Human Contribution to Climate Change Remains Questionable

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EOS, Transactions, American Geophysical Society, Vol 80, page 183-187, April 20, 1999

A Geophysicist Looks at Climate Change: Introduction

The principal focus of climate science is certainly atmospheric science and meteorology, but the subject is so complex that it involves many other areas of the earth sciences, as well as different disciplines, such as physics, chemistry, and even biology. This complexity makes climate science both fascinating and controversial. It also undergoes rapid change as new facts and analyses emerge. Yet, public interest in the possibility of climate change due to human activities has become so intense that the subject has to be addressed even before final judgments are possible.

The most widely quoted attempt to address climate changes of the past and to speculate about the future is the series of reports produced by the IPCC, the UN Intergovernmental Panel on Climate Change. Its first Scientific Assessment Report (1990) concluded that the climate record is "broadly consistent" with what might be expected from the human-enhanced greenhouse (GH) effect, as calculated by General Circulation Models (GCMs). The second scientific assessment, published in 1996, no longer made this claim; instead, it found it necessary to introduce a previously overlooked factor, human-caused atmospheric sulfate aerosols, to reach the conclusion that "the balance of evidence suggests there is a discernible human influence on global climate" [IPCC, 1996, p. 4]. This ambiguous statement in the Summary for Policymakers does not do justice to the vast compilation of data and model results brought together in the report itself by some hundred climate scientists. Their important work (more than 500 pages, but lacking an index) has been largely ignored by the public, while attention has focused on the politically negotiated (5-page) Summary. Those who are skeptical of the IPCC conclusion have viewed the statement about human influence as trivial and meaningless. On the other hand, the media and many policy experts have welcomed its convenient formula, which they regard as scientific proof of a coming climate catastrophe.

In fact, the IPCC statement is in many ways a truism. There certainly must be a human influence on some features of the climate, locally if not globally. The important question is whether the available evidence supports the results of the model calculations. Unless validated, the predictions of future warming based on GCMs cannot be relied on.

What follows is a personal view of the current state of climate science, how it relates to model results, and what might be expected in the future as human activities continue to raise the level of greenhouse gases in the atmosphere. A disclaimer is in order. Any brief treatment of this complex subject by an individual author inevitably selects certain facts as important and rejects other pieces of evidence as inadequate or unproven. Even so, such a treatment has the advantage of providing a consistent story, compared to a committee report that often dissolves in a mire of uncertainties. It also provides a convenient target for debate and thus may lead, if not to progress, then at least to a sharpening in efforts of data collection and theoretical work.

A Look at the Evidence

The subject of climate change must rest on observations of the climate in all of its aspects; with temperature as the most important and easily measured parameter. On the one hand, we are inundated with data, many of which do not add appreciably to the discussion; on the other hand, we lack crucial information about the past that may never be recovered. For example, individual temperature measurements using thermometers date back for only about 300 years; the record for the Northern Hemisphere dates from about 1860; and it is only since 1979 that weather satellites have been able to cover the complete globe, including the 70% of the surface covered by oceans. Yet we have increasing amounts proxy data from tree rings, ocean sediments, ice cores, and other evidence that tells us about climate in the distant past.

Paleoclimate

To gain perspective on the subject of climate change, one needs to look at the past. While the data are not exactly global and not always of the best quality, certain conclusions can be reached. The Earth's climate has never been steady; it has either warmed or cooled - without any human intervention. The measured variations have often been large and rapid - larger and more rapid than those predicted by climate models for the year 2100. In the last 3000 years, i.e., during recorded human history, temperatures in the North Atlantic have changed by as much as 3°C within a few decades [Keigwin, 1996]. During the most recent Ice Age, the variability has been even greater. Is the climate more stable during warmer periods? We cannot be sure, but the evidence points in this direction [Singer, 1998].

What has caused the climate to vary? All sorts of theories have been propounded and many have been backed up by data. It is clear, however, that different causes can be acting simultaneously, with their importance depending primarily on the time-scale involved. The frequent ice ages of the last few million years appear to be linked to changes in the absorbed incident solar radiation, in turn affected by orbit changes of the Earth - the so-called astronomical theory. Longer-term climate changes seem to be linked to continental drift and other tectonic events. Shorter variations, on the time-scale of decades, appear to be caused by atmosphere-ocean interactions and changes in ocean circulation. Alternatively, they could be due to external causes, such as variations in solar irradiance (solar "constant") [Soon, Posmentier, Baliunas, 1996; Lean, Beer, and Bradley,1995] or in solar activity (ultraviolet radiation or solar corpuscular radiation); there are suggestive correlations with cloudiness [Svensmark and Friis-Christensen, 1997] and with temperature [Friis-Christensen and Lassen, 1991], but as yet no convincing physical mechanism.

