analyses of long coupled model runs will be critical to resolve the influence of the ocean thermohaline circulation and other natural climate variations on Arctic climate and to determine whether natural climate variability will make the Arctic more or less vulnerable to anthropogenic global warming."

THE EFFECT ON ICE COVER

Both the Atlantic and Pacific play roles in arctic ice extent. Trenberth in 1994 talked about the warming of the western arctic following El Ninos by warming of the waters from the North Pacific. Joyce et al. also found decadal scale major shifts in hydrological variability in the North Pacific that related to the PDO.

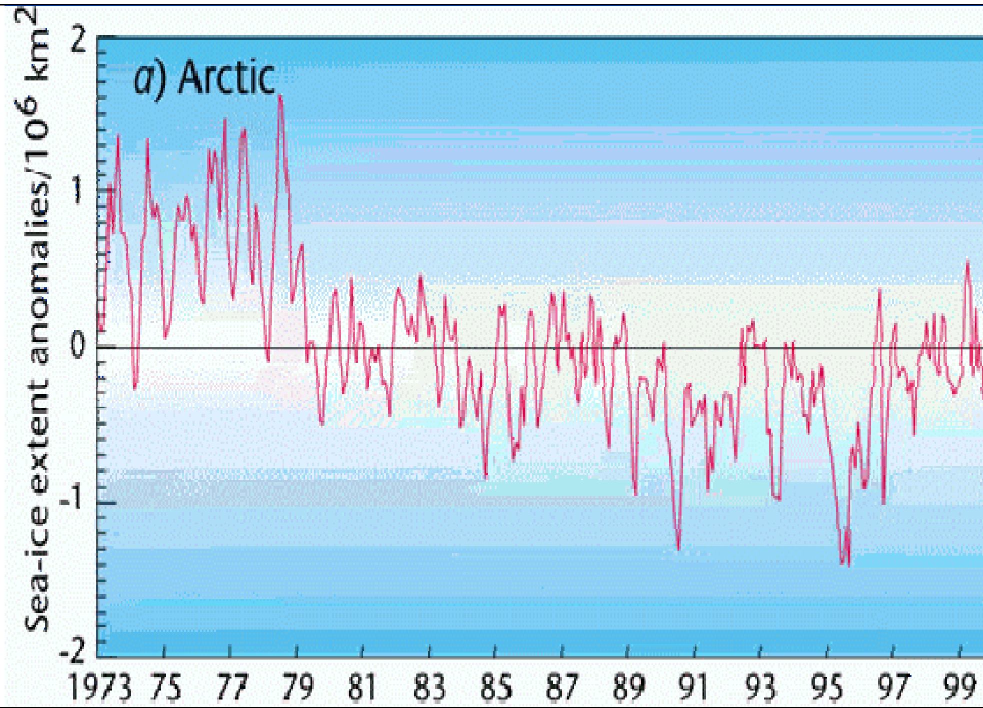


Figure 5: USGCRP Arctic sea ice extent (2000)

The sea ice extent diminished following the Great Pacific Climate Shift (flip of the PDO to positive) in the late 1970s (figure 5). It stayed relatively stable until the last few years when a more precipitous decline began (figure 6), related to a spike in North Atlantic warmth and a positive AO. That dropoff peaked in 2007.

