Uncertainties in Climate Modeling: Solar Variability and Other Factors

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September 17, 1996

The test of all knowledge is experiment. Experiment is the sole judge *of scientific truth.*
--Prof. Richard Feynman, 1963, The Feynman Lectures on Physics

The possible outcomes resulting from the predicted rapid and dramatic rise in global temperature deserve serious thought. What are the scientific facts in support of the claim that human-made global warming will be significant (i.e., larger than the natural fluctuations of climate) and even possibly catastrophic? How is it known that computer simulations of the climate, forecast 100 years into the future, are accurate?

One starts by testing the computer simulations against the record of temperature change of the last 100 years. In the last 100 years, the global average surface temperature of the earth has risen about 0.5 C. Also during that interval the concentration of anthropogenic greenhouse gases has increased in the atmosphere. The increase in concentration is roughly equivalent to a 50% buildup in carbon dioxide alone. That substantial buildup gives a way to test the computer simulations of climate change due to greenhouse gases from human actions. That is, by studying the temperature response to the 50% increase over the last 100 years the computer simulations can be tested against the actual response of the climate.

The computer simulations say that the global temperature should have risen in the last 100 years by roughly 0.5 - 1.5 C (aerosols, whose theoretical effect is included in that range, will be discussed below).While the magnitude of the rise, as post-predicted by the computer simulations, seems to agree with the observed temperature rise of 0.5 C, it is inconsistent with the timing of the warming.

The record of global temperature (Chart 1) shows that most of the warming of the last 100 years occurred before 1940. But most of the anthropogenic greenhouse gases entered the atmosphere after 1940. Human-made greenhouse gases cannot cause a warming that took place before they existed in the atmosphere. Therefore, most of the 0.5 C rise must be natural. Only a small part of the 0.5 C rise -- no more than a few tenths degree -- could have been caused by human-made greenhouse gases. In other words, the 0.5 - 1.5 C warming predicted by the computer simulations exaggerates the greenhouse effect produced by the equivalent 50% buildup of carbon dioxide.

The solar influence

If the anthropogenic greenhouse gases did not cause most of the warming early in the century, then what did? One possibility is that the total energy output of the sun changes, thereby causing some warming and cooling. The evidence for this is in two parts: first, the sun has been observed by NASA satellites to vary in total energy output in step with the 11-year sunspot cycle of magnetic changes in the sun. Although the satellite records only began in the late 1970s, which is too short a time to obtain information on century-long climate variations, the association of brightness changes with surface magnetic changes allows us to obtain information on the sun's brightness changes going back several centuries, because records of the sun's magnetism are available over that long period.

The length of the sunspot cycle is a particularly interesting proxy for changes in the sun's brightness. Chart 2 compares the sunspot cycle length with surface temperatures going back to 1750[1]. The correlation is nearly perfect.

The second part of the evidence for a solar influence on the climate is as follows. The sun's magnetic record can be converted to estimated brightness changes, using data from the sun and other sunlike stars, and input to a climate simulation. The results for the sun's changes are shown in Chart 3 for the years 1880-1993[2]. If the sun has changed brightness in the way the magnetic records have indicated, then changes in sun explain more than half of the variance of the temperature record from 1880-1993. The results for the sun suggest that its brightness changes have had a significant impact on climate change. A brighter sun may be the explanation for a substantial part of, and possibly most of, the 0.5 C global warming observed in the last 100 years.

Aerosols

Pollutants such as sulfur dioxide complicate predictions of global climate change. Aerosols form a haze that absorbs or reflects sunlight causing a cooling that offsets some of the predicted greenhouse warming. Aerosols may also alter cloud properties.

Studies[3,4]of the response of climate change to aerosols are based on computer simulations. The theoretical effect of aerosols has been to cool the climate forecasts (Chart 4)[3], both for the present and the future, and bring the computer forecasts more in line with the recent global temperatures. (However, allowing for the theoretical cooling effect of aerosols cannot explain the observed warming prior to 1940.) The modeled effect of aerosols does not change the conclusion that the computer simulations of climate are greatly exaggerating the size of the greenhouse warming.

Regional results and the "fingerprint" studies -- "Pattern" studies[3,4] of anthropogenic greenhouse gases with the added effect of aerosols are considered in ensemble, region by region, and with height. They form the basis for the claim that the anthropogenic effect on climate has been detected[5]. But checking the forecasts in specific regions shows instead that the simulations fail to agree with observations. For example, two regions where the aerosol effect should be verified are heavily-industrialized Europe and North America (Chart 4) [3]. There the aerosol effect worsens agreement of the computer simulations with the temperature observations.

Moreover, the combined greenhouse plus aerosol model can be tested with data from the region where the computer simulations predict the most warming, namely the troposphere over the southern oceans[6]. That test (Chart 5) shows no net rise in temperature from 1958 to the present.

Satellite temperature measurements

NOAA satellites have been measuring the temperature at a height of a few kilometers in the atmosphere essentially over the entire earth since 1979. [7] These records have smaller systematic errors than the surface records, which, unlike the satellite records, come from a variety of instruments, techniques and measurement histories, and whose coverage is sparse over large areas like the southern ocean. The very precise satellite record shows no net warming over the last 17 years -- contrary to the forecasts calculating the effect of the recent rapid increase in human-made greenhouse gases.