What about the association of climate change with atmospheric greenhouse gases? On the time-scale of hundreds of millions of years, carbon dioxide has sharply declined; its concentration was as much as 20 times the present value at the beginning of the Cambrian Period, 600 million years ago [Berner, 1997]. Yet the climate has not varied all that much and glaciations have occurred throughout geologic time even when CO2 concentrations were high.

On a time-scale of decades and centuries, there seems to be an association between temperature and CO2 concentration, as judged by measurements of Greenland and Antarctic ice cores. (The association is even better for the greenhouse gas methane.) Yet, the causal connection is not at all clear. Only recently has it been possible to obtain sufficient resolution to demonstrate that the increase in CO2 lags by about 600 years behind the rapid warming that signals deglaciation, the end of an ice age and the beginning of an interglacial warm period [Fischer et al., 1999].

Atmospheric Greenhouse Gases (GHGs)

There is general agreement that the increase in atmospheric GHGs, like CO2, methane, nitrous oxide, etc., over the last hundred years or so is due to human activities. Attention has focused mainly on CO2 as the most important anthropogenic GHG. Less than half of the released CO2 remains in the atmosphere, the rest is absorbed by the ocean and by the biosphere, thereby speeding up the growth of agricultural crops and forests. Informed opinion holds that half of the released CO_2 is absorbed into the shallow oceans within 30 years [Sarmiento, Orr, and Siegenthaler, 1992], that the mean residence time is about 75 years, and that a "tail" may last more than a century [IPCC, 1996, p. 76]. The residence time of methane is much shorter, only about 12 years. For reasons as yet unexplained, the rate of increase of CO_2 has slowed considerably in the last decade or so, and methane has stopped increasing altogether [Hansen et al., 1998]. This makes it extremely difficult to predict future concentrations of CO_2 and methane, the latter depending primarily on the rate of population growth. With respect to CO_2 , estimates of emissions vary greatly, depending on energy scenarios. These are determined not only by population growth and economic growth, but also by the availability of fossil fuels - in turn a strong function of technology and of price. Much to the surprise of many "experts", the price of oil has decreased in the last two decades, even as readily available low-cost resources are being depleted. There is considerable disagreement about the probable date when atmospheric GHG concentration might reach double the pre-industrial level. Estimates vary from the year 2050 all the way to never [Gerholm, 1992; Linden, 1999].

Temperature Data

There is general agreement that the global climate warmed between about 1880 and 1940, following several centuries of the "Little Ice Age," which in turn was preceded by the "Medieval Climate Optimum" around 1100 AD. There is less agreement about the causes of this recent warming, but the human component is thought to be quite small. [See BOX] This conclusion seems to be borne out also by the fact that the climate cooled between 1940 and 1975, just as industrial activity grew rapidly after WWII. It has been difficult to reconcile this cooling with the observed increases in greenhouse gases. To account for the discrepancy, the 1996 IPCC Report has focused attention on the previously ignored (direct) cooling effects of sulfate aerosols (from coal burning and other industrial activities), reflecting a portion of incident sunlight. But this explanation to support the "discernible human influence" conclusion is no longer considered as valid. Leading modelers [Tett et al., 1996; Penner et al., 1998; Hansen et al., 1998] all agree that the aerosol forcing is more uncertain than any other feature of the climate models. Models have not yet incorporated the much larger indirect cooling effects of sulfate aerosols (by increasing cloudiness), or the quite different optical effects of carbon soot from industrial and biomass burning and of mineral dust arising from disturbances of the land.

The temperature observations since 1979 are in dispute. On the one hand, surface observations with conventional thermometers show a rise of about 0.1°C per decade, less than half that predicted by most GCMs. On the other hand, satellite data, as well as independent data from balloon-borne radiosondes, show no warming trend between 1979 and 1997 in the lower troposphere, and could even indicate a slight cooling [Christy and Spencer, 1999]. Direct temperature measurements on Greenland ice cores show a cooling trend between 1940 and 1995 [Dahl-Jensen et al., 1998]. It is likely therefore that the surface data are contaminated by the warming effects of "urban heat islands." Some data support this hypothesis [Goodridge, 1996], others do not [Peterson et al., 1999].