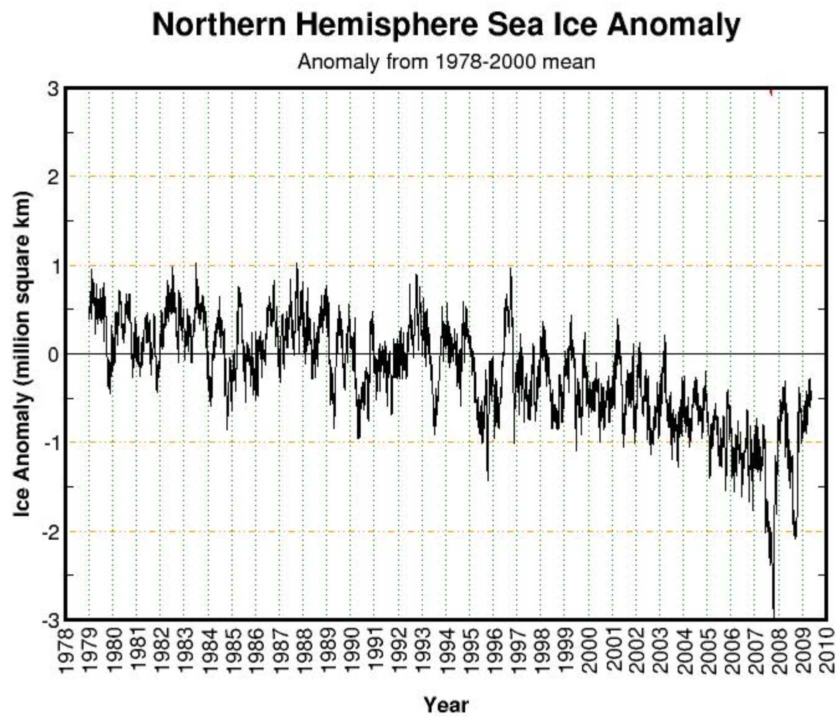


Figure 6: Northern Hemispheric Sea Ice Anomaly (UIUC Cryosphere)

Polyokov et al.(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."*

Rutger's Jennifer Frances (GRL) in 2007 showed how the warming in the arctic and the enhanced ice melting was in part the result of warm water (+3C) in the Barents Sea in the far North Atlantic moving into the Siberian arctic. The positive feedback of changed "albedo" or reflectivity due to open water then acts to enhance the warming.

We can see in figure 7 how the Atlantic warmth peaked in 2004 and 2005 several years ahead of the major decline. Cooling since suggests the ice may slowly recover year to year.

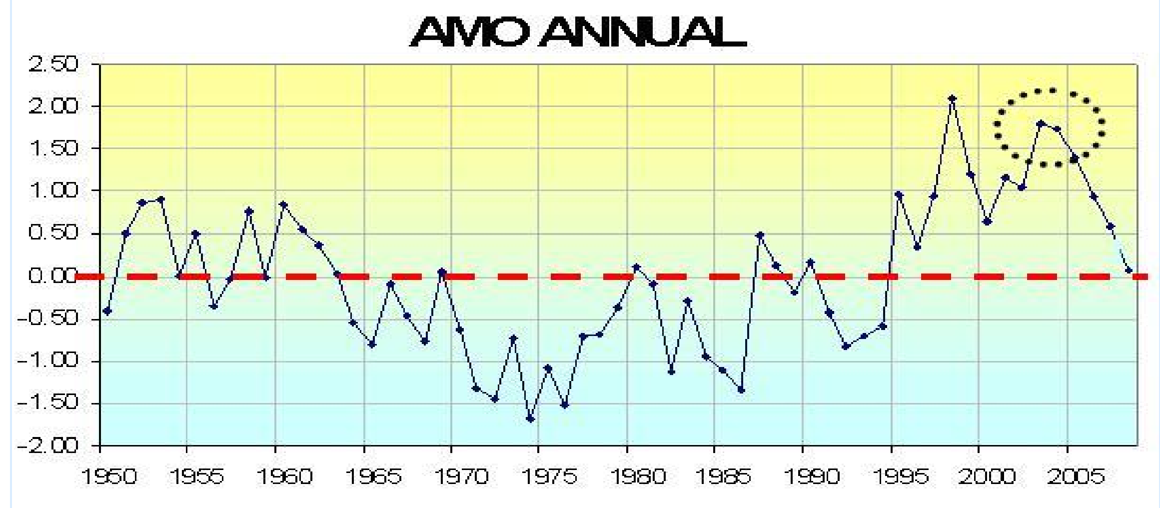


Figure 7: Annual Average AMO. Note the peaking of the AMO warming phase in 2004 and 2005 two years before the maximum ice melt in the arctic in line with the findings by Polyakov and Frances.

