

GEOLOGIC EVIDENCE OF THE CAUSE OF GLOBAL WARMING AND COOLING—ARE WE HEADING FOR GLOBAL CATASTROPHY?

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ABSTRACT

As shown in the Greenland GISP2 ice cores, late Pleistocene abrupt temperature fluctuations occurred in only 20–100 years, clearly not caused by atmospheric CO₂ because they occurred thousands of years before atmospheric CO₂ levels began to rise. Global temperature curves show a cool reversal from ~1950 to ~1977), inferring that global temperatures then were not driven by atmospheric CO₂. Solar irradiance curves almost exactly match the global temperature curve and satellite data suggest that the earth has received increased solar radiation over the past 25 years, coinciding with the present 25–year warm cycle. If the cycles continue as in the past, the current warm cycle should end soon, and global warming should abate, rather than increase, in the next 25–30 years. Using these data as a basis, the coming century should experience a cooler climate from ~2006 to ~2035, a warmer period (probably warmer than the 1977–2005 warm period) from ~2035 to ~2065, followed by another cooler period from ~2065 to about the end of the century. The coming decades will test this prediction.

INTRODUCTION

The present global warming and discovery of abrupt climate changes in the geologic record have pushed climate changes into the forefront of scientific inquiry with a great deal at stake for human population. However, we don't yet have an unequivocal, "smoking gun," cause-and-effect answer to the question of the fundamental cause of global climate change and thus must rely on empirical data to formulate possible causal mechanisms. Despite the media blitz over the latest IPCC report, the report provides no tangible evidence that CO₂ is *causing* global warming. It *assumes* CO₂ is the cause and computer model simulations are all based on that assumption.

Global warming over the past century, the latter part of which was coincident with rise in atmospheric carbon dioxide levels, has led to dire predictions for the coming century and controversy among scientists about the cause of the warming. The purpose of this paper is not to present a comprehensive review of all of these issues (that would require a book!), but to point out some interesting relationships between present global warming and isotopic fingerprints from ice cores and recurrent glacial advance and retreat cycles recently and in the geologic past.

IS GLOBAL WARMING REAL?

Little doubt remains that global temperatures have risen during the past several centuries. How much global warming has taken place and how much is expected the rest of this century? As shown on Figure 1, average, global, surface temperatures rose approximately 0.8 °C (~1.4° F) during the past century), but the rise hasn't been linear. For the past several hundred years, global temperatures have warmed and cooled in 25–35 year cycles, well before atmospheric CO₂ began to rise. Warming and cooling in the Northern Hemisphere mirrors the global curve and warming and cooling in the Southern Hemisphere follows a similar pattern.

As shown on Figure 1, the 1890 marked the low point of a cool period that extended into the early part of the century. From 1910 to about 1940, global temperatures rose 0.5. °C (0.9° F). However, during this time, industrial CO₂ input into the atmosphere remained low and didn't begin to rise sharply until about 1945 (Fig. 2). This rise in global temperature cannot have been caused by anthropogenic input of CO₂ into the atmosphere because it preceded the increase in CO₂.

Global and U.S. Mean Surface Temperatures

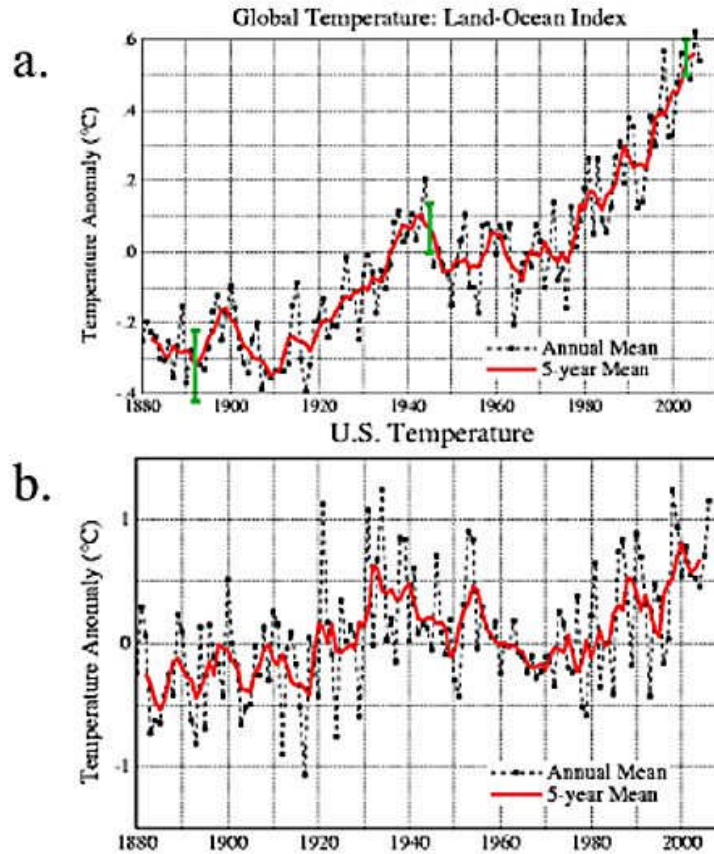


Figure 1. a. Global temperature change from 1880 to 2007. (NASA-GISS). Note the warming period from ~1910 to ~1945, the cool period from ~1945 to 1977, and the warm period from 1977 to 1998. b. U.S. temperature change from 1880 to 2007.

A ~30 year global cooling period occurred from the mid 1940s to 1977, during which time temperatures cooled 0.5°C (0.9°F) in the Northern Hemisphere and 0.2°C (0.4°F) globally (Fig. 3), despite rapid rise in atmospheric CO_2 . (Fig. 2). Many glaciers advanced significantly during this cool period. If CO_2 is the cause of global warming, the sharply rising atmospheric CO_2 during this time should have resulted in global warming, not ~30 years of global cooling.

In 1977, an abrupt climatic shift occurred and temperatures rose about 0.5°C (0.9°F) over the next 25 years as the earth entered the current warm period (Fig. 1a). During this time, atmospheric CO_2 continued to rise, but of the past four, 25–30–year global temperature fluctuations, only the last one (1977–present) could possibly be attributed to CO_2 .

Global temperatures rose from 1977 to 1998, during which glacial melting accelerated and sea surface temperatures increased. However, the thermal high of 1998 has not been exceeded and temperatures during the past 10 years declined slightly to 2007, then plunged dramatically in 2007–2008 (Fig. 2)

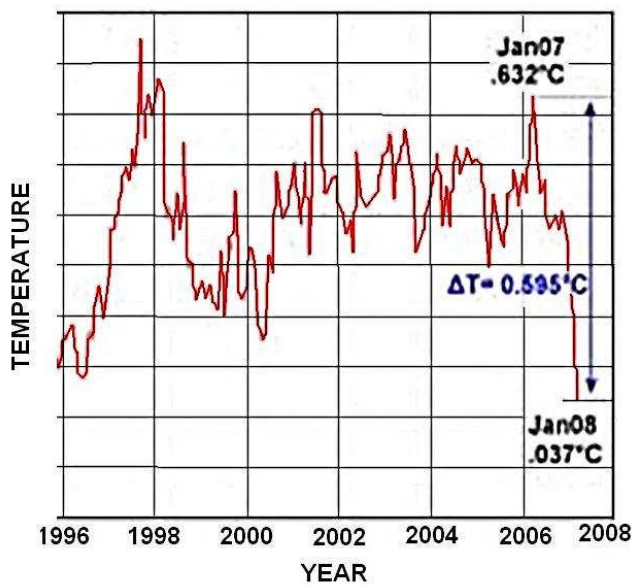


Figure 2. Global temperature 1996-2008

RISE OF ATMOSPHERIC CARBON DIOXIDE

Although CO₂ has long been recognized as a greenhouse gas, it makes up only ~0.03% of the atmosphere (Figure 3), far less than water vapor (2-4%). Atmospheric CO₂ levels have risen since 1945 to 0.038%, but the question is whether or not an increase of only 0.008% can overshadow the effects of solar changes. The answer to this question may be found in the geologic record of global climate changes and changes in atmospheric CO₂.

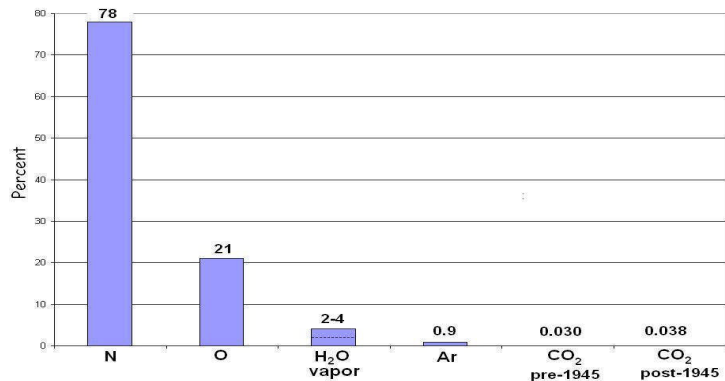


Figure 2. Composition of the atmosphere.

Measurements of CO₂ from air trapped in polar ice cores over tens of thousands of years shows that atmospheric CO₂ concentrations typically vary from about 270–285 ppm, averaging about 280 ppm. Atmospheric CO₂ concentrations have been stable at $\sim 280 \pm 10$ ppm during the past millennium until the industrial revolution when it rose gradually. In 1945, CO₂ began to increase rapidly. Atmospheric CO₂ levels rose CO₂ to ~ 370 in 2000. However, from 1945 to 1977, while CO₂ levels rose from approximately 300 ppm to 330 ppm, the global temperature rise reversed and cooled about 0.2 degrees during the same period (Fig. 3).

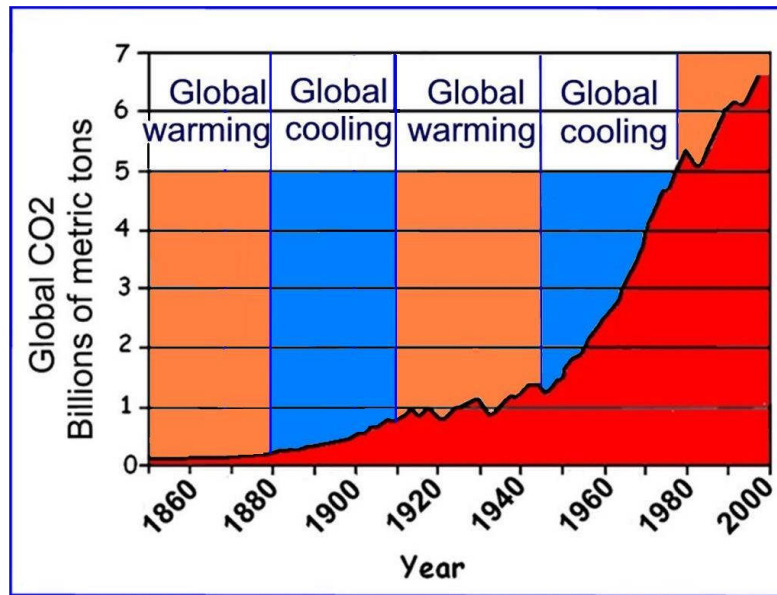


Figure 3A. CO₂ emissions to the atmosphere since 1850. Note that emissions rose sharply beginning in ~1945, but 30 years of global cooling followed. Global warming in the early part of the century (~1910-1945) occurred without substantial increase in CO₂.

