Global Warming: Is It Real?

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The atmospheric loading of several greenhouse gases is increasing. The most important of these is carbon dioxide, which is emitted to the atmosphere when fossil fuel is burned to supply energy. In this paper I discuss the implications of this in terms of global warming, and address the claims of the skeptics in the scientific community. [S0199-6231(00)00103-9]

Introduction

At the Third Conference of the Parties to the Framework Convention on Climate Change in Kyoto, Japan, representatives from countries around the world met in an attempt to decide on a set of ‘binding agreements’ on how to limit the emissions into the atmosphere of greenhouse gases, largely carbon dioxide (CO₂), which is emitted into the atmosphere when fossil fuels (coal, oil and natural gas) are burned to produce energy. The session ended with the United States tentatively (pending congressional approval) agreeing to reduce greenhouse emissions to 7 percent below 1990 amounts by 2010. (The administration has stated that it will not present the agreement to Congress unless and until there is some indication that developing countries will contribute to the reductions of emissions in some way that is yet to be spelled out.) Yet CO₂ emissions from the United States and Canada actually increased by about 9 percent between 1990 and 1996 [1], and at the current rate of increase they will increase by at least another 15 percent by 2010. Therefore if we are to abide by the Kyoto agreement CO₂ emissions must decrease by about one third of the emissions that would have occurred by 2010. Some argue that the economic disruption would be large and perhaps unnecessary because global warming is an unproven hypothesis [2]. Others insist that we need to go even further in reducing the use of fossil fuels because global warming will be disastrous [3]. The views of most climate scientists fall somewhere between these extremes. Here I explore the evidence that global warming has already been detected, whether it can be attributed to human activities, and whether the objections of the skeptics are valid. I further suggest that this is a problem that the engineering community must begin to address.

Most atmospheric scientists believe that an increase in the atmospheric loading of CO₂ will lead to global warming, an increase in the temperature of the Earth’s surface. The Intergovernmental Panel on Climate Change (IPCC) report has stated that “the body of statistical evidence ... when examined on the context of our physical understanding of the climate system, now points to a discernible human influence on global climate” [4]. Still, there are the skeptics. There are scientists who doubt that global warming is a real issue, either because it will not occur, or that it will not be severe, or that we can successfully adapt to it.

The Evidence

Let us agree up front that climate models are imperfect. However, simple physical principles and evidence from studies of ancient climates make certain things clear. During warmer climates in the past high latitudes warmed more than lower latitudes while the opposite is true of colder climates [5]. Thus, it is to be expected that high latitude snow extent on land and the extent of sea ice should decrease as the climate warms. Mountain glaciers should retreat. The surface air temperature should increase, but radiation models show that the temperature of the lower stratosphere should decrease [6]. Sea level should rise, both because of the melting of land ice and because of thermal expansion of sea water. If any one of these has occurred it can scarcely be counted as proof of global warming. Even if most or all have occurred absolute proof cannot be claimed. However, one is certainly justified in claiming strong evidence.

• The CO₂ content of the atmosphere remained nearly steady at approximately 280 parts per million by volume (ppmv) for 10,000 years until about 1850, when humans began emitting it into the atmosphere by burning fossil fuels. Since that time the CO₂ content has been rising concurrently with emissions from fossil fuels. It now stands at nearly 370 ppmv (CDIAC, 2000).

• Surface air temperatures measured on land and by ships of opportunity have been shown by several groups of scientists to indicate a warming of about 0.6°C during the last 150 years [7]. Recent data from satellite measurements over a much shorter time interval indicate a similar, but slightly smaller trend when corrected for the effect of orbital decay [8]. Still more compelling evidence was recently reported by a group of scientists who used proxy data (records from climate sensitive parameters like tree rings, ice cores, lake sediments and corals) to infer that temperatures during the latter part of the 20th century are significantly higher than anytime in the past 1000 years, and are rising more rapidly than at any time during the past 1000 years [9].