While it is certainly true that human life is affected by temperatures at the surface, the GCMs are best validated by observations in the troposphere. It should be noted also that GCMs predict a warming trend that increases with altitude up to about 250 millibars (~12 km), rising to about 0.5°C per decade [Tett et al., 1996] -- in clear disagreement with all observations, whether from the surface, balloons, or satellites.

Climate Models

The large discrepancy between model results and observations of temperature trends (whether from satellites or from the surface) demands an explanation. The twenty or so models developed around the world by expert groups differ among themselves by large factors. Their "climate sensitivities" (defined as the temperature increase for a doubling of GHG forcing) vary from as low as 1°C to as high as 5°C; the IPCC gives a conventional range of 1.5°C to 4.5°C. An intercomparison of models has established that a major uncertainty relates to how clouds are treated [Cess et al., 1990, 1996]. Since they cannot be spatially resolved, they must be parameterized in some fashion. In many models, clouds add to the warming, but in others, clouds produce a cooling effect. The situation is even more confused with respect to water vapor (WV), the most important greenhouse gas in the atmosphere, contributing over 90% of the radiative forcing. In current climate models, water vapor is taken to produce a positive feedback, thereby amplifying the warming effects of a CO2 increase. Everyone agrees that a warming produced by an increase in CO2, or by any other cause, will lead to more evaporation and therefore to a higher level of WV; but it is the WV concentration in the upper troposphere - not in the boundary layer -- that determines whether the feedback is positive or negative [Lindzen, 1990; Spencer and Braswell, 1998]. On that score, opinions differ widely and probably will continue to do so until the necessary data are at hand.

None of the climate models incorporate the effects of a variable Sun. It has always been assumed that solar variability is simply too small, but this view is now changing. Even if the radiative forcing from changes in solar irradiance is less than that from GHGs, the variability of the Sun in the ultraviolet is much greater. Evidence is now forthcoming that UV-caused variations of the ozone layer or changes in solar particulate emissions ("solar wind") could (indirectly) influence atmospheric circulation or cloudiness - which in turn can cause significant climate changes [Svensmark and Friis-Christensen, 1997]. Climate models generally do not incorporate the large surface albedo changes that have come about through land-clearing for agriculture and, more recently, through reforestation in some parts of the world.

Even though the models are not yet validated as far as temperature trends are concerned, some human influences on climate are already noticeable. Observations indicate that the diurnal temperature range has been decreasing in the Northern Hemisphere and perhaps in the Southern Hemisphere as well [Karl et al., 1991]. These could be traced to possible increases in aerosols or cloudiness. There is evidence also for winter warming, but not yet for the expected warming at high latitudes predicted by the climate models. On the other hand, observed stratospheric cooling appears in line with what one might expect from the increase in CO2, as well as from the ongoing depletion of ozone [Ramaswamy et al., 1996]. Yet until GCM climate sensitivity is validated, one cannot accept the predictions of large future temperature increases.

Impacts of Climate Change

If the climate were to change according to model predictions, one would expect to see fewer severe storms, in view of the reduced temperature gradient between the tropics and high latitudes. Model calculations do not indicate an increase of hurricanes, El Nino events, or other kinds of climate oscillations. The empirical evidence displayed in the IPCC Report shows a decline in hurricanes over the last fifty years in both frequency and intensity [IPCC, 1996, p. 170]; a future warming is not expected to affect frequency or intensity appreciably [Henderson-Sellers et al. 1998]. Observations on El Nino events are not conclusive as yet.

With respect to sea-level rise, it has been assumed, conventionally, that a warming will increase the rate of rise, because of the thermal expansion of ocean water and the melting of mountain glaciers. Certainly, when viewed on a millennial scale, sea level has been rising steadily. But when examined on a decadal scale, which is more appropriate to human intervention, sea-level rise is found to slow during periods of temperature increases, for example, during the temperature rise from 1900 to 1940 [Singer, 1997]. Evidently, increased evaporation, linked to warming, results in increased accumulation of ice in the polar regions, thereby lowering sea level. This conclusion seems to be backed by direct observation of ice accumulation, as well as by some modeling studies. A future modest warming should therefore slow down, not accelerate the ongoing rise of sea levels.

The Economic Impact of a Possible Climate Warming

Economists have recently re-examined the 1996 IPCC (Working Group III) review of economic impacts. (Some of these studies showed large losses for agriculture but not for sea-level rise, whereas others showed the opposite.) The re-examination shows a substantial gain for agriculture and little effect on other economic activities in the U.S.; they finally conclude that a warming, from whatever cause, would produce economic benefits rather than economic losses [Mendelsohn and Neumann, 1999]. The new findings on sea level rise (above) would reinforce their conclusion, which has not yet been widely publicized or discussed.