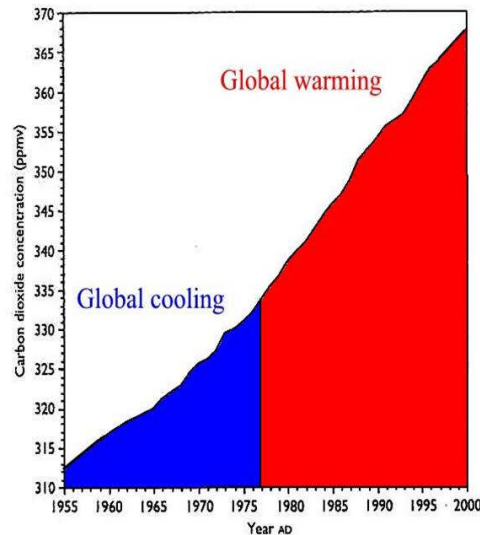


Figure 3B. Atmospheric CO₂ since 1955. Note that no sudden change in CO₂ occurred in 1977 at the time of abrupt climate change from cool to warm.

The high solubility and chemical reactivity of CO₂ permits ready exchange of CO₂ between the atmosphere and oceans. The amount of CO₂ in the oceans is about 50 times greater than in the atmosphere. CO₂ solubility depends on temperature, so changes in sea surface temperature affects CO₂ exchange with the atmosphere. Warming of sea surface water drives CO₂ into the atmosphere, as is seen in spikes in atmospheric CO₂ during strong El Niño years.

GLOBAL WARMING AND CO₂ DURING THE PAST CENTURY

Global warming from 1890 to 1945 not caused by atmospheric CO₂

Atmospheric temperature measurements, glacier fluctuations, and oxygen isotope data from Greenland ice cores all record a cool period from about 1880 to about 1910, reaching a low about 1890. During this period, global temperatures were about 0.9 °C (1.6 °F) cooler than at present. From 1880 to 1890, temperatures dropped 0.35 °C (0.6 °F) in only 10 years. From 1890 to 1900, temperatures rose 0.25 °C (0.45 °F) in 10 years, after which temperatures dipped slightly (0.15 °C (0.3 °F) until 1910. From 1910 to 1945, global temperatures rose 0.4 °C (0.7 °F), half of the total temperature rise for the past century. As expected, glaciers during this period retreated and, in general, followed the warming climate pattern. All of this occurred before CO₂ emissions began to soar

(after 1945) (Fig. 3A), so at least half of the warming of the past century cannot have been caused by manmade CO₂.

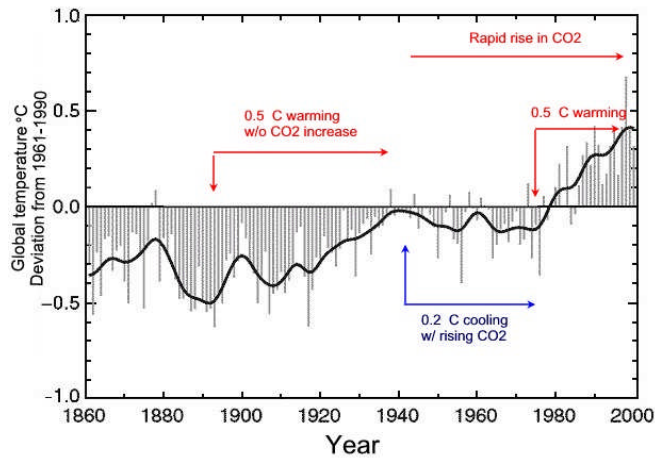


Figure 4. Global cooling during soaring atmospheric CO₂ emissions 1945 to 1977.

Global temperatures began to cool in the late 1940's at the point when CO₂ emissions began to soar (Fig. 3A). For 30 years thereafter temperatures declined 0.2 ° C (0.4 ° F) globally and 0.5 ° C (0.9 ° F) in the Northern Hemisphere (Fig. 5).

During this 30 year period (1945–1977), glaciers ceased the recession of the preceding ~30 years and began to advance. By 1980, many advancing glaciers had recovered much of the length lost in the previous ~30 year of warming. Many examples of glacial recession during the past century cited in the news media show contrasting terminal positions beginning with the maximum extent at the end of a ~30 year cool period and ending with the minimum extent of the present 30 year warm period. A much better gauge of the effect of climate on glaciers would be to compare glacier terminal positions between the ends of successive cool periods or the ends of successive warm periods.

Figure 5 shows global temperature and atmospheric CO₂ from 1940 to 1980. Note that even though CO₂ rises sharply, global temperature drops during that period. If CO₂ causes global warming, temperature should have risen, rather than declined.

Global warming during rising atmospheric CO₂ from 1977 to 2007

In 1977, global temperatures, which had been declining since the late 1940's, abruptly reversed and began to rise. Since then, global temperatures have risen ~0.5 ° C (0.9 ° F), alpine glaciers have retreated, Arctic sea ice has diminished, melting of the Greenland Ice Sheet has accelerated, and other changes have occurred. During this time, atmospheric CO₂ has continued to rise, the only period in the past century when global warming and atmospheric CO₂ have risen together.

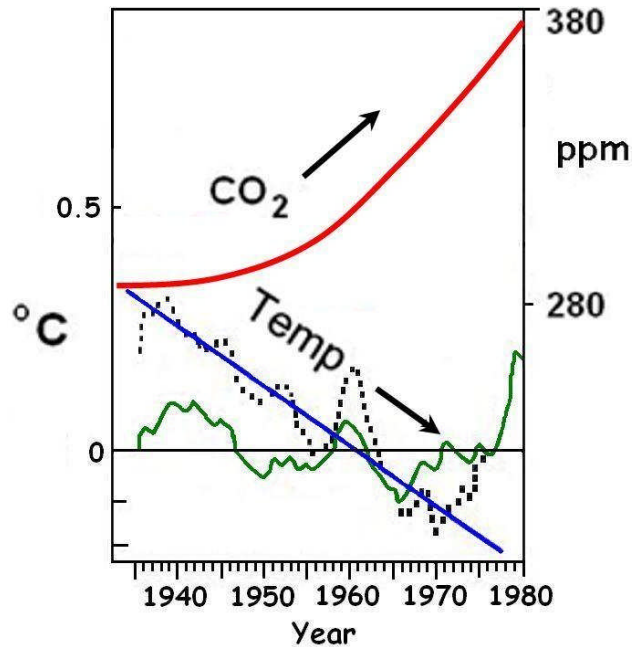


Figure 5. Global cooling during rapid increase in atmospheric CO₂ from 1940 to 1977.

Is Global Warming Caused by Rising CO₂?

No tangible, physical evidence exists that proves a cause-and-effect relationship between global climate changes and atmospheric CO₂. The fact that CO₂ is a greenhouse gas and that CO₂ has increased doesn't prove that CO₂ has caused global warming. As shown by isotope measurements from ice cores in Greenland and Antarctica and by measurements of atmospheric CO₂ during El Nino warming oceans emit more CO₂ into the atmosphere during climatic warming. The ice core records indicate that after the last Ice Age, temperatures rose for about 800 years *before* atmospheric CO₂ rose, showing that climatic warming causes CO₂ to rise, not vice versa. No doubt exists that the present high levels of atmospheric CO₂ are the result of human input, but the contribution that it makes to global warming remains to be proven.

Assertions by the ICPP and other CO₂ proponents

As seen in the previous discussion, no correlation exists between atmospheric CO₂ and the many global climate changes that have occurred over the past several centuries and the past 15,000 years. In a Newsweek article (August 13, 2007), author Sharon Begley states "*Current warming is 10 times greater than ever before seen in the geologic record. The chance that warming is natural is less than 10 percent.*" Every competent geologist knows that this statement is totally false and contrary to vast amounts of well-established data. Global climates have warmed about 4-7° F in a series of ~30 year cycles since the Little Ice Age 400 years ago, all with no correlation with atmospheric CO₂, yet the author claims that "*the pattern of warming has a human fingerprint.*" What is needed to bring clarity to the issue is not rhetoric like this, but a hard look at the huge amount of geologic data that shows we've had climate changes 20 times greater than the past century in a fourth of the time.

In February 2007, The International Panel on Climate Change (IPCC) released a summary report for policymakers by 33 authors. The panel conducted no research of its own but relied on previously published material. Neither the summary report nor the earlier full report contains any tangible, physical, cause-and-effect evidence that global warming is *caused* by anthropogenic CO₂ emissions. The IPCC conclusions are based on the empirical observation that global temperatures have risen during the past century and CO₂ has also risen and on computer model simulations that assume global temperatures will rise with increasing atmospheric CO₂. Because the coincidence of increase in global temperature and atmospheric CO₂ is an empirical relationship, that does not in itself prove that rising CO₂ is causing global warming. Nonetheless, the IPCC summary report for policymakers concludes that "*Most of the observed increases in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.*" They also concluded that "*The widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is extremely unlikely that global climate change of the past fifty years can be explained without external*

forcing, and very likely that it is not due to known natural causes alone.” Curiously, they later state the *“It is very unlikely that climate changes of a least the seven centuries prior to 1950 were due to variability generated within the climate system alone. A significant fraction of the reconstructed Northern Hemisphere interdecadal temperature variability over those centuries is very likely attributed to volcanic eruptions and changes in solar irradiance, and it is likely that anthropogenic forcing contributed to the early 20th century warming evident in these records.”* The report does not elaborate on why, if solar irradiance or volcanic eruptions were responsible for earlier climate changes, they could not also be the cause of changes since 1950, nor how anthropogenic emissions could be responsible for early 20th century warming before CO₂ emissions began to soar after 1945.

In his book *“The Inconvenient truth* Gore (2006) attributes global warming of the past century to anthropogenic CO₂ emissions, alleging that *“Our civilization has never experienced any environmental shift remotely similar to this. Today’s climate pattern has existed throughout the entire history of human civilization”* and that *“Every place—every city, every farm is located or has been developed on the basis of the same climate patterns we have always known. “*

Gore (2006) contends that the possibility of global warming being caused by natural climate cycles is a misconception. *“Climate does naturally change. By studying tree rings, lake sediments, ice cores, and other natural features that provide a record of past climates, scientist know that changes in climate, including abrupt changes, have occurred throughout history. But these changes all took place with natural variations in carbon dioxide levels that were small than the ones we are now causing. Cores taken from deep in the ice of Antarctica show that carbon dioxide levels are higher now than they have been at any time in the last 650,000 years, which means we are outside the realm of natural climate variation. More CO₂ in the atmosphere means warming temperatures.”* This is one example among many of circular reasoning and bad logic—it correctly admits that natural climatic cycles have been responsible for abrupt climate changes in the past when CO₂ levels were low and could not be the cause of the climate changes, then arrives at the peculiar conclusion that climatic warming must be caused by increasing CO₂.

Gore (2006) and other proponents of the CO₂ as the cause of global warming allege that *“there is virtually no serious disagreement remaining on any of these central points that make up the consensus view of the world scientific community.”* The basis for this claim apparently is based, at least in part, on the IPCC report and the claim that virtually all of the world’s scientists endorse it. However, the summary 2007 report for policymakers was compiled by only 33 authors and the full report, to be released in June 2007, was assembled by 143 authors and reviewed by 27 editors, hardly representative of the entire scientific community. Lindzen (2006) points out, *“there is no consensus”* -- no one has polled the world’s several hundred thousand scientists. Gore (2006) claimed that of 928 articles dealing with climate change in the past 10 years, none expressed any doubt about the cause of global warming. Lindzen (2006), however, found that of those 928 publications, only 13 favored CO₂ as the cause of global warming. Clearly, what needs to be done is to get away from the rhetoric and politicizing of global warming and carefully analyze the facts as they exist.