The University of Colorado's National Snow and Ice Data Center (NSIDC) summarized the role of the ocean cycles very well in October 2007 in this way:

> *"One prominent researcher, Igor Polyakov at the University of Fairbanks, Alaska, points out that pulses of unusually warm water have been entering the Arctic Ocean from the Atlantic, which several years later are seen in the ocean north of Siberia. These pulses of water are helping to heat the upper Arctic Ocean, contributing to summer ice melt and helping to reduce winter ice growth.*
>
> *Another scientist, Koji Shimada of the Japan Agency for Marine–Earth Science and Technology, reports evidence of changes in ocean circulation in the Pacific side of the Arctic Ocean. Through a complex interaction with declining sea ice, warm water entering the Arctic Ocean through Bering Strait in summer is being shunted from the Alaskan coast into the Arctic Ocean, where it fosters further ice loss.*
>
> *Many questions still remain to be answered, but these changes in ocean circulation may be important keys for understanding the observed loss of Arctic sea ice."*

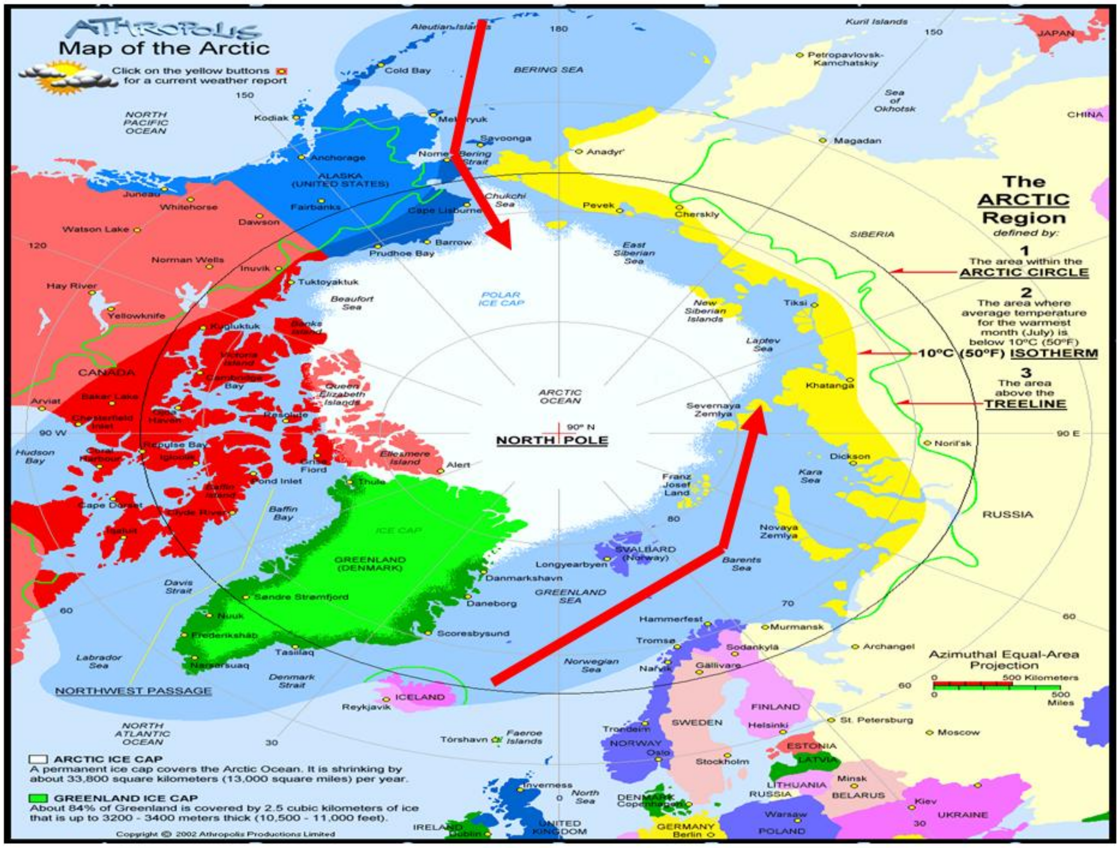


Figure 8: Pathways from ocean induced arctic warming as identified by Trenberth, JAMSTEC, NSIDC, Polyakov and Frances

The arctic temperatures plotted against the sum of the PDO and AMO shows the correlation. The Total Solar Irradiance (TSI) when added shows the same relationship.

