Climate change: Conflict of observational science, theory, and politics

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ABSTRACT

Debate over whether human activity causes Earth climate change obscures the immensity of the dynamic systems that create and maintain climate on the planet. Anthropocentric debate leads people to believe that they can alter these planetary dynamic systems to prevent what they perceive as negative climate impacts on human civilization. Although politicians offer simplistic remedies, such as the Kyoto Protocol, global climate continues to change naturally. Better planning for the inevitable dislocations that have followed natural global climate changes throughout human history requires us to accept the fact that climate will change, and that human society must adapt to the changes.

Over the last decade, the scientific literature reported a shift in emphasis from attempting to build theoretical models of putative human impacts on climate to understanding the planetwide dynamic processes that are the natural climate drivers. The current scientific literature is beginning to report the history of past climate change, the extent of natural climate variability, natural system drivers, and the episodicity of many climate changes.

The scientific arguments have broadened from focus upon human effects on climate to include the array of natural phenomena that have driven global climate change for eons. However, significant political issues with long-term social consequences continue their advance. This paper summarizes recent scientific progress in climate science and arguments about human influence on climate.

INTRODUCTION

Separating science from its use in public policy is not always possible. Discussions of science that is in the public purview cannot be

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restricted to the science alone. Scientists are required to place their work in its public context. Current continuing debate over whether humanity is changing the Earth's climate is an example of a debate in which science plays a secondary role to social policy and international economics. It is also a debate complicated by the mystique of computer modeling that obscures observational science. The purpose of this paper is to update the reader on the latest in scientific studies of climate change and to discuss roles of natural variability in the context of modern climate change.

The issue, simply stated, is that the Earth's climate has likely been warming over the last 150 yr, roughly coincident with the industrial revolution and with the end of an abnormal cold spell commonly referred to as the Little Ice Age. With the warming has come an increase in atmospheric carbon dioxide, some of which is attributable to human oxidation of carbon-based fuels, both fossil and biomass. The cause, the effects, and the relative scale of climate variation are in dispute. Polarized arguments are human versus natural climate change, small amount of warming versus unprecedented warming, and fossil fuel greenhouse gas-driven change versus natural drivers, largely solar and orbital. The suggested solution for human-driven climate change is elimination of fossil fuels from the global energy mix, particularly in industrialized countries. The solutions for the effects of natural climate change are adaptation and planning.

The people of the world who are most vulnerable to climate change (i.e., those on low-lying islands, in coastal areas subject to storm surge, on the margins of expanding deserts, etc.) have been led to believe that human beings can control climate through science, engineering, and technology according to political and economic needs. Obvious trends showing oceanic flooding, increased heat, desertification, and ecosystem changes are seen as preventable by the simple mechanism of decreasing human use of carbon-based energy. I suggest that the efforts of human beings cannot modify the enormous amount of solar energy driving Earth's dynamic climate system, regardless of how much science, technology, and engineering are currently available.

There are political forces at work that seek to exploit fears of human control of the Earth's climate as a device to transfer wealth and to effect social policies. Strong social forces and a very large amount of human ego are committed to ignoring rational science.

Our job as scientists is to test climate change arguments against observations and data and to advance data-driven science. This paper attempts to put some of the major arguments into scientific focus. I encourage readers to form their own opinions of the issues, then to test them against data and observations.

SCIENTIFIC BACKGROUND

Scientific research into climate change has progressed rapidly in recent years (see the references cited). One of the most difficult concepts to communicate to the media and to government has been demonstrating that the Earth's climate has changed frequently and radically in the recent past, without any input from humans. Recently, we have come to understand that there is superb correlation between the sun's activity and the Earth's climate. The works of Hoyt and Schatten (1997) and Bond et al. (2001) are of particular note and are discussed in detail in this paper. The recent literature is replete with additional studies correlating solar and orbital variability with climate change; some are cited here. These studies have been largely ignored in the popular press and in political circles.

There are many smaller climate drivers of natural origin in addition to the sun, such as volcanic eruptions, meteorite impacts, oceanographic circulation changes, orbital variations, tectonic uplift, and relative positioning of continents (Gerhard et al., 2001; Gerhard and Harrison, 2001). The Earth's climate is constantly changing, either cooling or warming, and natural swings in average temperature at the surface are huge over many timescales from 11-yr-long sunspot cycles to geologic time spans (Bluemle et al., 2001).