LESSONS FROM PAST GLOBAL CLIMATE CHANGES

Proponents of CO₂ as the cause of global warming have stated that never before in the Earth’s history of has climate changed as rapidly as in the past century and that proves global warming is being caused by anthropogenic CO₂. Statements such as these are easily refutable by the geologic record. Figure 5 shows temperature changes recorded in the GISP2 ice core from the Greenland Ice Sheet. The global warming experienced during the past century pales into insignificance when compared to the magnitude of at least ten sudden, profound climate reversals over the past 15,000 years (Figure 5).

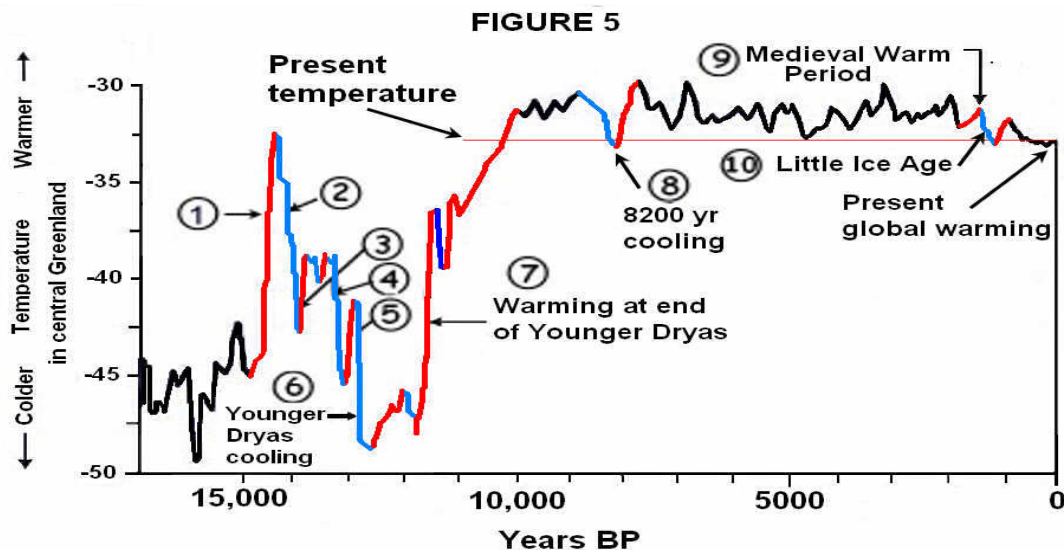


Figure 5. Temperature changes over the past 15,000 years. Red lines represent times of sudden warming, blue lines represent times of rapid cooling. Numbers refer to the events listed below. (Modified from Cuffey and Clow, 1997 and Alley, 2004)

Late Pleistocene abrupt climate changes

The magnitude and timing of past climatic changes are recorded in the isotope data from Greenland and Antarctic ice cores. These data clearly show that abrupt climate changes many times greater than those of the past century have occurred many times in the geologic past. Numbers correspond to the temperature curves on Figure 5.

- 1. About 15,000 yrs ago, a sudden, intense, climatic warming ($\sim 12^{\circ}\text{C}$; $\sim 21^{\circ}\text{F}$) caused dramatic melting of large Ice Age ice sheets that covered Canada and the northern U.S., all of Scandinavia, and much of northern Europe and Russia. Sea level that had been 120 m (~ 400 ft) lower than present rose quickly and submerged large areas that had been dry land during the Ice Age.
- 2. A few centuries later, temperatures again plummeted ($\sim 11^{\circ}$; $\sim 20^{\circ}\text{F}$) and glaciers advanced.
- 3. About 14,000 years ago, global temperatures rose rapidly ($\sim 4.5^{\circ}\text{C}$; $\sim 8^{\circ}\text{F}$) once again and glaciers receded.
- 4. About 13,400 years ago, global temperatures plunged again ($\sim 8^{\circ}\text{C}$; $\sim 14^{\circ}\text{F}$) and glaciers advanced.
- 5. About 13,200 years ago, global temperatures increased rapidly ($\sim 5^{\circ}\text{C}$; $\sim 9^{\circ}\text{F}$) and glaciers receded.
- 6. 12,700 yrs ago global temperatures plunged sharply ($\sim 8^{\circ}\text{C}$; $\sim 14^{\circ}\text{F}$) and a 1000 year period of glacial readvance, the Younger Dryas, began.
- 7. 11,500 yrs ago, global temperatures rose sharply ($\sim 12^{\circ}\text{C}$; $\sim 21^{\circ}\text{F}$), marking the end of the Younger Dryas cold period and the end of the Pleistocene Ice Age.

Early Holocene climate changes

8,200 years ago, the post-Ice Age interglacial period was interrupted by a sudden global cooling ($\sim 4^{\circ}\text{C}$; $\sim 7^{\circ}\text{F}$) that lasted for a few centuries (Figure 5, 6). During this time, alpine glaciers advanced and built moraines. The warming that followed the abrupt cool period was also abrupt. Neither the abrupt climatic cooling nor the warming that followed was preceded by atmospheric CO_2 changes.

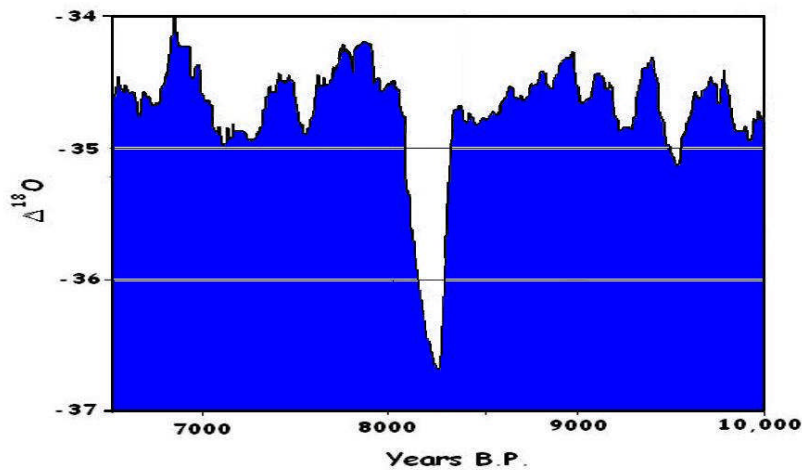


Figure 6. The 8200 sudden climate change, recorded in oxygen isotope ratios in the GISP2 ice core, lasted about 200 years.

Late Holocene climate changes

750 B.C. to 200 B.C. cool period

Prior to the founding of the Roman Empire, Egyptians records show a cool climatic period from about 750 to 450 B.C. and the Romans wrote that the Tiber River froze and snow remained on the ground for long periods (Singer, 2007).

The Roman warm period (200 B.C. to 600 A.D.)

After 100 B.C., Romans wrote of grapes and olives growing farther north in Italy that had been previously possible and of little snow or ice (Singer, 2007).

The Dark Ages cool period (440 A.D. to 900 A.D.)

The Dark Ages were characterized by marked cooling. A particularly puzzling event apparently occurred in 540 A.D. when tree rings suggest greatly retarded growth, the sun appeared dimmed for more than a year, temperatures dropped in Ireland, Great Britain, Siberia, North and South America, fruit didn't ripen, and snow fell in the summer in southern Europe (Baillie in Singer, 2007). In 800 A.D., the Black Sea froze and in 829 A.D. the Nile River froze (Oliver, 1973).

The Medieval Warm Period (900 A.D. to 1300 A.D.)

The Medieval Warm (MWP) Period was a time of warm climate from about 900–1300 AD when global temperatures were apparently somewhat warmer than at present. Its effects were evident in Europe where grain crops flourished, alpine tree lines rose, many new cities arose, and the population more than doubled. The Vikings took advantage of the climatic amelioration to colonize Greenland, and wine grapes were grown as far north as England where growing grapes is now not feasible and about 500 km north of present vineyards in France and Germany. Grapes are presently grown in Germany up to elevations of about 560 meters, but from about 1100 to 1300 A.D., vineyards extended up to 780 meters, implying temperatures warmer by about 1.0 to 1.4° C (Oliver, 1973, Tkachuck, 1983). Wheat and oats were grown around Trondheim, Norway, suggesting climates about warmer one degree C warmer than present (Fagan, 2000).

Elsewhere in the world, prolonged droughts affected the southwestern United States and Alaska warmed. Sediments in Lake Nakatsuna in central Japan record warmer temperatures. Sea surface temperatures in the Sargasso Sea were approximately 1°C warmer than today and the climate in equatorial east Africa was drier from 1000–1270 AD. An ice core from the eastern Antarctic Peninsula shows warmer temperatures during this period.

Oxygen isotope studies in Greenland, Ireland, Germany, Switzerland, Tibet, China, New Zealand, and elsewhere, plus tree-ring data from many sites around the world all confirm the presence of a global Medieval Warm Period. Soon and Baliunas (2003) found that 92% of 112 studies showed physical evidence of the MWP, only two showed no evidence, and 21 of 22 studies in the Southern Hemisphere showed evidence of Medieval warming. Evidence of the MWP at specific sites are summarized in Fagan (2007) and Singer (2007). Thus,

evidence that the Medieval Warm Period was a global event is widespread. The IPCC 2nd report (Climate Change 1995) included a graph showing the MWP with warmer temperatures than today and the Little Ice Age with much cooler temperatures.

Despite all of this physical evidence of the global MWP, the IPCC 3rd report (Climate Change 2001) reassessed the MWP on the basis of tree ring studies by Mann et al. (1998) and concluded that neither the MWP nor the Little Ice Age were global climatic events. Mann’s graph (Fig. 7) became known as “the hockey stick” of climate change and was used in the 2001 IPCC report to assert that climate had not changed until led to Gore’s 2007 famous assertion that “*Our civilization has never experienced any environmental shift remotely similar to this. Today’s climate pattern has existed throughout the entire history of human civilization.*”

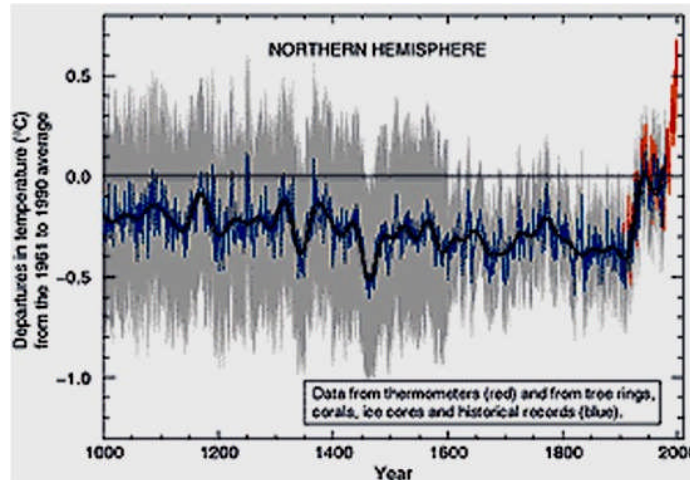


Figure 7. Mann (1998) “hockey stick” graph of temperature change over the past 1000 years

The Mann “hockey stick” was at odds with hundreds of historical and isotope sources, including the Greenland GRIP ice core isotope data, sea surface temperatures in the Sargasso Sea sediments (Fig. 8) (Keigwin, 1996), and paleo-temperature data other than tree rings (Fig. 9) (Loehle, 2007). McIntyre and McKittrick (2003) evaluated the data in the Mann paper and concluded that the Mann curve was invalid “*due to collation errors, unjustifiable truncation or extrapolation of source data, obsolete data, geographical location errors, incorrect calculation of principal components and other quality control defects.*” Thus, the “hockey stick” concept of global climate change is now widely considered invalid and an embarrassment to the IPCC.