The Ultimate Goal of the Climate Treaty

Most regard the objective of the climate treaty as the reduction of GHG emissions; but Article 2 of the Treaty states that the ultimate goal is to "achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." It is not clear what this means, or whether a higher or lower level of GHG will prove more "dangerous" [Singer, 1998]. As noted earlier, however, a warmer climate is likely to be a more stable one.

Conclusion

High government officials have declared repeatedly that climate science is "settled" and "compelling." The clear implication is that we know enough to act; any further research findings would be "policy-irrelevant" and not important to the international deliberations of the parties to the climate treaty. My essay concludes otherwise: The observational evidence described above suggests that any warming from the growth of greenhouse gases is likely to be minor, difficult to detect above the natural fluctuations of the climate, and therefore inconsequential. In addition, the impacts of warming and of higher CO2 levels are likely to be beneficial for human activities and especially for agriculture. Further, the ultimate goal of the climate treaty is still undefined; it could be a higher or a lower level of GHG than the present one. Finally, the Kyoto Protocol (calling for an average cut of 5.2% in GHG emissions by industrialized nations) is not sufficient to reduce significantly the ongoing growth of GHG in the atmosphere; its effect on temperature would imperceptible. As pointed out in the initial IPCC report, however, stabilization at the present GHG level requires that emissions be cut by 60-80% --worldwide. Altogether, the UN deliberations have emphasized emission controls and neglected sequestration of CO2 from the atmosphere into the ocean [Singer, 1997 pp. 84-87] - a fertile area for geophysical research

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BOX: Can the global warming during the early part of the century, from about 1880 to 1940, "be unequivocally related to human-induced changes in the chemical composition of the atmosphere" [Jones, 1998].

The IPCC arrived at the ambiguous conclusion that "the balance of evidence suggests there is a discernible human influence on global climate," based on "fingerprints" in the climate record, i.e., an increasing correlation (with time) between observed and calculated global temperature patterns [IPCC, 1996, Figure 8.10, p.433]. However, this positive trend in correlation depended entirely on the arbitrary choice of the time interval 1940-1990, during most of which temperatures were actually decreasing. A different choice of interval could have produced a zero or even a negative trend. Another piece of evidence cited in the IPCC report to support a human influence depended on showing an increasing temperature trend in the middle troposphere of the Southern Hemisphere [IPCC, 1996, Figure 8.7.c., p.428]. Again, this is related entirely to the particular choice of time interval [Michaels and Knappenberger, 1996]; more complete data sets give a contrary result - a greater warming trend in the Northern Hemisphere.

Following the publication of the IPCC report in 1996, an increasing number of researchers have adopted the view that much or most of the pre-1940 warming is due to natural causes and represents a recovery from the Little Ice Age. Some would assign a substantial portion to greenhouses gases [Wigley, Jones, and Raper, 1997]. Others claim that most of the temperature increase is caused by solar variability [Soon et al., 1996]. If one applies the "fingerprint" criterion used by the IPCC, then it can be seen from their Figure 8.10 [IPCC, 1996, p.433] that the pattern correlation has a negative trend during the major warming between 1900 and 1940, thereby denying the existence of an appreciable human contribution.

Perhaps the strongest argument against an appreciable human contribution comes from the observed cooling between 1940 and 1975 and the lack of warming since 1979 (in the weather balloon and satellite data).

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References

Berner R.A., The rise of plants and their effect on weathering and atmospheric CO2, Science, 276, 544-545, 1997.

Cess, R.D., G.L. Potter, et. al., Intercomparison and interpretation of climate feedback processes in nineteen atmospheric general circulation models, J. Geophys. Res., 95, 16601-16615, 1990.

Cess, R.D., G.L. Potter, et. al., Cloud Feedback in Atmospheric General Circulation Models. J. Geophys. Res. 101, 12,791-12,794, 1996.

Christy, J.R., and R.W. Spencer. J. Geophys. Res. 1999 (submitted)**.

Dahl-Jensen, D., Mosegaard, K, Gundestrup, N., Clow, G. D., Johnsen, S. J., Hansen, A. W., and N. Balling, Past temperatures directly from the Greenland ice sheet, Science, 282, 268-279, 1998.

Fischer, H., M. Wahlen, J. Smith, D. Mastroianni, and B. Deck, Ice core records of atmospheric CO2 around the last three glacial terminations, Science 283, 1712-1714, 1999.

