

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 has climate changed as rapidly as in the past century and that this proves that global warming is being caused by anthropogenic CO₂. Statements such as these are easily refutable by the geologic record. Figure 13 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 (Fig. 13). In addition, small temperature changes of up to a degree or so, similar to those observed in the 20th century record, occur persistently throughout the ancient climate record.

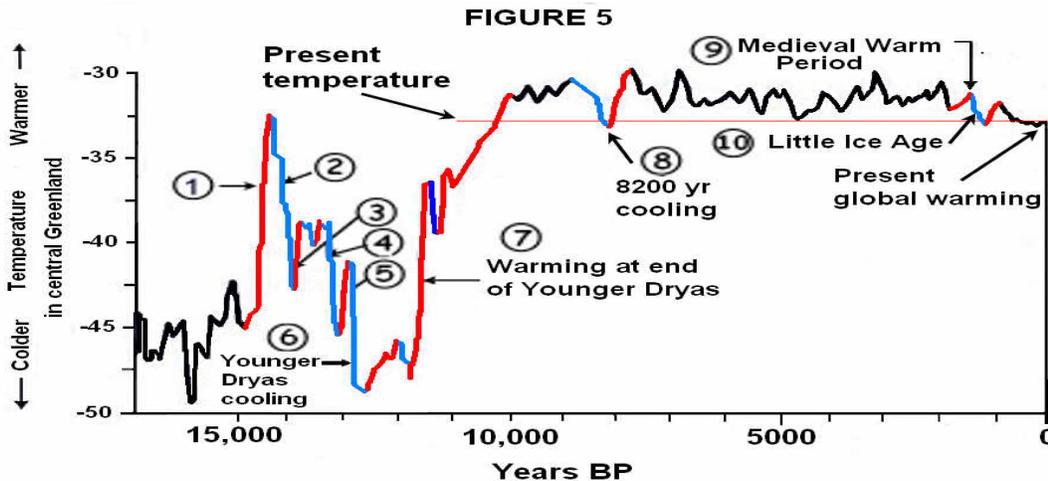


Figure 13. Temperature changes over the past 15,000 years. Red lines represent times of sudden warming, blue lines represent times of rapid cooling. Numbers refer to the events listed below. (Modified from Cuffey and Clow, 1997)

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. This warming occurred abruptly in only a few years (Steffensen et al., 2008).
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 (Fig. 14). 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 CO₂ changes.

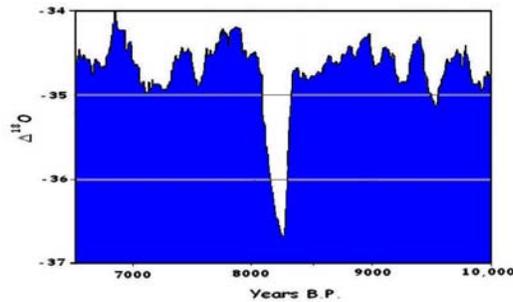


Figure 14. The 8200 year B.P. sudden climate change, recorded in oxygen isotope ratios in the GISP2 ice core, lasted about 200 years.

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 Period (MWP) was a time of warm climate from about 900–1300 AD when global temperatures were apparently somewhat warmer than at present. Its effects were particularly 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, 2007).

The Vikings colonized southern Greenland in 985 AD during the Medieval Warm Period (Lassen *et al.*, 2004) when milder climates allowed favorable open-ocean conditions for navigation and fishing. This was "close to the maximum Medieval warming recorded in the GISP2 ice core at 975 AD (Stuiver *et al.*, 1995).

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 statistical manipulation 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. 15) became known as "the hockey stick" of

climate change and was used in the 2001 IPCC report to assert that climate had not changed throughout the entire history of human civilization and there has never been an environmental shift remotely similar to this until the rise of

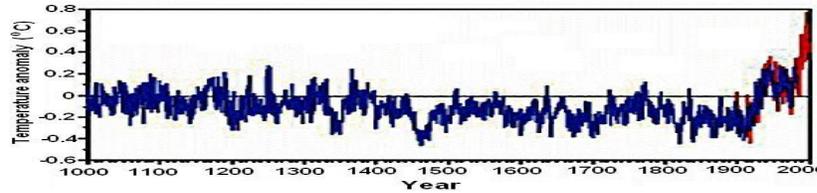


Figure 15. Mann et al. (1998) “hockey stick” graph of temperature change over the past 1000 years (IPCC)

The Mann “hockey stick” was at odds with hundreds of historical and isotope sources, including (1) the Greenland GRIP ice core isotope data, (2) sea surface temperatures from the Sargasso Sea sediments (Fig. 16A) (Keigwin, 1996), paleotemperature data other than tree rings (Fig. 16B) (Loehle, 2007), and (4) reconstructed summer sea surface temperatures near Iceland (Fig. 17) (Sicre et al., 2008).

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 has been comprehensively invalidated, to the great embarrassment of the IPCC.