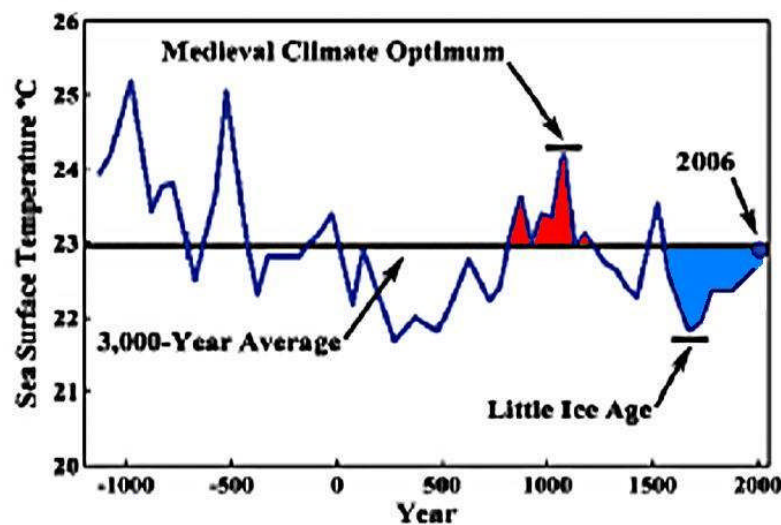


Figure 8. Surface temperatures of the Sargasso Sea reconstructed from isotope ratios in marine organisms (Keigwin, 1996).

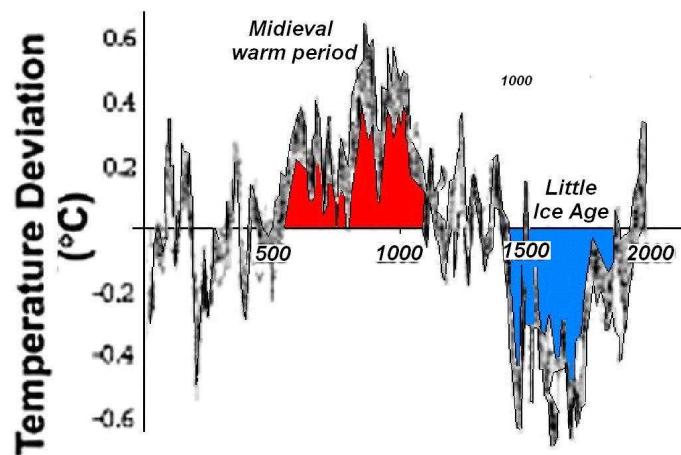


Figure 9. Reconstructed paleo-temperatures without tree ring data (Loehle, 2007)

The Little Ice Age (1300 A.D. to the 20th century)

At the end of the Medieval Warm Period, temperatures dropped dramatically in ~20 years and the cold period that followed is known as the Little Ice Age (LIA). The colder climate that ensued for several centuries was devastating. Temperatures of the cold winters and cool, rainy summers were too low for effective growing of cereal crops, resulting in widespread famine and disease.

Glaciers in Greenland began advancing and pack ice extended southward in the North Atlantic in the 13th century. Glaciers expanded worldwide. The population of Europe had become dependent on cereal grains as a food supply during the Medieval Warm Period and when the colder climate, early snows, violent storms, and recurrent flooding swept Europe, massive crop failures occurred. Three years of torrential rains that began in 1315 led to the Great Famine of 1315-1317. The Thames River in London froze over, the growing season was significantly shortened, crops failed repeatedly, and wine production dropped sharply.

Winters during the Little Ice Age were bitterly cold in many parts of the world (Fagan, 2000; Grove, 2004). Advance of glaciers in the Swiss Alps in the mid-17th century gradually encroached on farms and buried entire villages. The Thames River and canals and rivers of the Netherlands frequently froze over during the winter. New York Harbor froze in the winter of 1780 and people could walk from Manhattan to Staten Island. Sea ice surrounding Iceland extended for miles in every direction, closing many harbors. The population of Iceland decreased by half and the Viking colonies in Greenland died out in the 1400s because they could no longer grow enough food there and pack ice became an increasingly difficult problem. In parts of China, warm weather crops that had been grown for centuries were abandoned. In North America, early European settlers experienced exceptionally severe winters.

The cold and terrible famines of the early 1300s abated somewhat after a century or so, then turned even colder in the 16th and 17th centuries. The largest settlement in Greenland, about 225 farms, survived until about 1500 but with a shortened growing season and encroaching sea ice their situation became increasingly desperate (Fagan, 2000; Grove, 2004). In England, the Thames froze over and during the bitter cold winter of 1684, a three-mile wide strip of ice froze along the English channel. In 1695, ice blocked the coast of Ireland for much of the year and the entire cod fishery there failed (Fagan, 2000). Famines from 1690 to 1700 and in 1725 and 1816 resulted in several million deaths (Fagan, 2000).

Glaciers all over the world advanced to their most extended positions since the last Ice Age and build moraines well downvalley from their present termini. Villages in the European Alps were damaged or destroyed and alpine tree lines dropped several hundred meters.

In 1609, Galileo perfected the telescope, allowing observation of sun spots. From 1645 to 1715, solar activity was extremely low, with some years having no sunspots at all. This period of low sunspot activity, known as the Maunder Minimum, coincided with the thermal low of the Little Ice Age. The Spörer Sunspot Minimum also

occurred during a significant cold period of the Little Ice Age. Low solar activity during the Little Ice Age is also shown by changes in the production rates of radiocarbon and ^{10}Be in the upper atmosphere.

Global temperatures have risen about 1°F per century since the Little Ice Age, but the warming has not been continuous. Numerous 25-35 year warm/cool cycles appear in the record of glacial fluctuations and isotope records in Greenland ice cores.

CLIMATIC FLUCTUATIONS SINCE THE LITTLE ICE AGE— SHORT-TERM CLIMATE CYCLES

The global climate has warmed progressively since the LIA, but not at a constant rate. Oscillations between warm and cool periods have occurred in a fairly regular fashion about every 25-35 years (Figure 7).

Global temperatures have risen about 1°F per century since the cooling of the Little Ice Age, but the warming has not been continuous. Numerous ~ 30 year warming periods have been interspersed with ~ 30 year cooling periods (Figure 7). However, each warming period has been slightly warmer than the preceding one and cool period has not been quite as cool as the previous one. For example, the present warm period (1977–2007) is slightly warmer than the 1920–1950 warm period, and the 1947–1977 cool cycle (Figure 1) is not quite as cool as the ~ 1880 –1910 cool period.

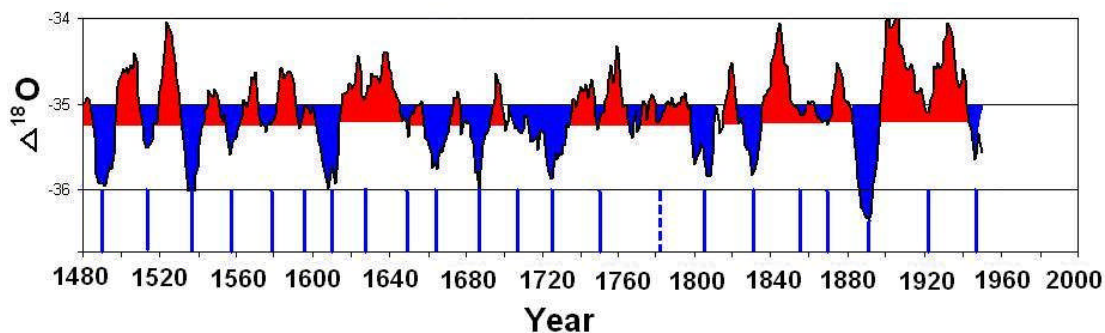


Figure 10. Cyclic warming and cooling trends in the past 500 years (plotted from GISP2 data, Stuiver and Grootes, 2000).

During each warm cycle, glaciers retreated and during each cool cycle, glaciers advanced. However, because each warm cycle was slightly warmer than the previous one and each cool cycle not quite as cool as the previous one, glacier termini have progressively receded upvalley from their Little Ice Age maximums. These relationships are well shown on glaciers on Mt. Baker, Washington where large distinct Little Ice Age moraines mark the glacier termini well below present ice termini. Successively higher moraines upvalley mark progressive advances and stillstands resulting from warm/cool cycles. The later moraines match the observed global climate changes (Fig. 1).

The oldest Little Ice Age moraines have trees growing on them dating back to the 1500's. A buried forest on the Coleman glacier moraine (Figure 11), dated at 680 ± 80 and 740 ± 80 ^{14}C yrs B.P., grew during the Medieval Warm Period atop an older moraine. The forest was buried by a Little Ice Age moraine. Annual rings from trees growing on successively younger moraines upvalley show moraine-building episodes in the 1600's, ~ 1750 , ~ 1790 , ~ 1850 , and ~ 1890 .



Figure 11. Little Ice Age moraine burying a forest that grew during the Medieval Warm Period, Coleman glacier, Mt. Baker, WA.

Ice margins of Mt. Baker glaciers are shown on air photos dating back to 1943 and on some earlier ground and air photos (Figures 9–13). Glaciers that had been retreating since at least the 1920's advanced during the 1947–1977 cool period to positions downvalley from their 1943 termini. They began to retreat once again at the start of the 1977–2007 warm cycle and present termini of the Easton and Boulder glaciers are about 1500 ft. upvalley from their 1979 positions.

These glacier fluctuations closely follow the global cooling record and indicate that the ~30 yr. warming and cooling cycles seen in the glacial record mimic global climate changes. Thus, pre-historic glacial fluctuations also appear to record global climate changes.

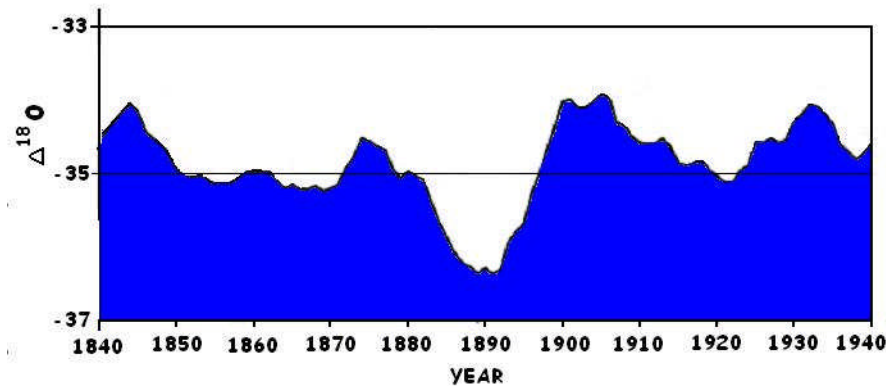


Figure 12. GISP2 oxygen isotope record of the 1875-1900 cool period.