However, many non-earth scientists believe that humans are causing climate change, based on the theory that increasing greenhouse gases in the atmosphere, in part because of use of fossil fuels, contribute to climate change, thereby adding to, in their minds, human modification of other dynamic Earth processes.

The argument that human civilization induces climate change is derived from computer models of greenhouse theory (general circulation models [GCM]; among the best known are the Hadley Center model in the United Kingdom and the National Oceanographic and Atmospheric Administration model in the United States). Although these models are complex mathematical simulations of atmosphere behavior according to greenhouse theory, they have not been able to replicate past climates and climatic change prior to the Little Ice Age (Mann et al., 1999) and are simplistic representations of what is currently understood about climate behavior (Soon et al., 2001a, b). Nonetheless, the models have vigorously pursued support from non-earth scientists and the media. The result is public policy proposals to control greenhouse gases to control changes in the Earth's climate (the Kyoto Protocol) without substantial credible scientific evidence to support the assertion that greenhouse gases from human activity are significant drivers of the Earth's climate.

Regarding computer models, A. Byrnes (2003, personal communication), a Kansas Geological Survey research scientist and a professionally well-known petrophysicist who frequently employs computer reservoir models, summed the current climate modeling controversy as follows:

> In multivariate phenomena, many variables do not exert independent influence. Observations made of multivariate phenomena are usually correct but present information about the phenomena from different perspectives; that is, they each test different hypotheses, make different assumptions, and hold different variables or boundary values constant. As with the three blind men describing an elephant, each is telling the truth, but each provides a completely different view. It is common to construct models that are internally consistent within the boundaries of a defined problem but which are not required to be externally consistent, where the model results may not explain but are not in conflict with observations outside the model. Fully accurate models must be able to explain, or at minimum not conflict with, all data, or there must be a valid reason for rejecting or ignoring data that are inconsistent with the model.

The viewpoint of earth scientists is that there is overwhelming geologic evidence that natural variability in Earth's climate greatly exceeds human-induced effects (Lamb, 1995; Bluemle et al., 2001; Gerhard et al., 2001), and that there is no current technology to control that natural variability. Correlation of sun intensity cycles, orbital variations, and geologic factors establish that Earth's climate is fundamentally beyond human control (Hoyt and Schatten, 1997; Bond et al., 2001; Davis and Bohling, 2001).

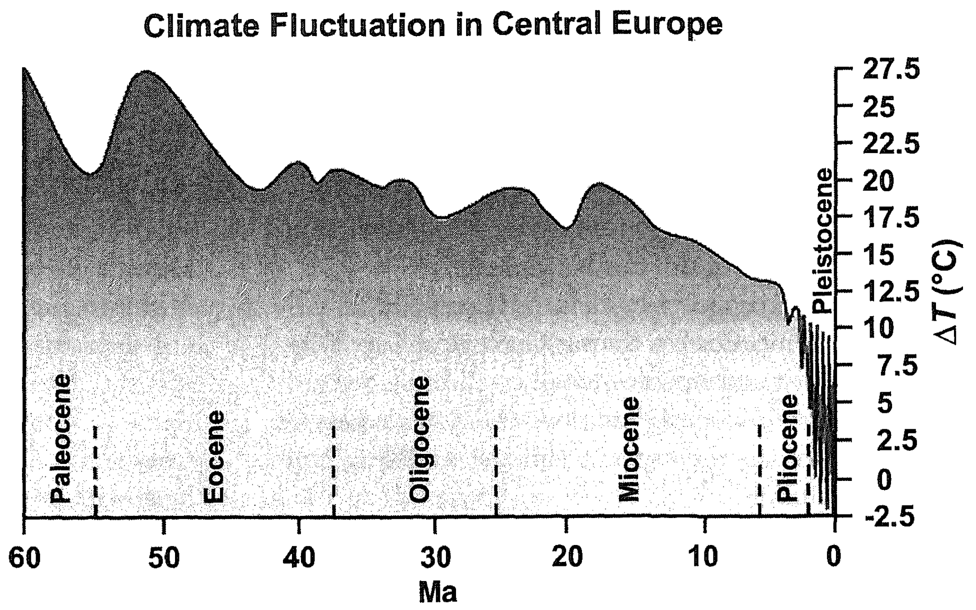
The Recent Literature

In recent years, the tone of scientific literature has evolved from arguments that attempted to demonstrate human effects on climate to studies that document natural climate drivers.