Temperature in the Arctic

Most computer simulations also post-predict a major, rapid warming in the Arctic, especially in the winter. The temperature record in the Arctic is thus a very sensitive test of the computer simulations. But over the last 50 years no net warming of the surface has been observed. The simulations also post-predict that the Arctic should have warmed by a degree or so in the last 17 years, the period during which satellites have made precise readings of the Arctic. Over the periods under study, the average temperature of the Arctic has not warmed. In the test of the Arctic records the computer forecasts exaggerate, by a very large amount, the warming that should have occurred.

Error budget and uncertainties in the computer simulations

Apart from the possible uncertainty of a significant solar variability effect in global climate change, there are other major uncertainties in the computer simulations. These uncertainties are demonstrated by the fact that simulations of the present-day climate differ from one another by 5 C in the tropics (and nearly 20 C in the polar regions).[8]

Water vapor feedback-- The computer simulations rely on water vapor, responsible for most of the natural greenhouse effect, to amplify the small warming directly resulting from the increase in carbon dioxide and other minor greenhouse gases [9]

However, this assumption has been challenged.[10] After considering the water vapor feedback, Lindzen gives a preliminary estimate of 0.3 C for the global temperature response of an effective doubling of carbon dioxide (without any offsetting cooling by aerosols considered). Without a substantial, positive water vapor feedback, other feedback mechanisms are much less effective in amplifying the effect of increases in the minor greenhouse gases.

Magnitude of other uncertainties -- Chart 6 [11] shows some of the uncertainties in the climate simulations. Compared to the 4 W m-2 radiative input to the atmosphere for an effective doubling of the concentration of carbon dioxide, the uncertainty in the effect of humidity alone is about 20 W m-2. An additional uncertainty of roughly 25 W m-2 stems from calculating the heat flow from the equator to the polar regions[12]. This gives rise, finally, to area-by-area "flux adjustments" of up 100 W m-2 in some areas of the coupled ocean-atmosphere simulations. (Additional uncertainties in cloud physics are not discussed here).

Summary

No evidence can be found in the observations of the global temperature for a dangerous warming derived from human actions.

The computer simulations of climate, which estimate a warming of roughly 1 C over the last 100 years, have overestimated the warming that has actually occurred by a factor of three or more. The same computer simulations projecting for the next 100 years (the time frame cited for the equivalent of a doubling of carbon dioxide) must be corrected for these overestimates of past warming. When corrected, the forecasted warming for the next 100 years is a few tenths C. That warming, spread over a century, will be negligible compared to the natural fluctuations in climate.

Furthermore, delaying the onset of drastic emission reductions by as much as 25 years results in a penalty of only 0.2 C in added temperature by 2100[13], according to the current computer forecasts which are known be exaggerating the warming. Investing in and waiting for better climate science would be appropriate, considering that the IPCC-forecasted warming has dropped by nearly a factor of two just in the last six years.

Notes

1. S. Baliunas and W. Soon, 1995, Astrophysical J., 450, 896.
2. W. Soon, E. Posmentier and S. Baliunas, 1996, Astrophysical J., in press, December 1.
3. J.F.B. Mitchell et al. 1995, Nature, 376, 50.
4. B.D. Santer et al. 1995, Climate Dyn., 12, 79. 1996, Nature, 382, 39.
5. "Increasing confidence in the identification of a human-induced effect
6. on climate comes primarily from such pattern-based work." (IPCC, 1996, p. 37, Sec. E.4).
7. P.J. Michaels, P.C. Knappenberger, R.E. Davis and D. Legates, 1996, submitted to AGU Fall 1996 meeting. The most rapid warming is predicted for 30-60o S latitude, at a pressure height of 850-300 mb.

8. J.R. Christy, 1992, Global Climate Change: Implications, Challenges and Mitigation Measures, ed. S.K. Majumdar et al. (Pennsylvania Acad. Sci.), p. 165; J.R. Christy 1995, Climatic Change, 31, 455.
9. IPCC, 1996, Sec.5.2.3.1
10. "This feedback operates in all the climate models used in global warming and other studies." IPCC, p. 200, 4.2.1. However, note: "...[I]ntuitive arguments for [the feedback] to apply to water vapour in the upper troposphere are weak; observational analyses and process studies are needed to establish its existence and strength there." (p. 200, 4.2.1). Also: "Feedback from the redistribution of water vapour remains a substantial uncertainty in climate models." (p. 201)
11. R. S. Lindzen, 1994, Ann. Rev. Fluid Mech, 26, 353; NAS R. Revelle Memorial Volume, 1966, in press.
12. Adapted from R. Lindzen, private communication.
13. 12 "...[W]ithout knowing the dynamical heat fluxes, it is clear...that one cannot even calculate the mean temperature of the earth." (Lindzen 1996, ref. 10)
14. 13 T.M.L. Wigley et al. 1996, Nature, 379, 240.

Testimony presented on September 17, 1996 to the Senate Committee on Energy and Natural Resources
Senate