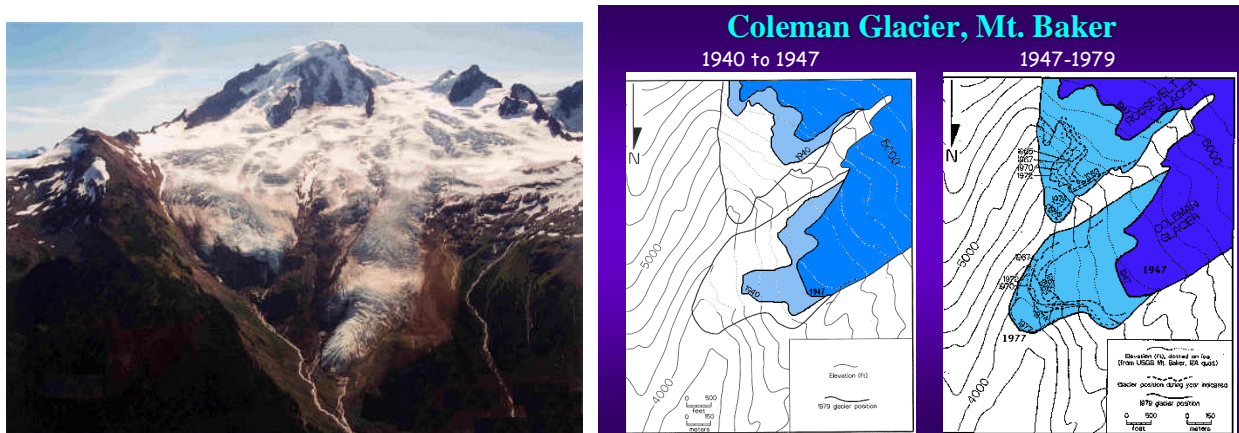


Figure 13A. Coleman Glacier, Mt. Baker WA.

Figure 13B. Retreat and advance of the Coleman glacier

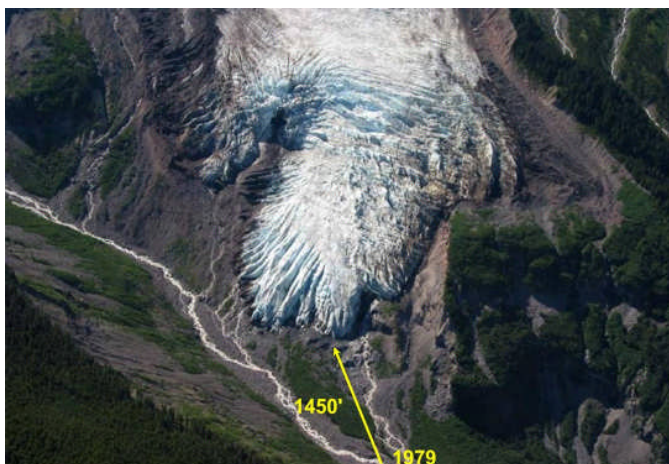


Figure 13C. Retreat of the Coleman glacier since 1979, the beginning of the present 30 yr. warm cycle.



Figure 14A Easton glacier, Mt. Baker, WA

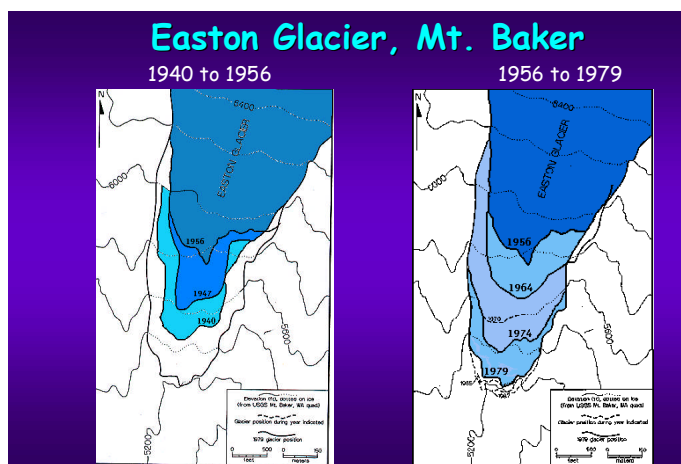


Figure 14B. Retreat and advance of the Easton glacier.



Figure 14C. Retreat of the Easton glacier since 1979, the beginning of the present 30 yr. warm cycle.



Figure 15A Boulder glacier, Mt. Baker, WA

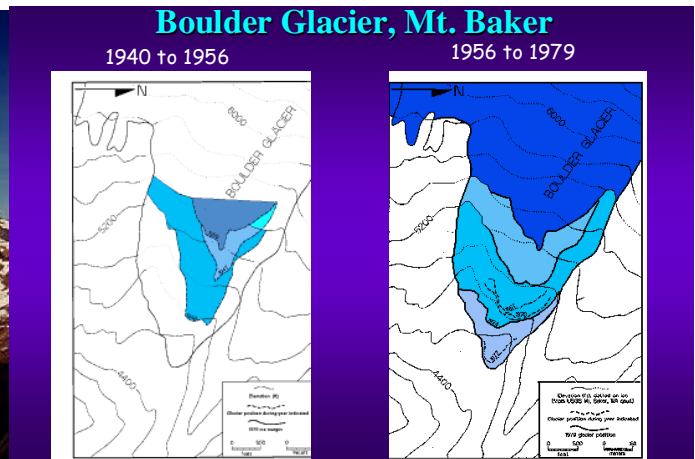


Figure 15B. Retreat and advance of the Boulder glacier.



Figure 15C. Retreat of the Boulder glacier since 1979, the beginning of the present 30 yr. warm cycle.

Each of these glacial fluctuations matches the both global temperature curve and sea surface temperatures recorded by the Pacific Decadal Oscillation (Fig. 16). The 1915 to 1945 PDO warm period occurred during the observed global warming of the atmosphere from 1915 to 1945 and to accelerated retreat of glaciers. The 1945-1977 PDO cool period took place during the global cooling of the atmosphere from 1945 to 1977 and to the advance of glaciers. The 1977 to 1998 PDO warm period occurred during global warming of the atmosphere from 1977 to 1998 and to accelerated retreat of glaciers. After the 1998 El Nino Pacific warm event, the PDO switched from its warm phase to a cool phase, but was interrupted by the 2005-2006 El Nino. In 2007-2008, the PDO resumed its cool phase and the winter of 2007-2008 was record-breaking cool globally.

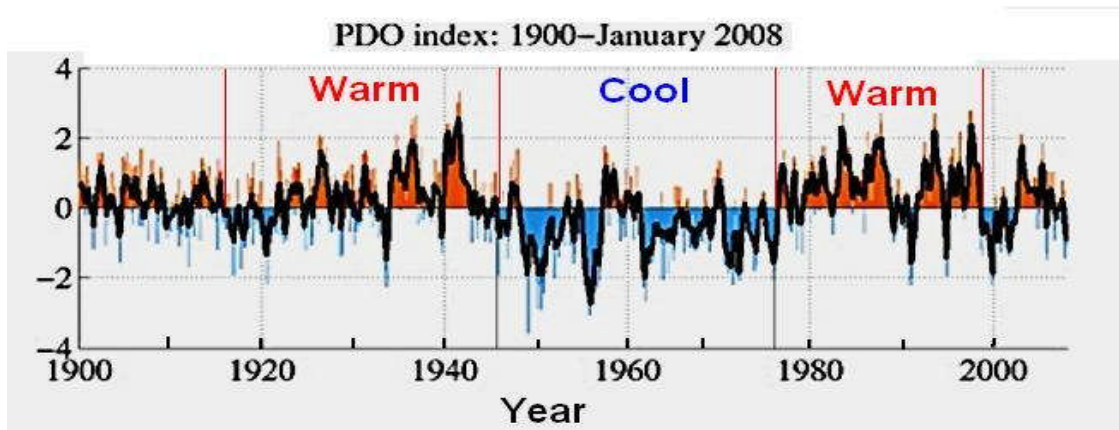


Figure 16. Pacific Decadal Oscillation from 1900 to 2008. The 1915 to 1945 PDO warm period corresponds to the observed global warming of the atmosphere for the same time span and to accelerated retreat of glaciers. The 1945-1977 PDO cool period corresponds to the observed global cooling of the atmosphere for the same time and to advance of glaciers. The 1977 to 1998 PDO warm period corresponds to global warming of the atmosphere from 1977 to 1998 and to accelerated retreat of glaciers.

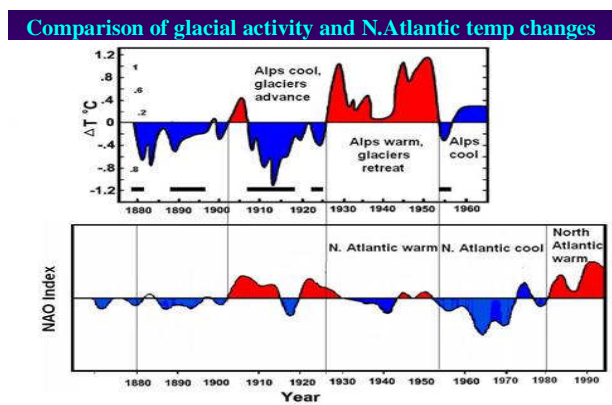


Figure 17A. Comparison of advance and retreat of glaciers on Mt. Baker with the Pacific Decadal Oscillation of the NE Pacific Ocean.

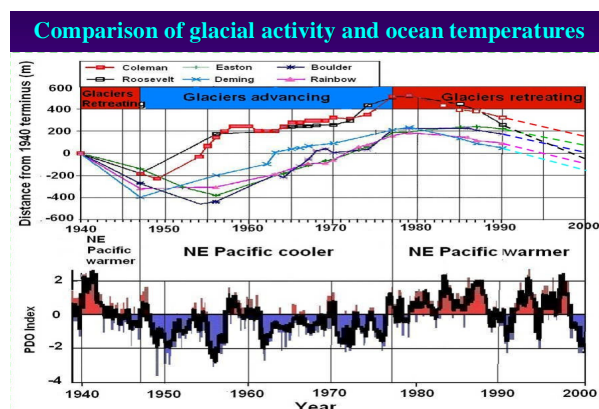


Figure 17B. Comparison of advance and retreat of glaciers in the Alps with the North Atlantic Oscillation.

The North Atlantic Oscillation shows patterns very similar to the PDO (Fig. 17B). Glacial advances and retreats in the European Alps correspond to warm and cool phases of the NAO in the same way as glacial advances and retreats in North America correlate with the PDO. All are in phase with observed atmospheric temperature changes over the past century.

Additional climate changes are recorded in the Greenland ice sheet isotope data. Figure 10 shows regular warm/cool cycles of approximately the same duration as the glacial moraine record extending back 500 years.

The importance of the various types of evidence of climate fluctuations is that they show long-standing evidence of cool/warm cycles over many centuries. Adding more recent, observed climatic fluctuations to the earlier records shows that we are now right where we ought to be in this pattern, i.e., at the end of the current 30 year warm period and just entering the next 25-30 year cool phase. Extending this ongoing record into the future provides an opportunity to predict coming climate changes.

MAGNITUDE AND SIGNIFICANCE OF PREVIOUS GLOBAL CLIMATE CHANGES

Most of the global climate changes described above were far more intense (12 to 20 times as intense in some cases) than the global warming of the past century (compare them in Fig. 5), and they took place in as little as 20–100 years. As shown on Figure 5, the global warming of the past century (0.8° C) is virtually insignificant when compared to the magnitude of the earlier global climate changes.