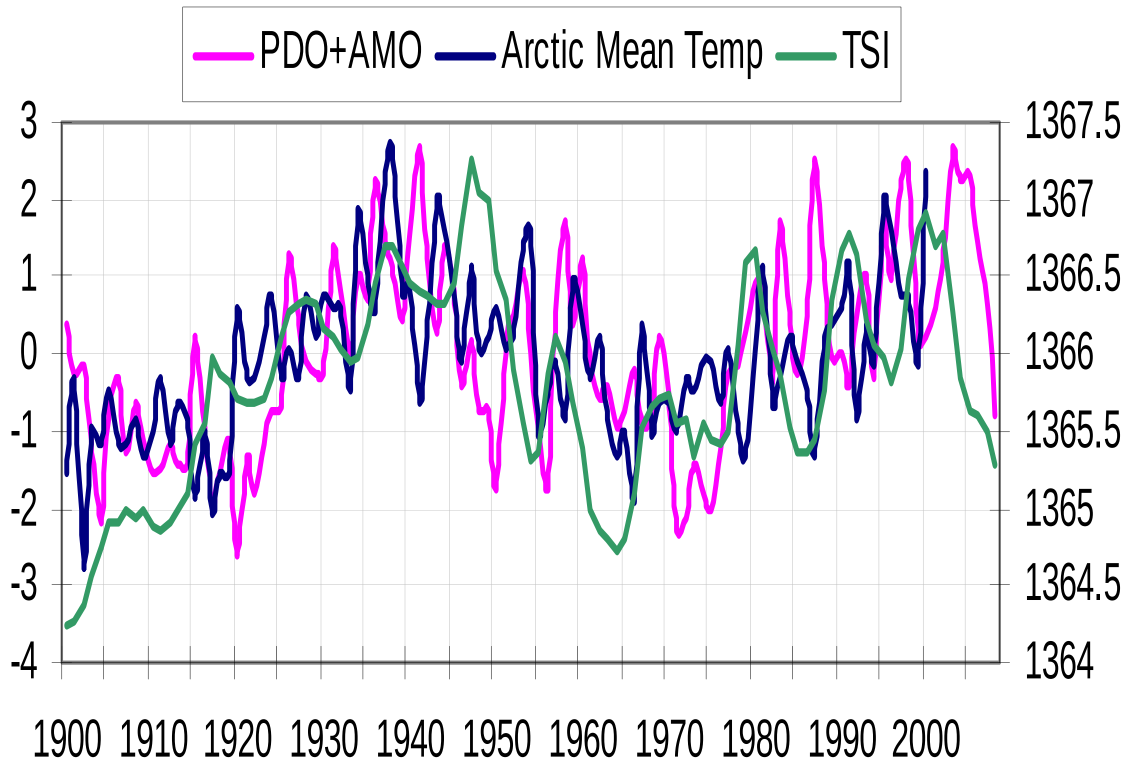


Figure 9: Plots of PDO and AMO and Total Solar Irradiance (TSI) (Hoyt and Scahatten retuned to ACRIM base) compared to arctic mean temperature. CO2 rose steadily during this entire period while the temperatures oscillated.

This was also clearly shown by Soon in 2005. It appears plausible the sun works through the oceans in accomplishing these polar changes in temperatures and ice. Cover

