ATMOSPHERIC CARBON DIOXIDE

Although CO₂ has long been recognized as a greenhouse gas, it makes up only ~0.03% of the atmosphere (Figure 2), 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.](image)

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 ~280 ± 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.

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 (Fig. 4). 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 CO$_2$ from 1940 to 1977.

Is Global Warming Caused by Rising CO$_2$?

No tangible, physical evidence exists that proves a cause–and–effect relationship between global climate changes and atmospheric CO$_2$. The fact that CO$_2$ is a greenhouse gas and that CO$_2$ has increased doesn’t prove that CO$_2$ has caused global warming. As shown by isotope measurements from ice cores in Greenland and Antarctica and by measurements of atmospheric CO$_2$ during El Nino warming oceans emit more CO$_2$ 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 CO$_2$ rose, showing that climatic warming causes CO$_2$ to rise, not vice versa. No doubt exists that the present high levels of atmospheric CO$_2$ 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 CO$_2$ proponents

As seen in the previous discussion, no correlation exists between atmospheric CO$_2$ 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 CO$_2$, 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 CO$_2$ emissions. The IPCC conclusions are based on the empirical observation that global temperatures have risen during the past century and CO$_2$ has also risen and on computer model simulations that assume global temperatures will rise with increasing atmospheric CO$_2$. 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 6 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](image)

**Figure 6.** 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 6.

1. About 15,000 yrs ago, a sudden, intense, climatic warming (~12° C; ~21° 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 than had been dry land during the Ice Age.

2. A few centuries later, temperatures again plummeted (~11°; ~20° F) and glaciers advanced.

3. About 14,000 years ago, global temperatures rose rapidly (~4.5°C; ~8° F) once again and glaciers receded.

4. About 13,400 years ago, global temperatures plunged again (~8°C; ~14° F) and glaciers advanced.

5. About 13,200 years ago, global temperatures increased rapidly (~5°C; ~9° F) and glaciers receded.

6. 12,700 yrs ago global temperatures plunged sharply (~8°C; ~14° F) and a 1000 year period of glacial readvance, the Younger Dryas, began.

7. 11,500 yrs ago, global temperatures rose sharply (~12° C; ~21° 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 (~4° C; ~7° F) that lasted for a few centuries (Figures 6 and 7). 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.

![Graph](image)

**Figure 7.** 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. 8) 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 8. Mann (1998) “hockey stick” graph of temperature change over the past 1000 years](image)

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. 9) (Keigwin, 1996), and paleo-temperature data other than tree rings (Fig. 10) (Loehle, 2007). McIntrye and McKitrick (2003) evaluated the data in the Mann paper and concluded that the Mann curve was invalid “due to collation erros, unjustifiable truncation or extrapolation of source data, obsolete data, geographical location erros, 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 9. Surface temperatures of the Sargasso Sea reconstructed from isotope ratios in marine organisms (Keigwin, 1996).

Figure 10. 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, ~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. 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, many climatologists and meteorologists predicted a return to a new Little Ice Age.

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. 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 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.