What many consider the baseline reference on assessing human versus natural climate control is the data compilation of Lamb (1995), a professor at the University of East Anglia. Although he was concerned about human climate modification, his book is a compendium of human measurements of climate through recorded human history, using quantifiable proxies such as artifacts, tax records, and food records. He identified the Medieval Climate Optimum, the Little Ice Age, and many other dramatic shifts in climate, documenting them with real human experiences. Included in these documents are the stories of Viking settlements on Greenland during the Medieval Climate Optimum (and consequent European discovery of North America) and their extirpation during the onset of the Little Ice Age, glacial waxing that destroyed aqueducts, records of vineyards in locations in England that are now too cold to support them, and population migrations that correspond to climate changes. Empirical data and first-order climate proxies reported in Lamb's work must be honored by any climate model that attempts to replicate the past 1500 yr. An additional review of past climate information is also provided by Bluemle et al. (2001) (Figure 1) over 60 m.y., with significant changes over the last 1000 yr (Figure 2).

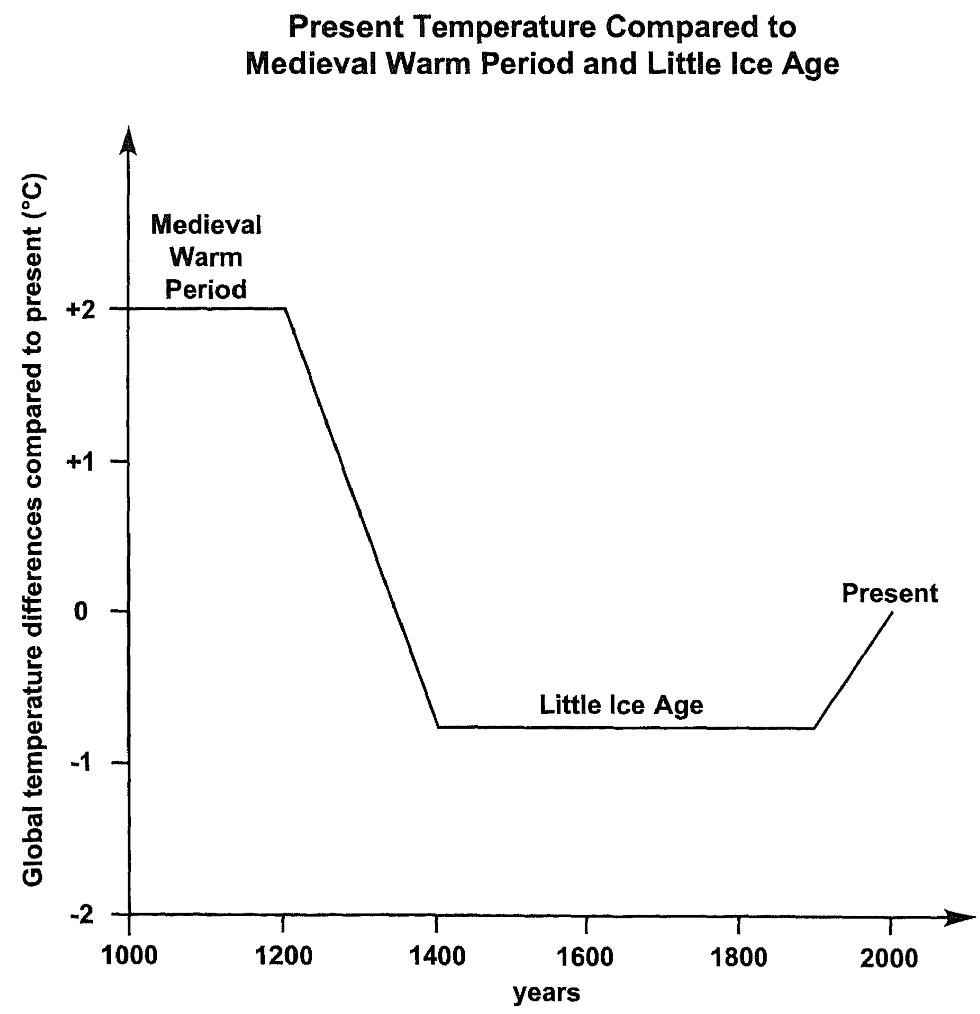
The latest Intergovernmental Panel on Climate Change (IPCC, a United Nations sponsored organization) report (Houghton et al., 2001) argues that there was no Medieval Climate Optimum, based on a controversial tree-ring data paper (Mann et al., 1999). The IPCC interpretation of discernible human impact on climate is based on the elimination of demonstrable natural major climate change over the last 2000 yr, but Mann et al.'s conclusions are contrary to the human experiences recorded by Lamb (1995). Since then, Esper et al. (2002), also using tree-ring data, demonstrated that there was significant warming and cooling during the past two millennia and demonstrated that current temperature change is consistent with past changes during recorded human history. Another critique of the Mann et al. paper is that of Daly (2000), who argued the methodology and conclusions of the Mann et al. paper. Broecker (2001) also found evidence that the Medieval Warm Period was a global event, using borehole temperatures, that these warm and cold cycles last about 1500 yr, and that the change in temperature is about 2°C. Soon et al. (2003) have developed a synopsis of literature about the past 1000 yr and argue forcefully for the global extent of