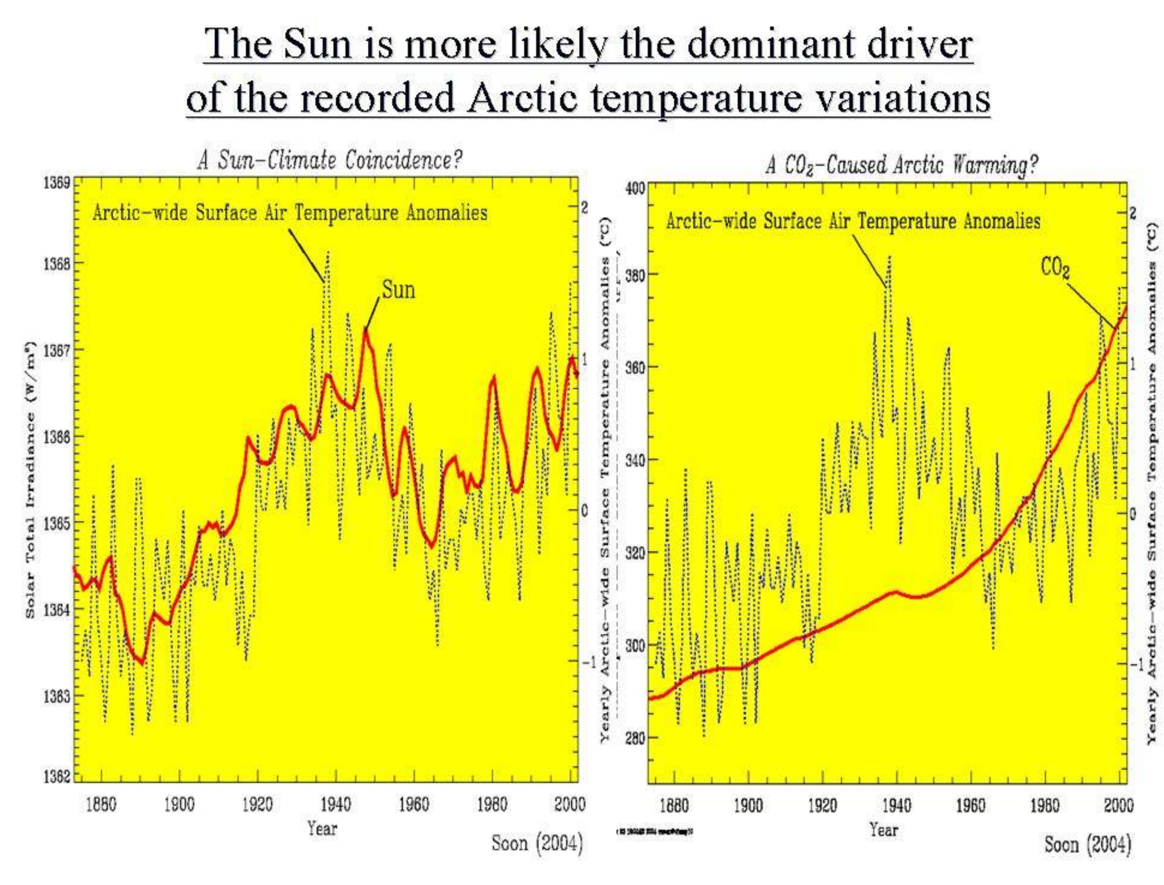


Figure 10: Soon (2005) plot of Polyakov (2003) arctic temperatures versus TSI (Hoyt and Schatten)

The Northwest Passage can be seen in this animation since 1979 is not uncommon, occurring briefly in many seasons during the late summer extent minima. This movie created by Climate Central shows the complete 30 year history of the NSIDC satellite derived arctic sea ice extent in a single video. Brown is land, black is shoreline, blue is water except for the large blue dot in the center of the plot. The movie plays double speed at the beginning because the early satellite collected data every other day.

UNDERSEA VOLCANIC ACTIVITY IN THE GAKKEL RIDGE

As reported by the AFP on the web site Sweetness and Light in June 2008, "Recent massive volcanoes have risen from the ocean floor deep under the Arctic ice cap, spewing plumes of fragmented magma into the sea, scientists who filmed the aftermath reported Wednesday.

