Greenhouse Warming Still Coming

Estimates of the carbon dioxide–induced climate warming predict a large effect that could be doubled by increasing trace gases; some effects of the warming may already be evident

IT has not killed fish in Adirondack lakes or eroded away gothic gargoyles, but the growing store of carbon dioxide in the earth's atmosphere from the burning of fossil fuels and deforestation looms as a far larger and more pervasive problem than acid rain. As testament to that, a major scientific review of the carbon dioxide problem, conducted under the auspices of the Department of Energy's Carbon Dioxide Research Division, has found that nearly a decade of research has not diminished the dimensions of the problem or, unfortunately, all the uncertainties.

The review, consisting of four major volumes commonly known as the state-of-the-art reports,* is nothing if not thorough. Four years in preparation, the review involved the participation of more than 70 scientists from five nations, includes 39 separately authored chapters, and was repeatedly reviewed chapter by chapter through a contract with the American Association for the Advancement of Science. Still, the views expressed remain those of the authors of each chapter.

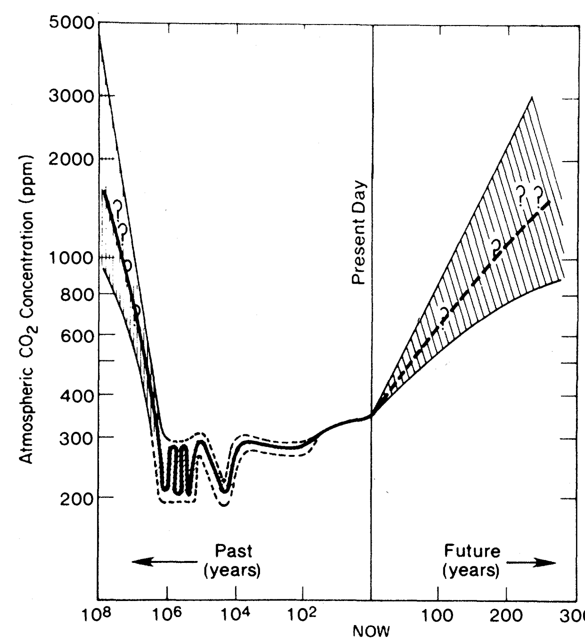
In their review of mathematical models that predict how much a given amount of carbon dioxide can warm climate, Michael Schlesinger of Oregon State University and John Mitchell of the United Kingdom Meteorological Office in Bracknell found a new consensus among the three latest, most sophisticated models. The first generation of climate models included a general circulation model (GCM) of the atmosphere, as used to predict day-to-day weather, linked to an admittedly simplistic ocean, a film of wetness with no capacity to absorb or transport heat. These GCM-swamp ocean models agreed on a modest 1.2° to 1.3°C global warming from a doubling of carbon dioxide as long as the model components that might amplify a warming, such as changing cloud cover or sea ice, were not operating. With such feedback mechanisms operating, the predicted warmings ranged from 1.3°C, which would make it warmer than any time in the past 100,000 years, to a hefty 3.9°C.

The predictions of the latest models that have been applied to the problem, called GCM–mixed-layer ocean models, have narrowed that range to 3.5° to 4.2°C. Unlike the swamp ocean models, the three mixed-layer ocean models have a measurably thick ocean surface that can exchange heat with the atmosphere. Sea ice forms in response to sufficient cooling. Clouds come and go when model conditions warrant. The sun rises and sets each model "day" and arcs higher or lower in the sky in accord with the changing seasons.

Despite their greater sophistication and generally larger global warming, the mixed-layer ocean models yield results that exhibit considerable qualitative resemblance to those of the simpler swamp ocean models, according to Schlesinger and Mitchell. Both models predict that the warming will be larger near the poles than near the equator. Both predict increases and decreases in precipitation depending on location, the largest changes being between 30°N and 30°S. And both call for general increases in precipitation poleward of these latitudes.

Even so, Schlesinger and Mitchell warn that "we know that not all of these simulations can be correct, and perhaps all could be wrong." For one thing, there is still considerable disagreement among the models about regional changes. Warming of tropical surface air ranges from 2° to 4°C from model to model. One model predicts that the soil in almost all of Europe, Asia, and North America will become drier, while two others foresee wetter soil during the summer over much of these continents. Another problem is that modelers can make reliable comparisons of their results with only one case, the present climate. The models do simulate global aspects of the present climate reasonably well, but, until paleoclimatologists can document past global climates sufficiently, a track record like that of daily weather forecasters cannot be developed.

Recognizing that the confidence level of today's climate models "is considerably less than, for example, that of a [mathematical



Carbon dioxide past and future
Atmospheric carbon dioxide concentrations are expected to increase within the next few decades to levels unknown on the earth for several million years. It is expected that they will continue to rise, reaching or exceeding the high but poorly known levels of 100 million years ago. [Source: R. H. Gammon, E. T. Sundquist, and P. J. Fraser]

*The four volumes are available separately from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. They are: *Detecting the Climatic Effects of Increasing Carbon Dioxide*, DOE/ER-0235, $22.95 (price code A11); *Projecting the Climatic Effects of Increasing Carbon Dioxide*, DOE/ER-0237, $34.95 (A18); *Direct Effects of Increasing Carbon Dioxide on Vegetation*, DOE/ER-0238, $28.95 (A14); *Atmospheric Carbon Dioxide and the Global Carbon Cycle*, DOE/ER-0239, $28.95 (A15). Each volume is available in microfiche for $5.95 (A01). A companion report on indirect effects and an index will soon be available.

model] that might be used in the design of a bridge," Martin Hoffert of New York University and Brian Flannery of Exxon Research and Engineering Company in Linden, New Jersey, reviewed climate models that predict how fast, given certain carbon dioxide releases, the climate will warm. They point out that storage of heat in the upper ocean will slow the warming by at least 10 to 20 years. Even with this delay, current models predict a global warming of the order of 1°C relative to the year 1850 by the year 2000. Increasing carbon dioxide would cause an additional warming of 2° to 5°C during the next century.