Figure 1. Climate change over 60 m.y., showing how climate has cooled naturally since the Cretaceous and the large oscillations of temperature during the Pleistocene. From Bluemle et al., 2001; used with permission from AAPG, whose permission is required for further use.



the Medieval Climate Optimum and subsequent Little Ice Age. They also tested the 20th century as "nominally the warmest of the last millennium" and "warmest year of the last millennium" (Mann et al., 1999, as cited in Soon et al., 2003, p. 29) and found that they are neither the warmest nor particularly unique. Observations such as these run counter to computer models, but are the basis for any rational scientific discussion of climate change. Recently, McIntyre and McKittrick (2003) replicated the Mann et al. study, demonstrating that

Figure 2. Simplified diagram of natural climate change over the last 1000 yr, showing that the Earth's climate has been warmer in the last 1000 yr than today, long before any human industrial development. Graph indicates that today's temperatures are considerably less than that of the Medieval Warm Period. Graph supplied by David Wojick.



the data used by Mann et al. are not consistent with the Mann et al. conclusions. Their paper has elicited numerous responses and has generated more discussion of the quality of the science underlying the IPCC reports (Houghton et al., 2001) than anything published heretofore.

Arguments that increased greenhouse gases are driving climate change require that temperature changes follow greenhouse gas changes, and computer models require that polar climates reflect these changes first (Doran et al., 2002). Fischer et al. (1999) demonstrated that carbon dioxide concentrations tend to lag climate change by as much as 400 yr through Phanerozoic history, thus arguing that historically, carbon dioxide concentration increase is a resultant, instead of a driver, of climate change. Doran et al. (2002) demonstrate that Antarctica is cooling instead of warming, indicating that greenhouse gases are not driving global climate. Davis and Bohling (2001) show that modern temperatures have been rising evenly and steadily since 1840, well before any industrial carbon dioxide emissions. Carbon dioxide was double present levels at 60 Ma and was likely 17 times present-day levels during the glacial episodes of the very late Precambrian (Moore et al., 1996), 500 Ma (commonly referred to as "Snowball Earth"). Most recently, Royer et al. (2004) argue on the basis of models that the carbon dioxide concentration of the atmosphere oscillated in parallel to global temperature, as indicated by extended glacial episodes with low concentrations of carbon dioxide. Although they use this correlation as evidence that carbon dioxide drives climate, they do not speculate on the origin of carbon dioxide concentration changes. Cooling during glacial episodes diminishes vegetative growth, and cooler oceans absorb carbon dioxide. Coupled with data showing a lag of carbon dioxide rise to temperature rise (Fischer et al., 1999, who demonstrated a multihundred-year lag of carbon dioxide adaptation to temperature change), there is little to sustain the opinion that carbon dioxide concentration is a major driver of global climate.