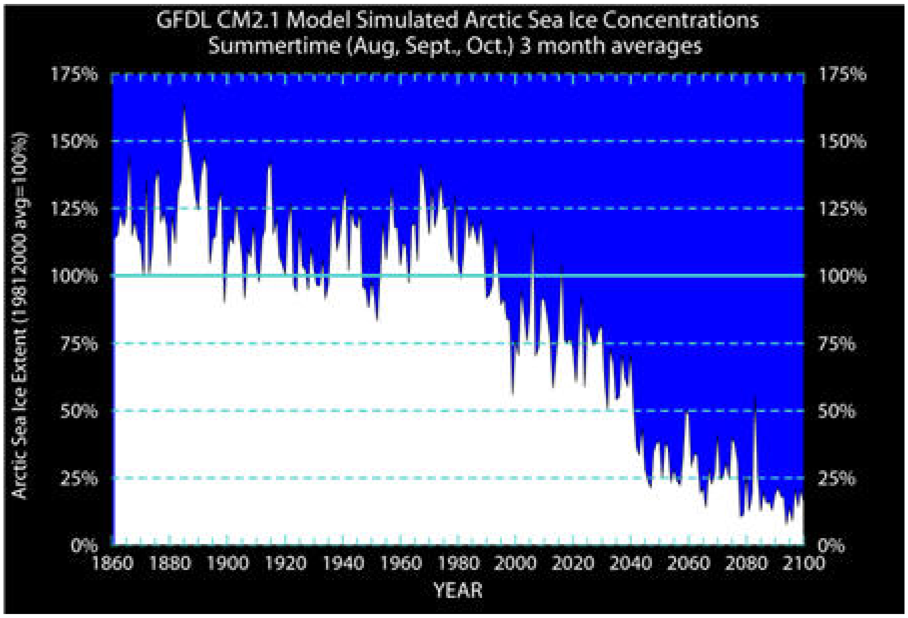
The eruptions — as big as the one that buried Pompei — took place in 1999 along the Gakkel Ridge, an underwater mountain chain snaking 1,800 kilometres (1,100 miles) from the northern tip of Greenland to Siberia.

Scientists suspected even at the time that a simultaneous series of earthquakes were linked to these volcanic spasms.

But when a team led of scientists led by Robert Sohn of the Woods Hole Oceanographic Institution in Massachusetts finally got a first-ever glimpse of the ocean floor 4,000 meters (13,000 feet) beneath the Arctic pack ice, they were astonished.

What they saw was unmistakable evidence of explosive eruptions rather than the gradual secretion of lava bubbling up from Earth's mantle onto the ocean floor…

Scientists at NOAA's Geophysical Fluid Dynamics Laboratory, the amount in ice began to decline precipitously in around 1999, which is when these volcanoes began their eruption.



TUNDRA SHRUB AND SOOT INVASION AND ICE MELT

Strack et al.(2007) in the GRL paper showed how invasive shrubs and soot pollution both have the potential to alter the surface energy balance and timing of snow melt in the Arctic. Shrubs reduce the amount of snow lost to sublimation on the tundra during the winter leading to a deeper end-of-winter snowpack. The shrubs also enhance the absorption of energy by the snowpack during the melt season by converting incoming solar radiation to longwave radiation and sensible heat. Soot deposition lowers the albedo of the snow, allowing it to more effectively absorb incoming solar radiation and thus melt faster.

This study used the Colorado State University Regional Atmospheric Modeling System version 4.4 (CSU-RAMS 4.4), equipped with an enhanced snow model, to investigate the effects of shrub encroachment and soot deposition on the atmosphere and snowpack in the Kuparuk Basin of Alaska during the May–June melt period. The results of the simulations suggest that a complete invasion of the tundra by shrubs leads to a

2.2C warming of 3 m air temperatures and a 108 m increase in boundary layer depth during the melt period. The snow-free date also occurred 11 d earlier despite having a larger initial snowpack. The results also show that a decrease in the snow albedo of 0.1, owing to soot pollution, caused the snow-free date to occur 5 d earlier. The soot pollution caused a 1.0C warming of 3 m air temperatures and a 25 m average deepening of the boundary layer.

SUMMARY

Arctic ice melt has increased in recent years as a result of warm water intrusion into the arctic from the Pacific and especially most recently from the Atlantic. The role of the undersea volcanic activity in the Gakkel Ridge is an unknown but a major eruption there in 1999 preceded the most recent rapid ice decline. There is evidence that the invasion of tundra shrubs and soot pollution may be altering the fall ice build up and melting and altering albedo. Similar arctic warmings occurred in the 1930s to 1950s as correctly documented by the IPCC AR4 and in the 1800s according to Siberian oceanographers. Arctic ice has started a recovery from the 2007 minimum.

Greenhouse gases are not the causes of these natural cyclical changes. Given the current cooling of the atmosphere and ocean, accelerated melting of the glaciers and icecaps and the resultant threat of catastrophic sea level is highly unlikely.

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