Carbon dioxide is not the only climatically significant gas whose atmospheric concentration is increasing, as pointed out in the review by Wei-Chyung Wang of Atmospheric and Environmental Research, Inc., in Cambridge, Massachusetts, and his colleagues. Increasing amounts of methane, produced by everything from cattle to rice paddies, and chlorofluorocarbons of ozone-depletion fame, among other trace gases, could upset the earth's radiative balance and warm the climate as much as carbon dioxide by the middle of the next century. This forecast also is circumscribed by uncertainties that are, if anything, greater than those about carbon dioxide.

"The expected climate change could soon be obvious."

Significant uncertainties about the future warming are not limited to climate modeling. The state-of-the-art volume on the global carbon cycle, edited by John Trabalka of Oak Ridge National Laboratory, reveals that geochemists still cannot figure out where all the carbon dioxide being produced today is going. Fossil fuel burning releases 5×10^{15} grams of carbon per year and deforestation releases carbon at 12 to 52% of that rate. That is up to 50% more carbon than they can find accumulating in the atmosphere or can calculate would be absorbed by the oceans. Something is obviously out of whack in the geochemists' models of the carbon cycle, and that something could invalidate projections of the amount of carbon dioxide left in the atmosphere to warm the climate in the next century.

Even greater uncertainties than those in the workings of the carbon cycle are those in the operation of the human economy and its consumption of coal, oil, and gas. The oil crisis interrupted a steady upward trend in fossil fuel burning of 4.4% per year and lowered forecasters' projections of future emissions from the range of 2.0 to 4.5% per year to 0 to 2% per year. Thus, the doubling of carbon dioxide levels that might have occurred by 2025 is now not expected until near the end of the next century, or even later.

The uncertainties presented in good scientific order in chapter after chapter can become daunting, but in their summary of climate projection studies Michael MacCracken and Frederick Luther of the Lawrence Livermore National Laboratory make clear what most researchers believe: carbon dioxide has already increased by 25%, it will in all likelihood continue to increase, and the basic physics of the greenhouse effect is well understood. (A water–carbon dioxide greenhouse has always warmed the earth's surface from −18°C to habitable temperatures.)

"Theoretical understanding provides a firm basis," they write, "for projecting that continuing emissions of CO_2 and trace gases will warm the global climate by a few degrees Celsius during the next century." The important uncertainties concern how and where the temperature and precipitation changes will occur, they say. It is certainly wrong to claim, as has Sherwood Idso of the U.S. Water Conservation Laboratory in Phoenix, that the climate models are fundamentally flawed and the greenhouse effect will be nil, according to an appendix to the modeling volume authored by Luther and Robert Cess of the State University of New York at Stony Brook. They conclude that prior applications of Idso's primary approach "violate the law of conservation of energy (the first law of thermodynamics); therefore, these results are incorrect."

If that kind of confidence is well founded, the expected climate change could soon be obvious. Summing up the volume on detecting such climate effects, MacCracken and Luther find that, in addition to the increase of carbon dioxide since the middle of the last century, "Northern Hemisphere land temperatures, sea surface temperatures, and sea level have also increased during this period. Model projections of the climatic response to an increased CO_2 concentration indicate that such changes should be expected. The apparent agreement strongly suggests a causal relation. . . . If CO_2 and trace gas concentrations continue to rise as projected and model calculations are essentially correct, the increasing global scale warming should become much more evident over the next few decades. If such changes do not become apparent, our understanding of the uncertainties and completeness of current climate models will require extensive reconsideration." ■ RICHARD A. KERR

Briefing:

Did Ancient Humans Make Stone Caches?

Some of the oldest putative living sites of human ancestors have been found at Olduvai Gorge in Tanzania. Dated to almost 2 million years ago, these assemblages of stone artefacts and broken animal bones have frequently been thought of as temporary home bases, rather in the manner of modern hunter-gatherers' campsites. But, according to data recently reported by Richard Potts of the National Museum of Natural History, Washington, D.C., it seems that the analogy might have been stretched just a little too far.

Modern hunter-gatherers usually establish a particular home base for a period of just a few weeks or perhaps a couple of months. The camp becomes the focus of social activities and it is the place to which plant and animal foods are brought, shared out and eaten. The band then moves on to another location, partly to shift the center of gravity of their foraging but also because the accumulated litter and debris make the camp less and less habitable: the insects and scavengers increase uncomfortably.

Now, paleoanthropologists are careful to emphasize that 2-million-year-old hominids were not simply quaint and primitive versions of modern hunter-gatherers. Their brains were little more than half the size of ours, for instance, which is apparently reflected in their simple technology. And it has become clear that active hunting was a less developed aspect of their economy than it is for modern hunter-gatherers. Nevertheless, there has been a very seductive assumption that the overall pattern of life was the same: namely, a small band of individuals, moving from temporary home base to temporary home base throughout the year.

If Potts is correct in his recent work, however, that assumption collapses. He has studied the fossil bone fragments from five archeological sites at Olduvai Gorge, and deduces that the bones accumulated there over a period of between 5 and 10 years. It appears that each site was a place to which hominids of 2 million years ago returned from time to time over a considerable period, apparently to butcher parts of carcasses. This is quite unlike the modern hunter-gatherers' temporary home base, which is occupied briefly and then abandoned. The pattern at Olduvai just happens to be rather more like the bone accumulation that occurs at hyena dens.