• Radiosond (balloon) data by Angell [10] has shown that the temperature of the lower stratosphere has been decreasing since measurements began in 1958.

• Gernot Pazell of the Institute of High Mountain Research has reported that Alpine glaciers are in retreat [11]. Diaz and Graham [12] have reported that tropical glaciers in the Andes are also melting. Many more numerous observations from the World Glacier Monitoring Service confirm these observations [13].

• Scientists at the British Antarctic Survey have shown that five northerly ice sheets on the Antarctic Peninsula have shrunk dramatically in the past fifty years [14]. Johannessen et al. [15] have shown from satellite measurements that the extent of northern hemisphere sea ice has decreased recently. Rothrock, Yu and Maykut used recently released data from submarines to show that the Arctic sea ice in the 29 locations where measurements were made has decreased in thickness ranging from 0.9 to 1.8 meters [16].
• Levitus and coworkers [17] have recently used more than five million measurements of the temperature of the world ocean at various depths and locations to show that the temperatures have increased in the middle depths by an average of about 0.06°C between the 1950s and the mid-1990s, increasing the sensible heat by $2 \times 10^{23}$ joules. Watts and Morantone [18] had previously suggested, based on data of mid-depth Atlantic ocean temperature changes reported by Roemmich and Wunsch [19], that much of the global warming temperature signature lay in the deep ocean.

While this appears to be a substantial “fingerprint” indicating that the climate has already begun to respond to atmospheric CO$_2$ loading, there are certain claims by the skeptics that need to be addressed. Let us examine their doubts in light of the most recent scientific evidence.

The Skeptics: Are Their Doubts Scientifically Valid?

It is argued by those to whom I refer as the skeptics that the science of global warming is sufficiently controversial that we should wait until some of the problematic questions are cleared up before acting to reduce greenhouse emissions. I will now cite the most prominent objections along with scientifically based responses. It must already be clear that I believe that global warming has begun and that it is the result of human activities.

• **Is the increase in atmospheric CO$_2$ the result of the burning of fossil fuels?** On October 19, 1997 in a speech at the World Petroleum Congress in Beijing, Lee R. Raymond, Chairman and Chief Executive Officer of the Exxon Corporation stated that “only 4 percent of the carbon dioxide entering the atmosphere is due to human activities-96 percent comes from nature.” This is an excellent example of a statement that is true but terribly misleading. Carbon emissions from the burning of fossil fuels is currently approximately 6 GtC/year (gigatons carbon per year) while the oceans emit about 90 GtC/year [20]. However, the oceans also absorb about 90 GtC/year (or possibly slightly more since the atmospheric loading has increased). Similarly the annual exchange between the atmosphere and the terrestrial biosphere is approximately 100 GtC/year. The balance between these fluxes over a period of 10,000 years strongly implies an equilibrium state before humans began to alter it. But how can we be certain that the increase is in fact coming from human emissions? One piece of circumstantial evidence comes from the fact that the difference between the CO$_2$ contents of the northern and southern hemispheres has increased during the last 30 years from 1 ppmv to 3 ppmv, higher in the northern hemisphere, where most human activities occur [21]. A more compelling piece of evidence is associated with the difference in the atmospheric concentrations of different carbon isotopes. Most carbon is in the form of the isotope $^{12}$C. A small amount exists as the radioactive isotope $^{14}$C. Since fossil fuels are old, they contain no $^{14}$C. The increase in CO$_2$ in the atmosphere is diminished in $^{14}$C, and is therefore coming from old carbon—from fossil fuels [21].

• A report by the George C. Marshall Institute states that there has been no warming in the contiguous United States from 1895 to 1985 [22]. No climatologist claims that warming will occur everywhere during the early parts of the transient response to increased CO$_2$. The zonally averaged temperature (averaged over all longitudes) has increased [4].