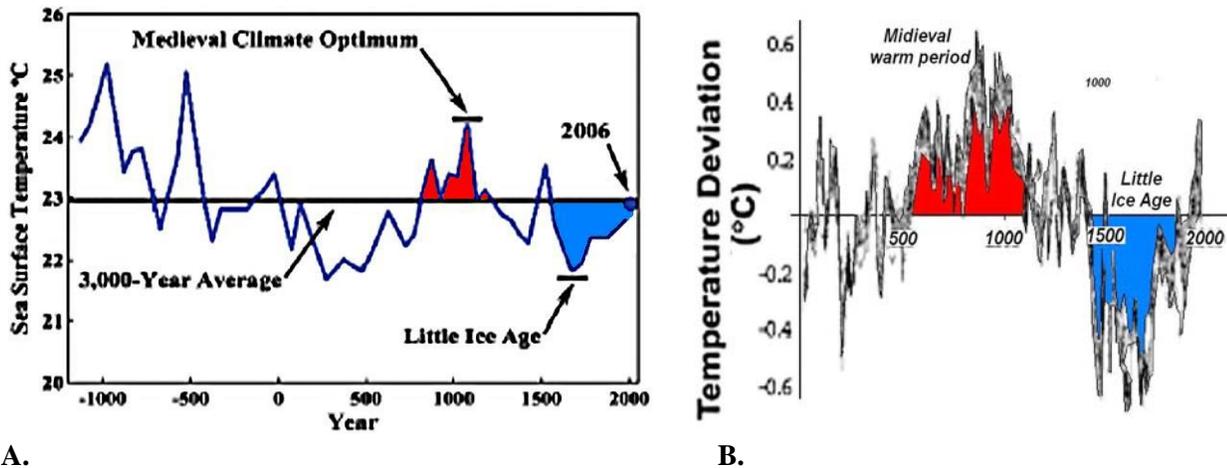


Figure 16A. Surface temperatures of the Sargasso Sea reconstructed from isotope ratios in marine organisms (Keigwin, 1996). **B.** Reconstructed paleo-temperatures without tree ring data (Loehle, 2007)

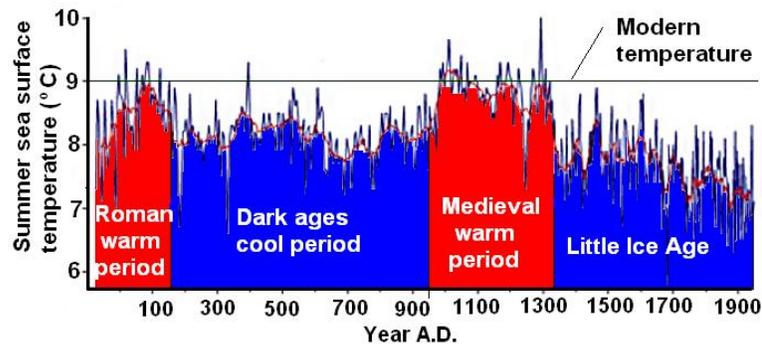


Figure 17. Summer sea surface temperatures near Iceland. (Sicre et al., 2008)

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

At the end of the Medieval Warm Period, ~1230 AD, temperatures dropped ~4°C (~7° F) in ~20 years and the cold period that followed is known as the Little Ice Age. The colder climate that ensued for several centuries was devastating (see e.g., Grove, 1988, 2004; Singer and Avery, 2007; Fagan, 2000). Temperatures of the cold winters and cool, rainy summers were too low for growing of cereal crops, resulting in widespread famine and disease. When temperatures

declined during the 30-year cool period from the late 1940's to 1977, some climatologists and meteorologists predicted a return to a new Little Ice Age.

Glaciers expanded worldwide (see e.g., Grove, 1988, 2004; Singer and Avery, 2007). Glaciers in Greenland began advancing and pack ice extended southward in the North Atlantic in the 13th century. 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 (Fagan, 2000; Singer and Avery, 2007).

Winters during the Little Ice Age were bitterly cold in many parts of the world. 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. 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.

In 1609, Galileo perfected the telescope, allowing observation of sun spots. From 1645 to 1715, solar activity was extremely low, with 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 and Dalton sunspot minima also occurred during significant cold periods within 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.

Fluctuations since the Little Ice Age--short-term climate cycles

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-long warm/cool cycles appear in the record of glacial fluctuations and isotope records in Greenland ice cores. Each warming period has been slightly warmer than the preceding one and each cool period has not been quite as cool as the previous one. During each warm cycle, glaciers retreated and during each cool cycle, glaciers advanced. Glacier termini have receded progressively upvalley from their Little Ice Age maximums.

North America

Comparison of historic retreats and advances of Jackson and Agassiz glaciers in Glacier National Park, Montana, with tree-ring reconstructions of North Pacific surface temperature anomalies shows that the maximum Little Ice Age glacial advance coincides with a period of cooling that began in the late 1700s and persisted until about 1830 with only one brief interruption (Pederson *et al.*, 2004). The mid-19th century recession of the Jackson and Agassiz glaciers correlates with strong climatic warming, and both glaciers retreated ~3-14 m/yr (Carrara and McGimsey, 1981). Strong warming from ~1915 to ~1945 caused the glaciers to retreat at rates >100 m/yr. The North Pacific switched from its warm phase to its cool phase in the mid-1940s and modest glacier advances occurred until the 1970s. The Pacific Ocean switched back into its warm mode in 1977 and moderate retreat of the Jackson and Agassiz glaciers took place through the 1990s. These glacier oscillations coincide almost exactly with global climate changes and all but the last 20 years of the more than 230 year record took place well before CO₂ could possibly have been a factor.