Are Humans Responsible for Global Warming?

A REVIEW OF THE FACTS

APRIL 2007

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ENVIRONMENTAL DEFENSE
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The case for attributing the recent global warming to human activities rests on the following undisputed scientific facts:

- Carbon dioxide (CO_2) is a greenhouse gas that warms the atmosphere.
- Since pre-industrial times, atmospheric CO_2 concentrations have increased from about 280 parts per million (ppm) to over 380 ppm. Current concentrations of CO_2 and other greenhouse gases are unprecedented in at least the last 650,000 years, based on records from gas bubbles trapped in polar ice.
- Independent measurements demonstrate that the increased CO_2 in the atmosphere comes from burning fossil fuels and forests. The isotopic composition of carbon from these sources contains a unique "fingerprint."
- Since pre-industrial times, global average temperatures have increased by about 0.7°C, with about half of the warming occurring over the past few decades.
- The only quantitative and internally consistent explanation for the recent global warming includes the intensified greenhouse effect caused by the increase in CO_2 and other greenhouse gases.

The U.S. National Academy of Sciences—the independent organization of the country's most renowned scientists established by Congress to advise the nation on scientific and technical issues—has concluded: "The scientific understanding of climate change is now sufficiently clear to justify nations taking prompt action."

Some argue that the recent global warming is due to natural fluctuations and not to human activities. This argument and its fallacies are discussed below.

Argument 1: CO_2 is not coming from human activities

CO_2 has natural sources: volcanoes for example. All animals exhale it. How can human activities be affecting the concentration of CO_2 on a global scale?

The Facts

Natural processes emit large quantities of CO_2 into the atmosphere, but they also remove it—at nearly identical rates. This balance maintained the concentration of CO_2 at a stable level for thousands of years prior to the Industrial Revolution. In the case of global warming, the question is: What is causing the *increase* in CO_2 concentrations? The answer turns out to be incontrovertible. The isotopic composition of carbon in atmospheric CO_2 provides a unique "fingerprint" that tells scientists that the lion's share of the additional CO_2 accumulating in the atmosphere is from the burning of fossil fuels.

Argument 2: No one really knows why the climate varies

The global climate has fluctuated considerably over the Earth's history, either for unknown reasons or because of "internal variability" in the climate system. We do not know enough about the climate system to attribute the present global warming to any specific cause.

The Facts

It is true that the Earth's climate has exhibited wide swings over geologic time due to natural processes. However, scientists have reasonable qualitative explanations for most of the significant variations in

climate over geologic time;[1] they can be largely attributed to specific processes, not to unknown internal oscillations. Many of the major climatic changes can be traced to changes in the Earth's orbit around the sun (Hays et al. *Science*, **194**, 1976, pg. 1121). Others can be linked to specific events (such as the impact of a comet or meteorite or the assembly or breakup of supercontinents) that led to large changes in the concentration of atmospheric greenhouse gases. For more recent times (the past millennium), scientists have been able to quantitatively attribute the major temperature fluctuations to changes in solar activity, volcanic eruptions, and human-produced greenhouse gases and particulate pollution. These natural processes can not explain the current warming.

Argument 3: The Medieval Warm Period disproves global warming

The current warming trend is analogous to the Medieval Warming Period (MWP). Since the MWP was obviously a natural event, the current warming is also likely caused by natural processes.

The Facts

The Medieval Warm Period (MWP) refers to a relatively warm period lasting from about the 10th to the 14th century.[2] However, the initial evidence for the MWP was largely based on data[3] gathered from Europe, and more recent analyses indicate that the MWP was not a global phenomenon.

A number of reconstructions of millennium-scale global temperatures have indicated that the maximum globally averaged temperature during the MWP was not as extreme as present-day temperatures and that the warming was regional rather than global. Perhaps the most well-known of these is that of Michael Mann and colleagues (*Nature*, **392**, 1998, pg. 779). Their reconstruction produced the so-called "hockey stick" graphic that contributed to this conclusion in the 2001 assessment of the Intergovernmental Panel on Climate Change: "The…'Medieval Warm Period' appear(s) to have limited utility in describing trends in hemispheric or global mean temperature changes in past centuries."

The accuracy of the "hockey stick" graphic was widely discussed in the press when the Mann et al. methodology was criticized by McIntyre and McKitrick (*Geophys. Res. Lettr*, **32**, 2005, pg. L03710). Less attention was given to subsequent studies, such as that of Moberg and colleagues (*Nature*, **433**, 2005, pg. 613) and Osborn and Briffa (*Science*, **311**, 2006, pg. 841) that were based on different, independent methodologies but reached conclusions similar to Mann.

Observations of melting high altitude glaciers are perhaps even more telling. Andean glaciers that have been intact for more than 5,000 years are now rapidly melting (Thompson et al. *Proc. Nat. Acad. Sci.*, **103**, 2006, pg. 10536). If the MWP was truly global, these glaciers would not have survived.