None of these sudden, pre-1977 global climate changes could possibly have been caused by human CO₂ input to the atmosphere because they all took place long before human CO₂ contributions to the atmosphere began. The cause of the ten ‘natural’ climate changes that occurred earlier could easily have been the same as the cause of present global warming.

If CO₂ is indeed the cause of global warming, then global temperatures should mirror the rise in CO₂. For the past 1000 years, atmospheric CO₂ levels have remained fairly constant at about 280 ppm (parts per million). Atmospheric CO₂ concentrations began to rise during the industrial revolution early in the 20th century. In 1945, atmospheric CO₂ rose sharply. By 1980 it has risen to just under 340 ppm. During this time, however, global temperatures fell about 0.5° C (0.9° F) in the Northern Hemisphere and about 0.2° C (0.4° F) globally (Fig. 3). In 1977, global atmospheric temperatures again reversed suddenly, rising about 0.5° C (0.9° F) above the 1945-1977 cool cycle in 25 years. If CO₂ is the cause of global warming, why did temperatures fall for 30 years while CO₂ was sharply accelerating? Logic dictates that this anomalous cooling cycle during accelerating CO₂ levels must mean either (1) rising CO₂ is *not* the *cause* of global warming or (2) some process other than rising CO₂ is capable of overriding its effect on global atmospheric warming and CO₂ is inconsequential.

If we look at temperature patterns since the latter part of the Little Ice Age (~1600 to 1860 A.D.), a very similar pattern emerges--25-30 periods of alternating warm and cool temperatures during overall warming from the Little Ice Age low. These temperature fluctuations took place well before any effect of anthropogenic atmospheric CO₂ and were far greater. About 80% of the CO₂ from human activities was added to the atmosphere after 1940, so the early 20th Century and earlier warming trends had to be natural and the recent trend in surface warming cannot be primarily attributable to human-made greenhouse gases. Thus, CO₂ cannot possibly have been the cause of these climatic changes so why should we suppose that the last few must be? We clearly need to look to causal mechanisms other than rising CO₂ if we are to truly understand global warming.

SOLAR IRRADIANCE AND GLOBAL CLIMATE CHANGE

The global climate changes described above have coincided with changes in sunspot activity, solar irradiance, and rates of production of ¹⁴C and ¹⁰Be in the atmosphere by radiation, suggesting that the climate changes are caused by fluctuations in solar activity. A good example of the relationship between solar activity and climate occurred

When Galileo perfected the telescope in 1609, scientists could see sunspots for the first time. They were of such interest that records were kept of the number of sunspots observed, and although perhaps not entirely accurate due to cloudy days, lost records, etc., the records show a remarkable pattern for nearly a century (Fig. 22). From 1600 to 1700 AD, very few sunspots were seen, despite the fact that many scientists with telescopes were looking for them, and reports of aurora borealis were minimal. This interval is known as the Maunder Minimum (E.W. Maunder, 1894; E.E. Maunder, 1922). After 1700 AD, the number of observed sunspots increased sharply from nearly zero to 50-100 (Fig. 22). The Maunder Minimum was preceded by the Sporer Minimum (~1410-1540 AD) and the Wolf Minimum (~1290-1320 AD) (Fig. 27). Each of these periods is characterized by low numbers of sunspots, significant changes in the rate of production of ¹⁴C in the atmosphere, and cooler global climates.

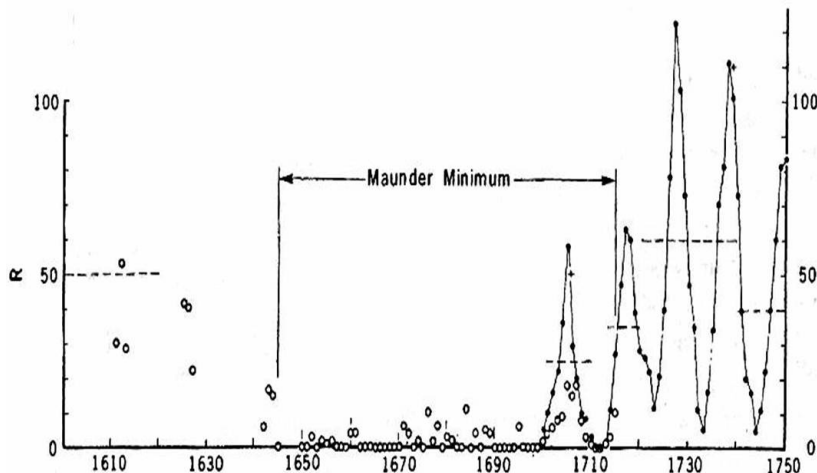


Figure 22. Sunspots during the Little Ice Age. (Modified from Eddy, 1976)

Global temperature change, sunspots, solar irradiance, ^{10}Be and ^{14}C production

Good correlations can now be made between global temperature change, sunspots (Fig. 23) (Eddy, 1976; Stuiver and Quay, 1980), solar irradiance (Lean, 1989, 1991, 2000, 2001, Lean and Rind, 1998; Lean et al., 1995, 2002), and ^{10}Be (Beer et al., 1994, 1996, 2000) and ^{14}C production (Stuiver, 1961, 1994; Stuiver and Brasiunas, 1991, 1992; Stuiver et al., 1991, 1995) in the atmosphere. ^{10}Be is produced in the upper atmosphere by radiation bombardment of oxygen. Increased radiation results in increased ^{10}Be production. Plots of ^{10}Be production and sunspots (Figs. 24, 25) indicate a good correlation between the two. Thus, ^{10}Be measurements can serve as a proxy for solar activity.

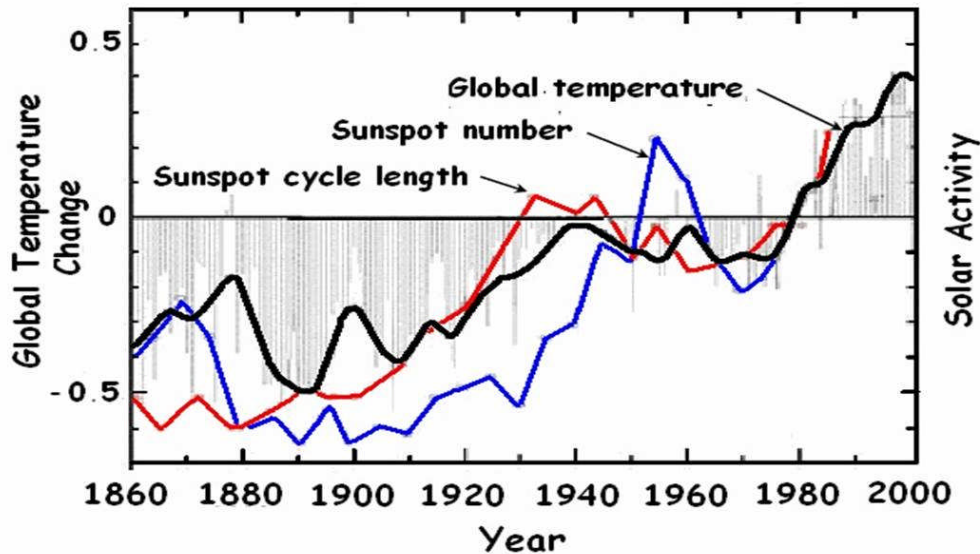


Figure 23. Variation in global warming and cooling with solar activity from 1860 to 1990. Note how closely the trends of the curves follow one another almost exactly. Contrast this with the lack of correlation of CO_2 variation and global temperature and in pre-1980 global temperature changes.

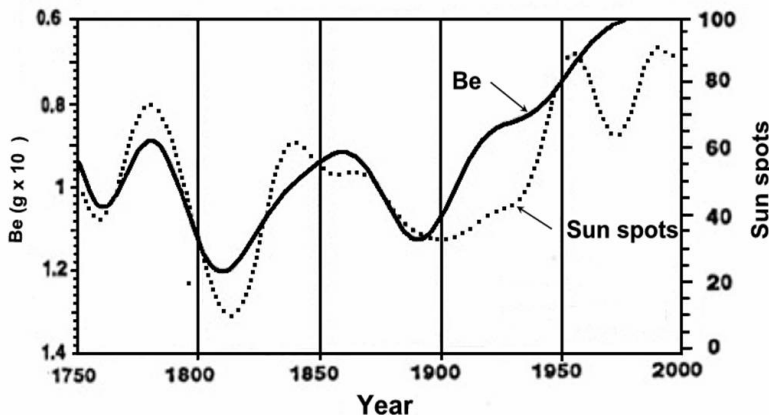
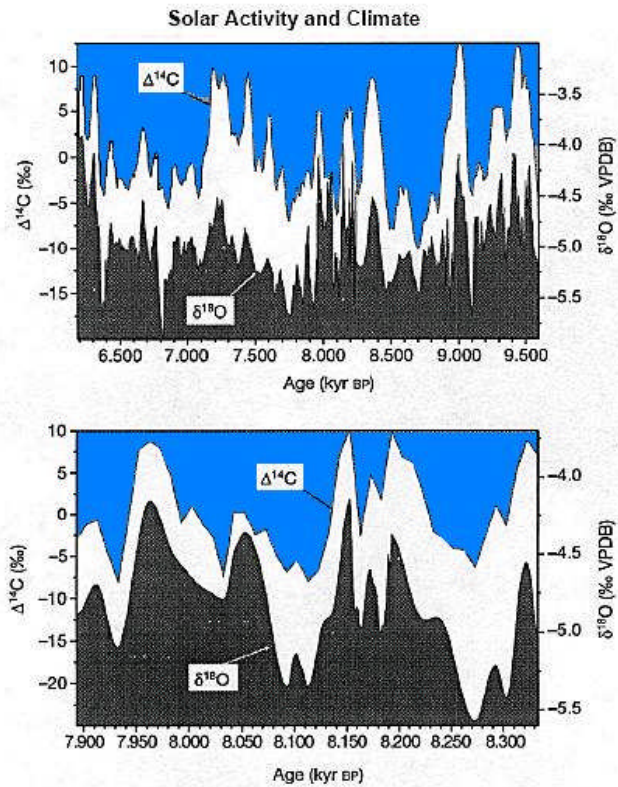


Figure 24. Variation of ^{10}Be production in the upper atmosphere with sun spots.



Values of carbon-14 (produced by cosmic rays – hence a proxy for solar activity) correlate extremely well with oxygen-18 (climate proxy); data are from a stalagmite in Oman [Neff 2001]. The time interval covers more than 3,000 years, from about 9,600 to 6,200 years before present (BP). The lower graph shows a particularly well-resolved time interval from 8,350 to 7,800 years BP. It would be difficult to explain this detailed correlation except through the modulation of galactic cosmic rays by changes in the solar wind and solar magnetic activity [Singer 1958]. The mechanism whereby cosmic rays influence terrestrial climate is most likely a change in cloudiness, as suggested by Svensmark [2007a, 2007b].

Figure 25. Correlation of temperatures derived from oxygen isotope ratios with production rates of radiocarbon in the upper atmosphere.

The close correspondence of solar activity to global climate change from 1750 to 1990 is shown in Figure 26. Not only did atmospheric global temperature change with solar activity, but so did sea surface temperatures. This is in sharp contrast to the lack of correlation of atmospheric CO_2 changes to global warming and cooling prior to 1980. Solar irradiance and global temperature show the same relationship as solar activity (sunspots) and global temperature. Solar irradiance from 1750 to 1990 shows almost exactly the same pattern as global warming and cooling over the past 250 years.