In the lower troposphere, atmospheric temperature change should be an early warning of greenhouse gas impacts on Earth's climate. There is continuing debate over whether this zone is warming, cooling, or stable, but the overwhelming data suggest stability (National Research Council, 2000; Christy, 2003; Santer et al., 2003). Recent arguments that corrections of balloon and satellite data may reflect a tiny amount of warming (Santer et al., 2003) contrasted with the findings of the National Research Council (2000). Temperature changes in the lower troposphere are so slight ($\pm 0.1\,^{\circ}C$) as to be unresolved noise, whatever their direction (Christy, 2003).

Arguments of greenhouse gas climate forcing results in increased severe weather events have been examined by Starkel (2002), who could not identify any increase in storm events based on statistical analysis of fluvial runoff events through the Holocene; there is no evidence that severe weather events have increased in the 20th century and some suggestion that they have actually decreased (Gulev et al., 2001; see also Crisci et al., 2002). Despite the evidence, the popular myth of increased severity of storm events continues in the media and in other non-earth sciences (Rombeck, 2004).

The role of orbital variations on climate has been addressed by several scientists. Zahn (2002) reviews recent literature to document that Milankovitch orbital variations are linked to climate change periodicity, whereas Preto et al. (2001) interpret orbital variations in carbonate buildups of the Middle Triassic.

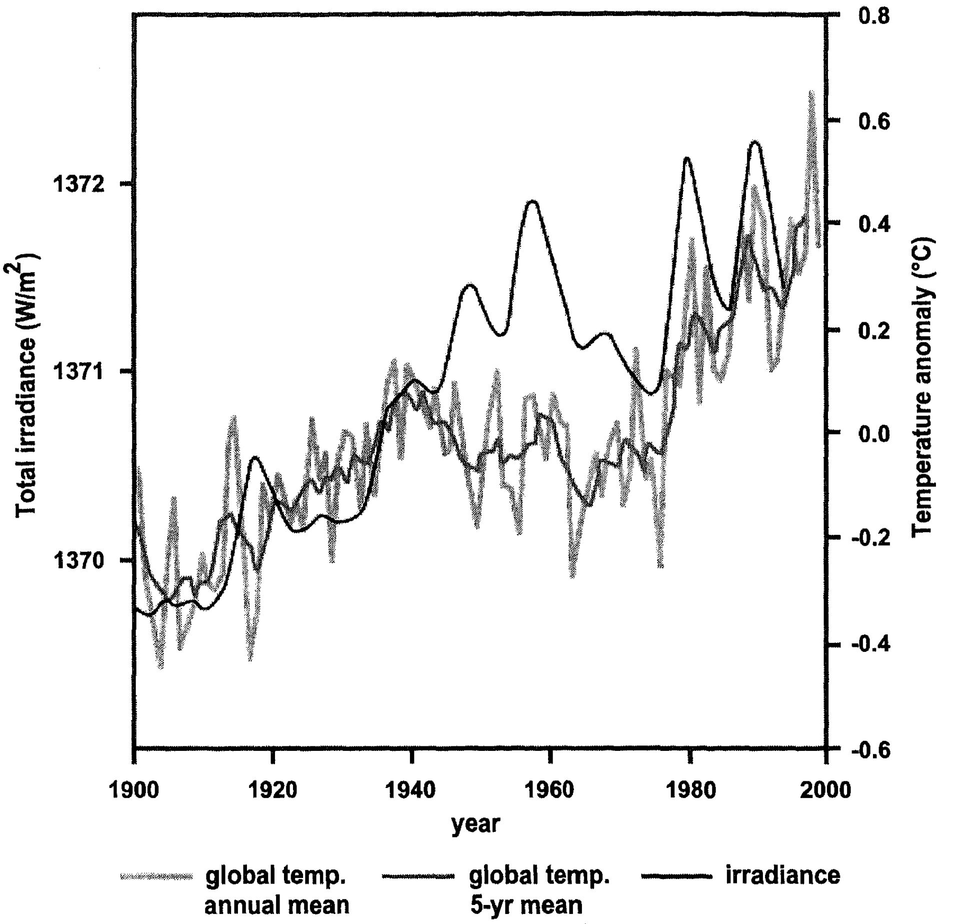
Modern literature abounds with good observations and measurements. Few lend credence to any measurable human impact on Earth's climate, but many demonstrate great natural variability of climate.

What Known Dynamic Processes Might Drive Natural Climate Variability?