More generally, it is a logical fallacy to argue that because the climate has changed in the past due to natural causes, the current warming trend must also be due to natural causes. The debate over the magnitude and causes of earlier climate change such as the MWP is of scientific interest, but it does not invalidate the considerable direct scientific evidence that human-produced greenhouse gases have been causing the Earth to warm recently.

Argument 4: Recent predictions of a new ice age disprove global warming

In the 1970s climate scientists were saying an ice age was imminent. Now they say the Earth is warming. They don't know what they are talking about.

The Facts

The Earth's climate for the past 2 million years has been characterized by ice ages lasting close to 100,000 years, punctuated by relatively short (10,000- to 30,000-year) warm periods or "interglacials." The swing from glacial to interglacial is caused by changes in the Earth's orbit around the sun amplified by natural feedbacks involving greenhouse gases (Hays et al. *Science*, **194**, 1976, pg. 1121).

The Earth entered the present interglacial about 10,000 years ago. All things being equal (i.e., in the absence of a large human-produced source of CO_2) it is highly likely that the Earth will swing back into a glacial period or ice age. But this will not occur for thousands of years.

As early as the 19th century, scientists recognized that greenhouse gases warm the planet, and that increases in atmospheric carbon dioxide could lead to global warming on time scales of decades to centuries—much shorter than the fluctuations related to ice ages and interglacials. Around the same time, global temperatures began to increase and scientists became increasingly concerned that humans were interfering with the climate.

In the 1950s the upward trend in global temperatures unexpectedly halted and temperatures declined somewhat. This led some scientists to become concerned about global cooling and, in turn, to headlines in the popular press about an imminent ice age. What the skeptics fail to admit is that within the scientific literature—as opposed to the popular press—global warming remained a serious concern. Many scientists of the time argued that whatever the cause of the cooling, natural or otherwise, it would be eventually overshadowed by the warming effect of carbon dioxide. In 1979, the National Academy of Sciences warned that a doubling of carbon dioxide would increase global temperatures by 1.5 to 4.5°C (*Carbon Dioxide and Climate: A Scientific Assessment,* NAS Press, 1979) and shortly thereafter a resumption of the upward trend in temperatures was detected.

Over the past quarter century, scientific research on global climate change has intensified, and programs on an international scale have been organized. More and more data are included in computer models that are capable of recreating past trends and more precisely predicting future scenarios. We now know that the mid-20th century pause in global warming was caused by pollution from burning coal, which produced tiny particles or aerosols that blocked the energy from the sun. As aerosol emissions were controlled but greenhouse gas pollution continued to increase, the cooling effect of the aerosols was overwhelmed by the greenhouse gases, and global warming resumed.

Argument 5: Scientists cannot "prove" current warming is not natural

Climate scientists can not prove that the current warming is not due to natural processes and therefore can not claim with certainty that the warming is due to human interference.

The Facts

It is of course true that, in a complex system like climate, it is virtually impossible to prove a negative; i.e., that natural processes are not causing the current warming. What we can do is eliminate every possible natural explanation that can be posited.

Thermodynamics tells us that the warming of the Earth's lower atmosphere *must* arise from one or more processes that supply excess heat to the lower atmosphere. Besides the greenhouse effect, the viable processes are (1) increased output from the sun; (2) increased absorption of heat from the sun due to a change in the Earth's planetary reflectivity or "albedo"; and (3) an internal variation in the climate system that transfers heat from one part of the Earth to the atmosphere. Direct observations confirm that none of these explains the observed warming over the latter half of the 20th century. For example there has been no appreciable change in solar output over the past two decades (see Figure 1).

Figure 1.
Change in solar output from 1980 to 2005.