• The same report suggests that while the Earth has been warming, the variations in global temperatures correlates with sunspot activity [22]. The National Solar Laboratory reported that satellite measurements showed a cyclical variation in solar radiation intensity of about 1.6 w/m$^2$ at the top of Earth’s atmosphere, where the intensity is 1360 w/m$^2$. This amount is about 0.1 percent. To translate this into variations in the effective radiative flux at the top of the atmosphere we need to divide by the ratio of the Earth’s surface area to the area of the disk that sees the Sun, or 4. Thus, the change in radiative forcing from the solar variability is about 0.4 w/m$^2$. Radiation models indicate that a doubling of CO$_2$ will lead to an increase in radiative forcing of about 4 w/m$^2$, ten times that of solar variability.

• The authors of the Marshall Institute report further state that in transient climate models full warming occurs within ten to twenty years, and that we therefore should have much more warming than the data suggest [22]. But in the runs examined in the report the CO$_2$ content was doubled as a step function, so that only the steady state result is meaningful. If the CO$_2$ level is increased gradually, as is done in more recent models [23], the temperature rises much more slowly.

• In 1979 satellites began measuring the temperature of the atmosphere using a Microwave Sounding Unit (MSU) that essentially measures the vibration frequency of oxygen molecules in the air [24]. The record shows a slight global cooling of $-0.05^\circ$C per decade from 1979 to 1996 [4]. In contrast, the record shows a warming of about 0.12°C per decade in the upper troposphere. These results have caused many to doubt the validity of the surface temperature record referred to earlier. However, in a paper published in Nature, Wentz and Schabel [8] pointed out that the results are affected by the altitude of the satellite. Once the results are corrected for orbital decay, they show a temperature increase in the lower troposphere of 0.07°C per decade, smaller than the ground based measurements, but of the same order of magnitude.

• A frequently cited claim [2] is that according to responses to a questionnaire from the organization Greenspace most climate scientists are skeptical of CO$_2$-induced global warming. Michaels claims that only 13 percent of climate scientists subscribe to the alarmist version of greenhouse warming, while 32 percent said the theory was possible and 47 percent said it was probably not true. Michaels does not state the questions that the climate scientists were responding to. The first question was “Do you think that there will be a point-of-no-return, at some time in the future, at which continued business-as-usual policies run a serious risk of instigating a runaway greenhouse effect?” A “runaway greenhouse effect” is a state of the atmosphere in which internal feedbacks within the climate and the carbon cycle will cause the CO$_2$ to increase all by itself until the planet becomes a hot as, say, Venus. It is surprising that so many climate scientists take such an extreme view. The next question was “How satisfied are you with the progress of climate negotiations?” 62 percent responded that they were too slow or far too slow. The third question was “How seriously has the work of the climate scientists been taken since the IPCC report and the Scientists’ Statement of the World Climate Conference were published in 1990?” Only 3 percent stated that this was given too much or far too much weight. Practically all of the scientists believe that the Scientists’ Statement, namely, that we face substantial climate change due to a human induced greenhouse effect, ought to be taken seriously.

• Another claim by Michaels [2] is that in order to stabilize CO$_2$ in the atmosphere emissions must be reduced by 60 percent to 80 percent. In this claim he is probably correct.

An Engineering Problem

It appears very likely that as CO$_2$ levels in the atmosphere increase the Earth will become warmer. The results of climate model studies indicate that a CO$_2$ doubling would raise temperatures globally by 1.5–4.5°C, and evidence that the Earth is already warming appears to be firm. Although climate models disagree in the details of their predictions, they nearly all predict more summer dryness in continental interiors [4]. It will in all liklihood be at least a decade and possibly much longer before models are able to predict details of regional climate change. In the meantime the skeptics will no doubt remain skeptical.

Yet the evidence that global warming is already occurring is strong, and it seems reasonable that we should act to prevent it from becoming extreme. But this is certainly no time to abandon our trust in technology. Abundant energy is necessary for modern society. There are ways to reduce CO$_2$ emissions by increasing...
end use efficiency [25]. However, the real key to supplying carbon
free energy lies in development of affordable and safe nuclear
(fission and fusion) and renewable energy [26]. In a very real
sense global warming has become an engineering problem.

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