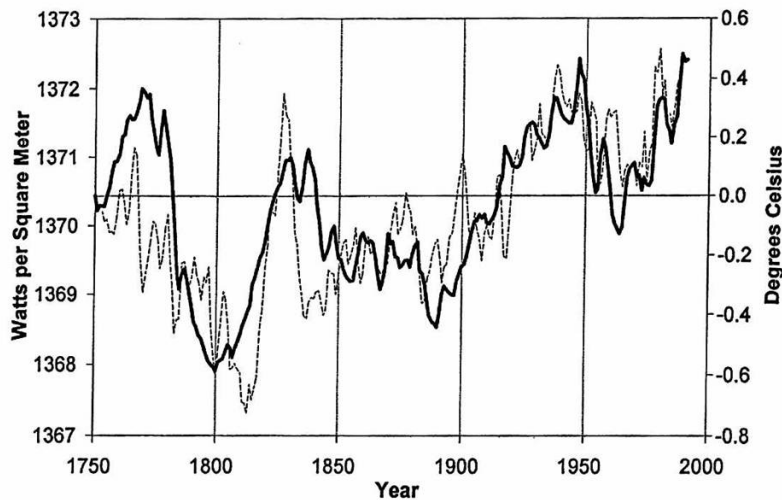


Figure 26. Solar irradiance and global warming and cooling from 1750 to 1990. During this 250 year period, the two curves follow a remarkably similar pattern. (Modified from Hoyt and Schatten, 1997)

A similar relationship between solar irradiance and climate change for the past 400 years is shown in Figure 26. The very low sunspot activity that began about 1600 AD is also marked by a decrease in solar irradiance that heralded the beginning of the Little Ice Age. Solar irradiance also dropped during the Dalton Minimum in the early 1800s. Since then, solar irradiance has risen with an oscillatory pattern (Fig. 26)

The correspondence of global cold periods with solar irradiance and sun spot cycle length is remarkable. Figure 276 shows the close relationship of time of glacial advance with low solar irradiance. Figure 28 shows a comparison of the correlation of solar irradiance and global temperature and the lack of correlation of atmospheric CO₂ and global temperature.

Solar irradiance, sunspots, and glaciers

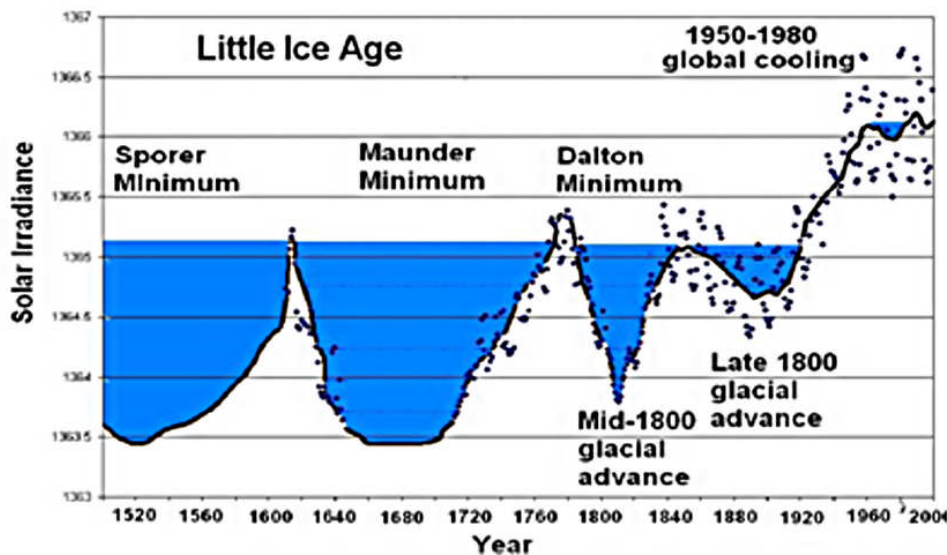


Figure 27. Solar irradiance, sunspots, and glacial fluctuations. Blue areas are times of glacial advances. Note that each period of glacial advance is marked by a time of low solar irradiance, including the 1880 to 1910 and 1945 to 1977 glacial advances during global cool periods. Is the correspondence of the extended length of sun spot cycle 23, recent global cooling, and the setting up of the cool phase of the PDO purely coincidental or is there a cause-and-effect relationship?

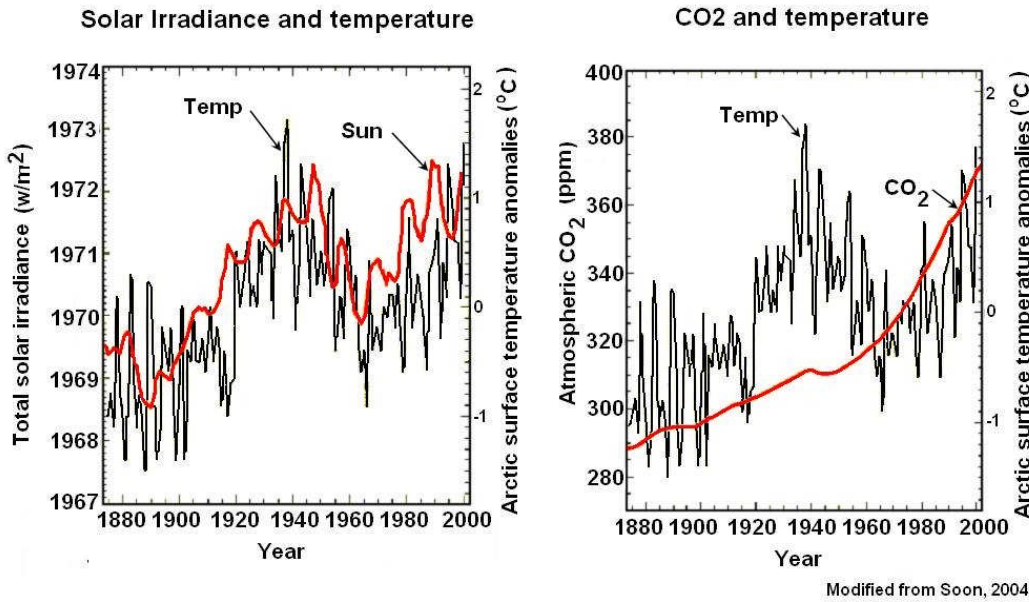


Figure 28. Comparison of the correlation of global temperature with solar irradiance and the lack of correlation with CO₂.

Low sun spot frequency in sun spot cycle 23 is extended beyond the normal length and cycle 24 is overdue. The recent global cooling and setting up of the cool phase of the PDO is reminiscent of solar and climatic conditions at the beginning of the Little Ice Age.

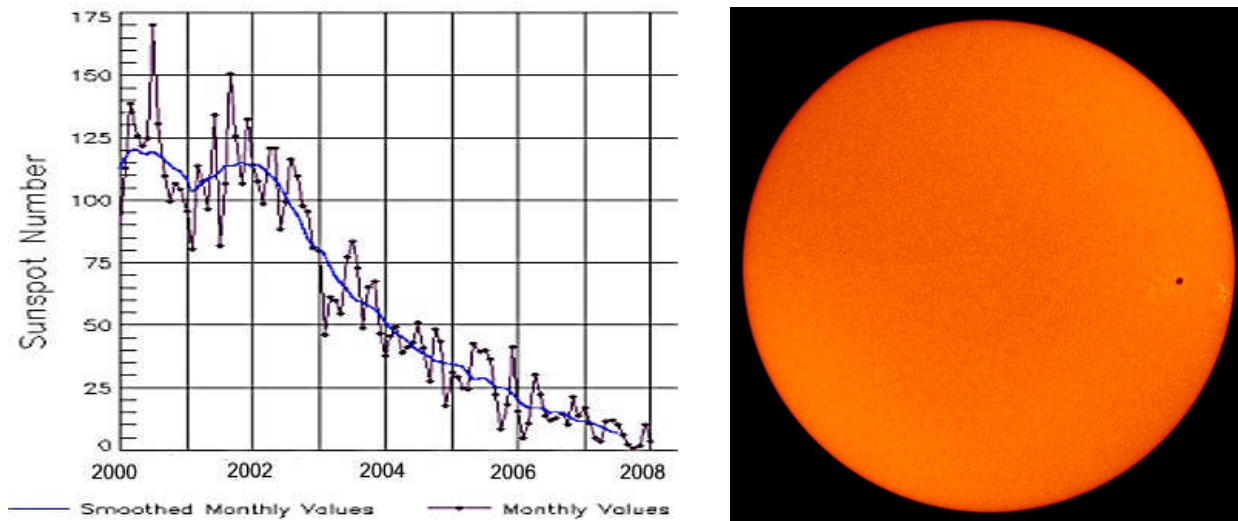


Figure 28. Decline in sun spots since 2000, which corresponds to setting up of the Pacific Decadal Oscillation cool phase and slight global cooling since 1998.

CLIMATE CHANGES IN THE COMING CENTURY

IPCC Predictions:

What does the century have in store for global climates? According to the IPCC, Al Gore's recent book, and many computer modelers who believe that CO₂ is the cause of global warming, the Earth is in store for climatic catastrophe later this century. Computer models predict global warming of as much as 5-6° C (10-11° F) (Fig. 4), which would cause massive starvation from crop failures, melting of most of the world's glaciers, sea level rise with drowning of some low-lying islands and coastal cities, and numerous environmental changes. All of this is

predicated on the assumption that global warming is caused by increasing atmospheric CO₂ and that CO₂ will continue to rise rapidly.

The Intergovernmental Panel on Climatic Change (IPCC) has projected that in the next century, global warming will continue to rise to catastrophically higher and higher levels (Figure 4). The basis for this prediction is that the IPCC believes that rising atmospheric CO₂ is the cause of global warming and that CO₂ levels will continue to rise in the future, so global temperatures will also continue to rise. Computer models, programmed to calculate rise in global temperatures as a function of CO₂, predict that by 2100, atmospheric CO₂ will rise to 540-970 ppm and global temperature will increase 0.6 °C (1.1° F) by 2010, 1.2° C (2.1° F) by 2038, and up to 10.7°C (19° F) by 2100.

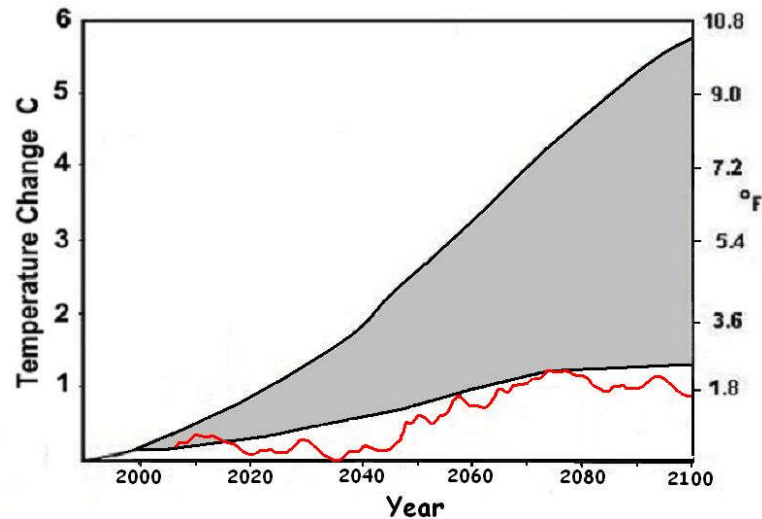


Figure 19. IPCC computer-projected global temperature increase for the coming century. Gray area is the range of IPCC predictions; red line is the Easterbrook projection based on past cyclic climate changes.