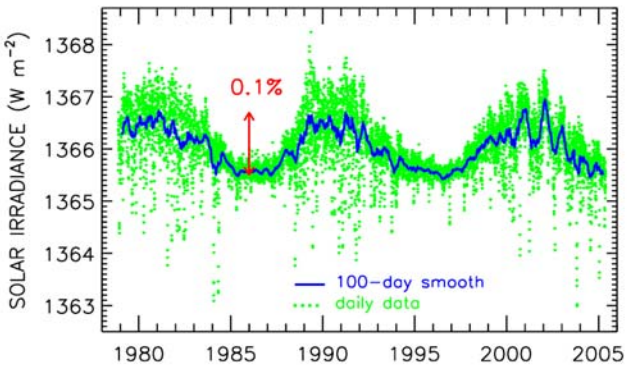


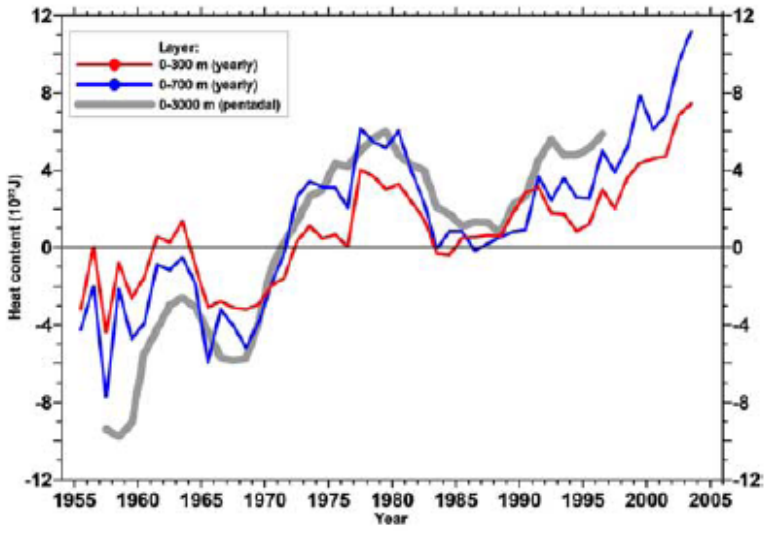
Figure 1 shows the relative change in solar output determined from two of satellite measurements over a two-decade period. The data show variability in solar output corresponding to the 11-year sunspot cycle, but no secular trend.

Source: After Lean and Froelich, 2006.

Satellite data reveal that the Earth's reflectivity increased (causing cooling instead of warming) in the '60's, '70s, and early '80s and has decreased modestly since.[4] The overall warming from the recent decrease in reflectivity is also small compared to the greenhouse warming.

In the case of internal variations, the ocean is the only viable reservoir of internal heat that could have caused the atmosphere to warm on decadal time-scales. However, observations show that the heat content of the ocean has increased instead of decreased over the past few decades (See Figure 2). This indicates that the atmosphere has been a source of heat to the ocean rather than vice versa. Moreover, the amount of heat increase in the ocean is consistent with what is needed to balance the Earth's energy budget given the excess heating from the enhanced greenhouse effect and the amount of excess heat observed to be stored in the atmosphere (Hansen et al. *Science*, **308**, 2005, pg. 1431). In other words, the amount of heat stored in the ocean over recent years matches the amount of heat that models predict should be trapped on Earth due to the increase in greenhouse gases.

Figure 2.
Change in heat content of ocean 1955 to 2005



Source: After Levitus et al. 2005.

FIGURE 2 SHOWS THE RELATIVE CHANGE IN THE HEAT COTENT OF THE OCEAN FROM 1955 TO 2005 BASED ON A COMPREHENSIVE ANALYSIS OF OCEAN TEMPERATURE MEASUREMENTS. THE DATA SHOW SHORT TERM VARIABILITY BUT A CLEAR UPWARD TREND ON DECADAL TIME-SCALES.

Conclusion

- The Medieval Warm Period does not represent an analogy to the warming of the late 20th century, for which scientists have independent evidence of human causation, and the evidence strongly suggests that the MWP was a regional, rather than a global phenomenon.
- Our understanding of the climate system is sufficient to provide qualitative models for most global or hemispheric climatic variations over geologic history and quantitative models for variations over the past millennium.
- The Earth's climate may return to ice age conditions in thousands of years, but this does not preclude devastating effects from global warming over the next few centuries.

- All known natural explanations for the current global warming trend have been eliminated by direct observations. The human-intensified greenhouse effect provides the only quantitative explanation for the current warming trend.

About the authors

Dr. Wang received his doctorate from Harvard University and works as a climate scientist at Environmental Defense. He has published several peer-reviewed papers on the global methane budget and was the author of "The Latest Myths and Facts on Global Warming," which was read into the congressional record by Senator John McCain in 2005. The report is available at http://www.undoit.org/pdfs/mythsvfacts.pdf.

Dr. Chameides, chief scientist at Environmental Defense, is a member of the U.S. National Academy of Sciences and has been named a National Associate of the National Academies. He is also an American Geophysical Union Fellow, and has received the American Geophysical Union's Macelwane Award. Dr. Chameides has served as editor of the *Journal of Geophysical Research* and is the author or co-author of more than 120 scientific publications and five books. He received his doctorate from Yale University.

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[1] The explanations are qualitative instead of quantitative because we do not have quantitative data from these events in the distant past to construct their exact histories.

[2] It has been suggested based on temperature reconstructions and model simulations that the MWP may have been caused by increased solar activity or a dearth of volcanic activity.

[3] Because worldwide temperature measurements do not exist before the 19th century, temperature records before the 19th century are based on reconstructions of the temperature from the variations in temperature-sensitive proxies (e.g., tree rings, isotopes in ice cores).

[4] These variations are possibly due to changes in the concentrations of atmospheric aerosols produced from the burning of fossil fuels and biomass.