Recently, we have come to understand that there is superb correlation between the sun's activity and the Earth's climate. Hoyt and Schatten (1997) present historical sunspot activity and climate change correlations over the last few centuries showing correlation of lower temperature with lower sunspot activity. This culminates in the Maunder Minimum of sunspot activity that correlates with the Little Ice Age (see also Pekarek, 2001).

Among many recent papers detailing the effects of orbital and solar variability on Earth's climate through time, perhaps the most significant is that of Bond et al. (2001). Bond et al. measured the cosmogenic nucleides ^{10}Be (from Greenland ice cores) and ^{14}C (from tree rings), whose abundance is inversely proportional to irradiance, interpreting a correlation of Heinrich events of ice rafting (ice drifts) indicating warming to cooling episodes over nearly 12,000 yr. The ^{14}C data extend to the Little Ice Age, whereas the ^{10}Be data extend to about 3000 yr ago. The graphical correlations demonstrate 1500-yr-long climate cycles and are, in my judgment, the most important piece of evidence demonstrating solar dominance of climate change (Figure 3).

Figure 3. A graph of the 20th century solar variability and Earth's temperature. Solar data provided by Gerard Bond, Columbia University. Temperature data from Goddard Institute for Space Studies. This plot demonstrates the close correlation between the Earth's temperature and solar activity for the 20th century. Less positive correlation during World War II may reflect data-quality gaps and increased dust because of that conflict and atmospheric atomic testing. Irradiance is solar input, expressed as watts per square meter. The discrepancy in the 1940s may be caused by the effects of dust and smoke added to the atmosphere by World War II (see Koren et al., 2004, who attribute cooling to smoke inhibition of cloud formation in the Amazon).



Arguments that the variation in solar intensity is insufficient to produce measurable climate change have been answered by Carslaw et al. (2002). In their review article, Carslaw et al. point out that solar effects are multiplied by clouds, generated through solar variability. There is also a major climate role for orbital variations (see Khodri et al., 2001; Naish et al., 2001; Zahn, 2002, for examples).

Petit et al. (1999) demonstrated that natural forcing, likely orbital and solar, have created about 100,000-yr glacial cycles in Antarctica, based on the study of the Vostock ice core, with companion increases in carbon dioxide. Although they interpret that carbon dioxide helped drive the climate cycles, it is apparent that the two curves are either synchronous, or that temperature change predates carbon dioxide increases. An interpretation that the carbon dioxide increase reflects natural warming and thus greater vegetation emissions is equally valid. Naish et al. (2001) state that the temperature was 3–4°C higher than present at the Oligocene–Miocene boundary, and that the greenhouse gas levels were at least twice ambient. Fischer et al. (1999) demonstrated that there is a multihundred-year lag of carbon dioxide adaptation to temperature change, and that carbon dioxide grows in concentration after onset of temperature rise, thus suggesting that the second interpretation of the Vostock data is the more correct.

Davis and Bohling (2001) and Kotov (2001) argue that both past and present trends suggest that the future climate will be natural continuing warmth, followed by descent into colder, perhaps glacial, conditions (Figure 4). As Davis and Bohling point out, one can make the argument that climate is either cooling or warming, depending on the time span used to make the assessment. Their data demonstrate that the overall long-term trend is cooling, but episodes of warming and cooling alternate frequently and sometimes very quickly.

In summary, current science has identified solar and orbital variability as the major driver of Earth's climate changes, modified both by other natural processes and perhaps modified by human intervention through increased greenhouse gas emissions. Although theory still considers greenhouse gases as significant contributors to climate change, the only positive correlation between a process and climate change is between solar (and orbital) variability and climate change, as documented by

Bond et al. (2001) and others. These climate drivers cannot be purposefully deflected nor climate modified with current technology.

THE POLITICAL ISSUE

The primary political device for climate control, the Kyoto Protocol, purports to keep the Earth's temperature from increasing by greatly reducing the use of fossil fuels energy in industrialized countries, particularly the United States, while permitting unrestrained uses of fossil energy in developing countries. The backers of the Kyoto Protocol do not convincingly argue that such draconian measures will make a measurable difference in climate, but they do admit it will create huge increases in the cost of energy (Energy Information Administration, 1998; see also AAPG position paper, Climate Change Policy, http:dpa.aapg.org /gac/papers/climate_change.cfm). It will likely restrict access of Americans to sufficient energy to maintain our current standard of living. Proponents argue that caution demands that we take these measures just in case the theory is correct (Oil & Gas Journal, 2000; Foster et al., 2000).