Friis-Christensen, E., and K. Lassen, Length of the solar cycle: An indicator of solar activity closely associated with climate, Science, 254, 698-700, 1991.

Gerholm, T.R., in The Greenhouse Debate Continued, (S. F. Singer, ed.), ICS Press, San Francisco, CA, 1992.

Henderson-Sellers, A., H. Zhang, G. Berz, K. Emanuel, W. Gray, C. Landsea, G. Holland, J. Lighthill, S-L. Shieh, P. Webster, and K. McGuffie, Tropical cyclones and global climate change: a post-IPCC assessment. Bull. Am. Meteorol. Soc., 79, 19-38, 1998.

Hansen, J. E., Sato, M., Lacis, A., Ruedy, R., Tegen, I., and E. Matthews, Climate forcings in the Industrial era, Proc. Natl. Acad. Sci. USA, 95, 12753-12758, 1998.

IPCC WGI, Climate Change 1995: The Science of Climate Change, (J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg and K. Maskell, eds.), Cambridge University Press, Cambridge, UK, 1991.

Jones, P. D., It was the best of times, it was the worst of times, Science, 280, 544-546, 1998.

Karl, T. R., Kukla, G., Razuvayev, V. N., Changrey, M. J., Quayle, R. G., Heim Jr., R. R., Easterling, D. R., and C. B. Fu, Global warming: Evidence for asymmetric diurnal temperature change, Geophys. Res. Ltrs., 18, 2253-2256, 1991.

Keigwin, L.D., The Little Ice Age and Medieval Warm Period in the Sargasso Sea, Science, 274, 1504-08, 1996.

Lean, J., Beer, J., and R. Bradley, Reconstruction of solar irradiance since 1610: Implications for climate change, Geophys. Res. Ltrs., 22, 3195-3198, 1995.

Linden, H. R, Let's focus on sustainability, not Kyoto, Electricity J., March 1999.

Lindzen, R. S., Some coolness concerning global warming, Bull. AMS, 71, 288-99, 1990.

Mendelsohn, R., and J. E. Neumann (eds.), The Impact of Climate Change on the United States Economy, Cambridge University Press, Cambridge, UK, 1999.

Michaels, P.J., and P.C. Knappenberger, Human effect on Global Climate? Nature, 384, 522-523, 1996

Penner, J. E., Chuang, C. C., and K. Grant, Climate forcing by carbonaceous and sulfate aerosols, Clim. Dyn., ***, 1998.

Peterson, T.C., K.P. Gallo, J. Lawrimore, T.W. Owen, A. Huang, and D.A. McKittrick, Global rural temperature trends, Geophys. Res. Ltrs, 26, 329-332, 1999.

Ramaswamy, V., Schwarzkopf, M. D., and W. J. Randel, Fingerprint of ozone depletion in the spatial and temporal pattern of recent lower-stratospheric cooling, Nature, 382, 616-618, 1996.

Sarmiento, J. L., Orr, J. C., and U. Siegenthaler, A perturbation simulation of CO2 uptake in an ocean general circulation model, J. Geophys. Res., 97, 3621-3646, 1992.

Singer, S. F., Global warming will not raise sea-levels, Abstract for 1997 Fall Meeting of the AGU; also S. F. Singer, Hot Talk, Cold Science: Global Warming's Unfinished Debate, The Independent Institute, Oakland, CA, 1997, p. 57.

Singer, S. F., Forum: Reply, EOS Trans AGU., 79, 188, 1998.

Soon, W. H., Posmentier, E. S., and S. L. Baliunas, Inference of solar irradiance variability from terrestrial temperature changes, 1880-1993, J. Astrophys., 472, 891-902, 1996.

Spencer, R.W., and W. D. Braswell, How dry is the tropical free troposphere? Implications for global warming theory, Bull. AMS, 78, 1097-1106, 1997.

Svensmark, H., and E. Friis-Christensen, Variation of cosmic ray flux and global cloud coverage: A missing link in solar-climate relationships, J. Atm. Terr. Phys., 59, 1225-1232, 1997.

Tett, S. F. B., Mitchell, J. F. B., Parker, D. E., and M. R. Allen, Human influence on the atmospheric vertical temperature structure: detection and observations, Science, 274, 1170-1173, 1996.

Wigley, T. M. L., Jones, P. D., and S. C. B. Raper, The observed global warming record: What does it tell us? Proc. Natl. Acad. Sci. USA, 94, 8314-8320, 1997.

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