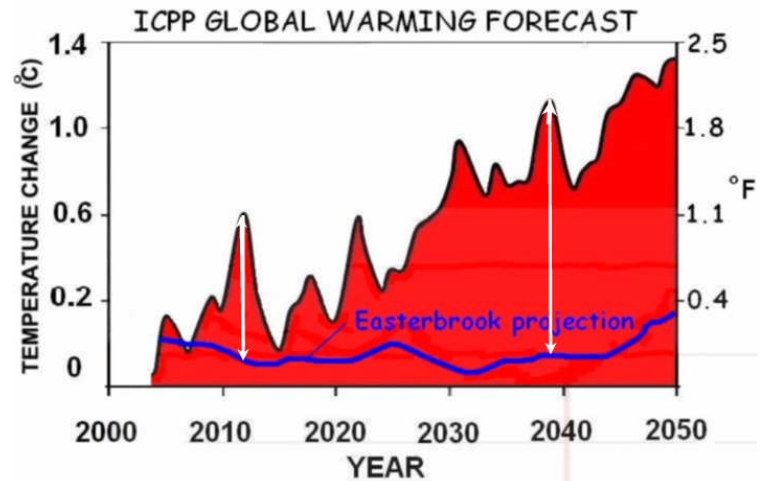


Figure 20. Comparison of IPCC global warming predictions to 2050 and the Easterbrook projection.

The validity of these predictions depends on the assumptions that (1) the cause of global warming is rising CO₂, (2) the rise in CO₂ is caused by anthropogenic fossil fuel emissions and other human activities, and (3) anthropogenic fossil fuel emissions will continue to rise throughout the present century. With so much at stake, verifying the soundness of these assumptions is of critical importance.

The ramifications of such an increase in global warming are far reaching, even catastrophic in some areas. Such a rise of global surface temperatures would have devastating results. The Arctic Ocean would become free of its cover of sea ice, the Greenland ice sheet would diminish rapidly, and alpine glaciers would disappear. Water supply in areas that depend on snowmelt would be severely impacted. Melting of Greenland and Antarctic ice would cause sea level to rise, flooding low coast areas and submerging low coral islands in the oceans. Crops in critical agricultural areas would fail, resulting in widespread starvation of millions of people in agriculturally

marginal areas. Wheat/grain belts, such as the mid-continent area of North America, would have to shift northward. Droughts would become increasingly severe in dry areas. Environmental impacts would be severe, resulting in extinction of some species and drastic population decreases in others.

Predictions Based on Past Climate Patterns

Considering all the positive correlations between solar activity and global climate change, what if the cause of global warming is solar, rather than atmospheric CO₂? Then all of the computer models are meaningless and we can look to past natural climatic cycles as a basis for predicting future climate changes. The climatic fluctuations over the past few hundred years suggest ~30 year climatic cycles of global warming and cooling, on a general rising trend from the Little Ice Age cool period. If the trend continues as it has for the past several centuries, global temperatures for the coming century might look like those in Figure 15. Global cooling should begin soon and last until about 2040, then warm again until about 2070, and cooling again to the end of the century. The total increase in global warming from now to the end of the century should be only about 0.4°C, compared to nearly 11°C (maximum) predicted by the IPCC (Fig. 16)

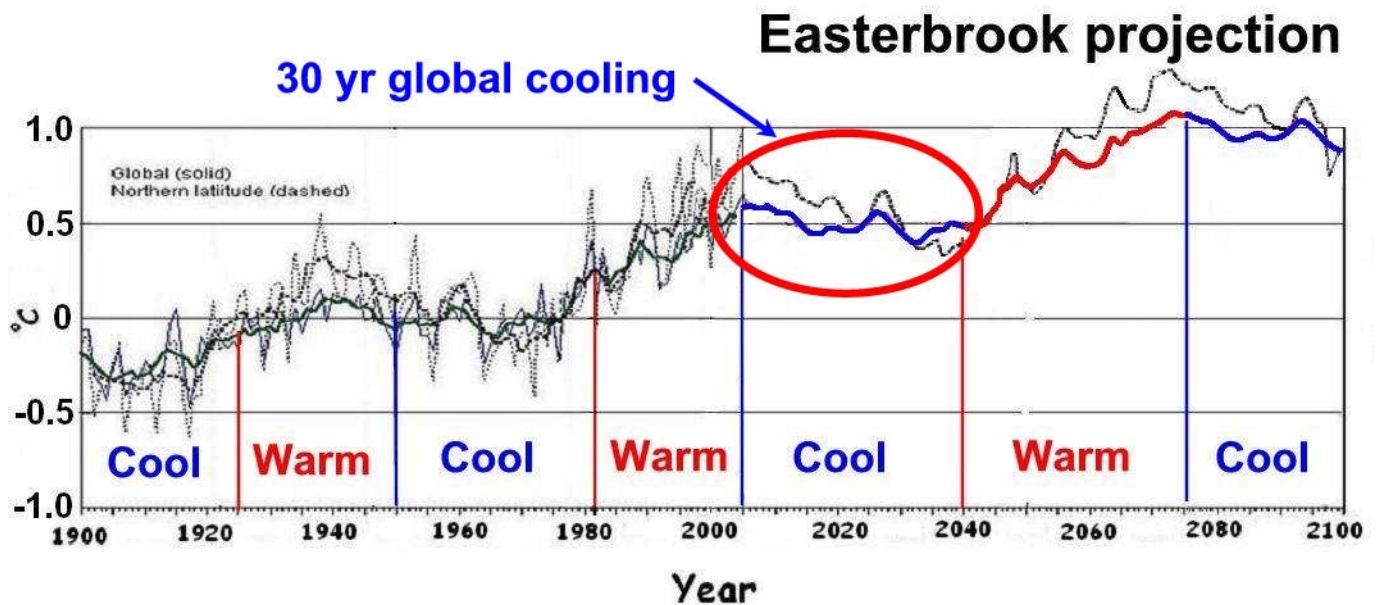


Figure 21. Global temperature projection for the coming century, based on warming/cooling cycles of the past several centuries. The 30-year global cooling prediction was first made in 1998 and reaffirmed in 2001. The recent setting up of the cool phase of the PDO appears to confirm the strong likelihood that the prediction will indeed happen.

RECENT GLOBAL COOLING AND PACIFIC DECADEAL OSCILLATION (PDO) COOLING IN THE PACIFIC OCEAN

Global temperatures peaked in 1998 and have not been exceeded since then, despite dire predictions by the IPCC and CO₂ advocates. Instead, the climate cooled slightly from 1998 to 2007 and then cooled dramatically in 2007-2008 (Fig. x). Pacific Ocean temperatures began a cooling phase in 1999 that was briefly interrupted by El Nino in 2005-2006 and dramatic cooling in 2007-2008 appears to be a continuation of a global cooling trend set up by the PDO cool phase (Fig. 18).

The announcement by NASA’s Jet Propulsion Laboratory that the Pacific Decadal Oscillation (PDO) had shifted to its cool phase (Fig. 18) is right on schedule as predicted by past climate and PDO changes (Easterbrook, 2001, 2006, 2007). It is *not* an oddity superimposed upon and masking the predicted severe warming by the IPCC.

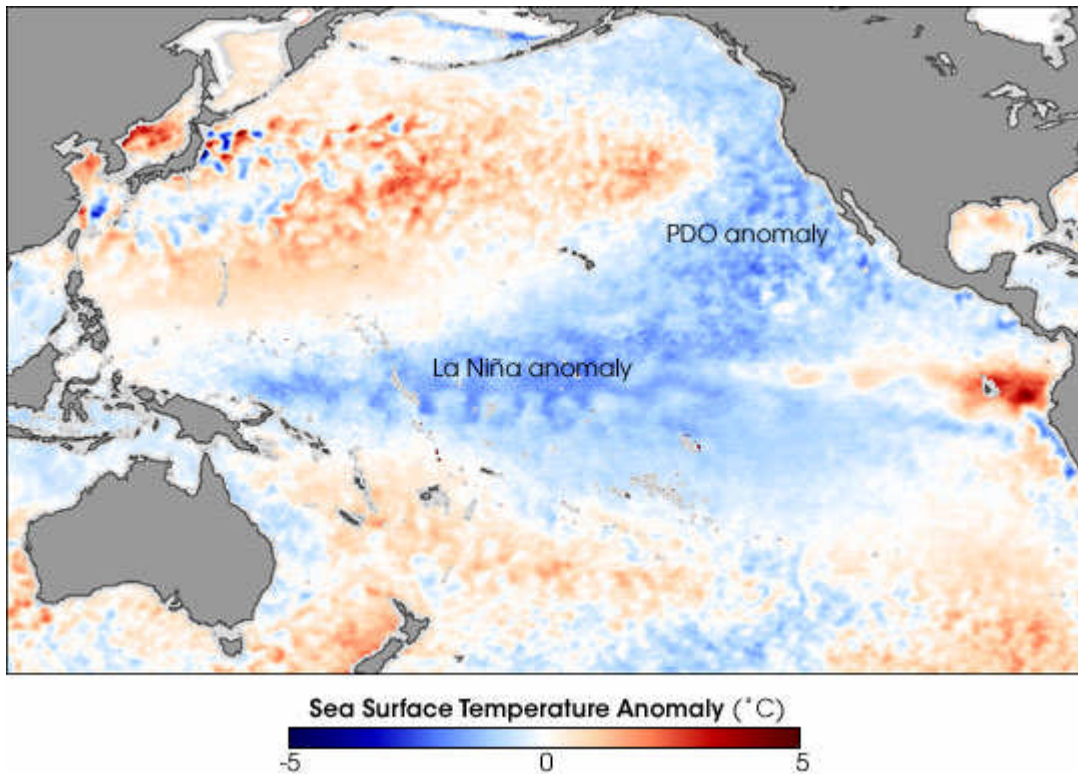


Figure 18. Cooling of the Pacific Ocean and setting up of the PDO. Sea surface temperature anomaly in the Pacific Ocean from April 14–21, 2008. The anomaly compares the recent temperatures measured with an average of data from 1985–1997. Places where the Pacific was cooler than normal are blue, places where temperatures were average are white, and places where the ocean was warmer than normal are red. The cool water anomaly in the center of the image shows the lingering effect of the year-old La Niña. However, the much broader area of cooler-than-average water off the coast of North America from Alaska (top center) to the equator is a classic feature of the cool phase of the Pacific Decadal Oscillation (PDO). The cool waters wrap in a horseshoe shape around a core of warmer-than-average water. (In the warm phase, the pattern is reversed). Unlike El Niño and La Niña, which may occur every 3 to 7 years and last from 6 to 18 months, the PDO can remain in the same phase for 20 to 30 years. (NASA image by Jesse Allen, AMSR-E data by Chelle Gentemann and Frank Wentz, Remote Sensing Systems. Caption by Rebecca Lindsey, adapted from a press release from NASA JPL).

As shown by the historic pattern of PDOs over the past century (Fig. 2) and by corresponding global warming and cooling, the pattern is part of ongoing warm/cool cycles that last 25-30 years. Thus, the past 30 years of global warming has apparently ended.