One of the major discussion points in the public climate debate has been the ultimate effect of climate change on human endeavors, from rising sea levels to crop growth rates. The human contribution to climate change is very small and will likely not be identifiable within the background of natural change. The total projected human addition to the carbon budget is about 5% (Energy Information Administration, 1998), of which industrialized world contribution is about 60%. Because

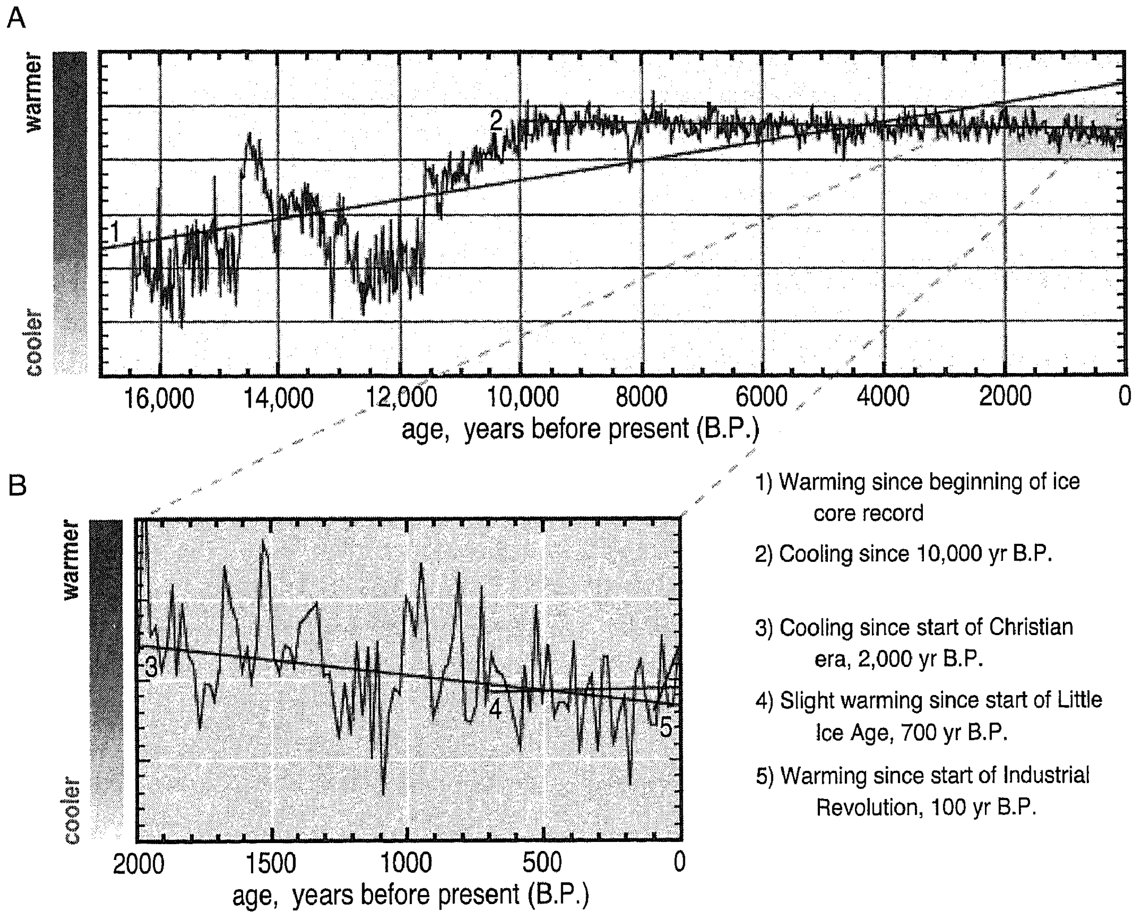


Figure 4. Climate changes over time, naturally. This diagram shows that one can argue either warming or cooling by choosing the length of time over which the observation is made. Most climate models do not attempt to replicate climate changes that occurred prior to the Little Ice Age because they cannot be explained by greenhouse gas changes. (A) Climate change over the last 17,000 yr. Climate has been highly variable over this time span, with general cooling for about 10,000 yr. Variability in the curve permits interpretation of either cooling or warming depending on the time span chosen. (B) Climate change over the last 2000 yr, illustrating the same variability over a shorter time span, with more detail. An increase in O_{16}/O_{18} ratio of 0.07% in marine sediments corresponds approximately to a fall in water temperature of 1°C (Moore et al., 1996). From Davis and Bohling (2001); used by permission of AAPG, whose permission is required for further use.

most of the carbon dioxide produced cannot be captured, it cannot be sequestered. There is no alternative method of generating the energy needs of modern society exclusive of fossil energy. Rightly or wrongly, people are truly worried about future effects of climate change, no matter why it occurs, and because there is no current technically possible way to control natural climate change, these effects will occur, despite huge investment by government in schemes to reduce carbon contribution to the atmosphere. Sequestration, emissions limits, and possible alternative energy sources cannot alter natural climate change. Increases in total energy consumption have absorbed increases in alternative energy generation, so that alternative energy is slightly decreasing.

Continuing arguments that humans change climate and that people can stop climate change through a political process condemns the people who will be adversely affected by any climate change to suffer those effects. The only alternative action the world can take is to plan now for climate adaptation and mitigation for its growing population. Delays in planning and mitigation are caused by the mistaken and unrealistic assumption that politics can alter global natural processes (Jenkins, 2001).

A REAL PRECAUTIONARY PRINCIPLE

True precaution requires that the world's peoples be made aware that natural processes are at work that may raise sea levels, flood lowlands, and gradually shift climatic zones northward. Alternatively, the Earth may be over because of a slide back into glacial conditions. To hold out hope that human intervention in energy use can alter that scenario is to insure that humans will suffer the results of climate change because technically feasible mitigation was not adopted. It is incumbent upon us to insure that public policy begins the planning to meet this contingency, focused on mitigation of climate change, instead of the hope that we will be able to stop it.

Columnist George Will (2003, p. 7B) recently wrote that "Geology has joined biology in lowering mankind's self esteem. Geology suggests how mankind's existence is contingent on the geological consent of the planet." Not the other way around. Climate will change, either warmer or colder, over many scales of time, with or without human interference. It is incumbent upon us to plan for and to mitigate climate changes, for we cannot alter the scenario, but we can minimize human misery resulting from such change.

RESEARCH NEEDS TO RESOLVE DEBATE

There are several research gaps in the debate. First and most important, the general circulation models should be opened to all scientists so as to include modeling of natural variability based on observations. A global time-temperature curve covering the last 10,000 yr would be a helpful addition to the record and can be developed in a conference setting to debate proxies and develop a baseline of global climate change. We need to investigate processes by which solar and orbital variability affect climate. Testing of GCM against the historical record is highly desirable. Finally, we must conduct research into the best mitigation methods to minimize negative human impacts of climate change, no matter what the source. This research will require funding that is not now available.

AUTHOR'S NOTE

I published my first paper on climate change in 1996 (Gerhard, 1996). In that paper, I commented on the similarities between the climate debate and the debate that established the science of geology. Geognosy, the Wernerian theory of the Earth, had held sway for decades before it was demolished by empirical observations that led to Hutton's concept of Uniformitarianism. The old Wernerian hypothesis is comparable to today's computer modeling of greenhouse gas control of climate change, in that its adherents try to prove it correct, instead of testing the validity of the hypothesis. Geognosy ultimately was shown to be without merit.

We have had similar such issues in our science since then. The two most obvious are the continental drift theory and evolution. Continental drift theory took 50 yr to establish against theoretical geophysical objections that there was no mechanism by which this could occur; therefore, the empirical observations were without merit. The empirical observations ultimately proved the theory. This debate led to plate tectonic understanding and to the establishment of a unified field theory of Earth behavior and history. The current public debate over evolution, in which there is large-scale public resistance to science because of religious and human egotistical premises, despite the massive information and observations that support the concept, is another example of the problem. We find antievolutionists trying to advance a more palatable "theory" of divine intervention.

I find it amazing that the huge amount of observations, data, and information about how climate changes is ignored in order to continue the hunt for a human imprint on climate change. Why is it that we spend so much time and resources trying to prove a theory of greenhouse gas climate control instead of testing the hypothesis? We would serve science in public policy better if we would bring the scientific method to the quasipolitical argument over climate change.

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