Waiting for the Warming: The Catch-22 of CO_2

By STEFI WEISBURD

A climatic time bomb is ticking away in the sky. The problem waiting to happen is the growing abundance of carbon dioxide (CO_2) and other trace gases released into the atmosphere over the last century by the burning of fossil fuels and other industrial practices. Numerous studies have shown that these gases capture heat escaping from the earth and send it back to warm the planet like a greenhouse (SN: 10/22/83, p. 260) — possibly leading to melting ice caps, rising sea levels and altered rainfall patterns all over the globe.

The catch-22 of the greenhouse issue is that there is not enough information for scientists and policy makers to confidently predict and plan for the future warming, but if they wait long enough for enlightenment it may be too late to prevent or prepare for it. Even if greenhouse emissions were completely stopped today, say some climatologists, our children or grandchildren would live in a warmer world. Researchers have recently concluded that most of the warming, due to all of the CO_2 already added to the atmosphere, probably has yet to be felt.

"We are building in a significant future climate effect without knowing how large it is," says Jim Hansen at NASA Goddard Institute for Space Studies in New York City. And "that is why we have to look at this now rather than wait until the future," adds Michael Schlesinger in the department of atmospheric sciences at Oregon State University in Corvallis.

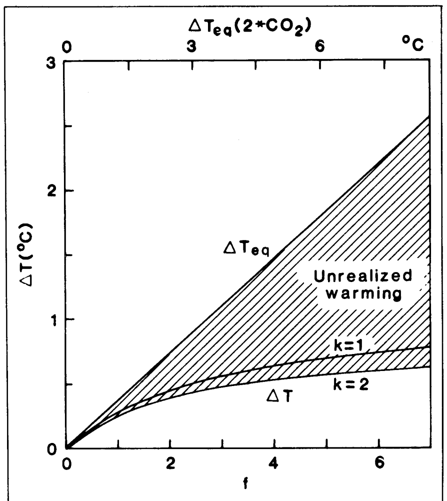
In the June 20 NATURE, Schlesinger and Tom Wigley at the University of East Anglia in Norwich, England, demonstrated analytically that the lag time between increased greenhouse-gas levels and warmer temperatures is not a fixed, physical constant, as many past CO_2 studies have assumed, but instead depends quite strongly on a quantity called climate sensitivity. (This helps explain why different climate models in the past have churned out a variety of response times.) Hansen and his colleagues published similar findings, based on earlier numerical work, in the Aug. 30 SCIENCE.

Climate sensitivity is a measure of how much warmer the earth will eventually get for a given increase in trace gases. It depends on how a number of factors, such as clouds and snow cover, combine to amplify or dampen the gas-induced warming. Unfortunately, estimates of climate sensitivity are highly inexact. The National Academy of Sciences, for example, calculated temperature increases of anywhere from 1.5° to 4.5°C for a doubling of carbon dioxide.

The recent papers show that for climate sensitivities and warming at the lower end of this scale, the response time will be relatively short. Likewise, the greater the climate sensitivity, the greater the ultimate warming and the longer the delay time. One scenario considered by Hansen's group, for instance, produced a characteristic lag time of 15 to 25 years for an ultimate warming of 1.5°C when CO_2 levels doubled from 300 to 600 parts per million. For an ultimate rise of 3°C, the characteristic lag time was 50 to 100 years. (The characteristic lag time is the time the ocean takes to reach 63 percent of its final, equilibrium temperature.)

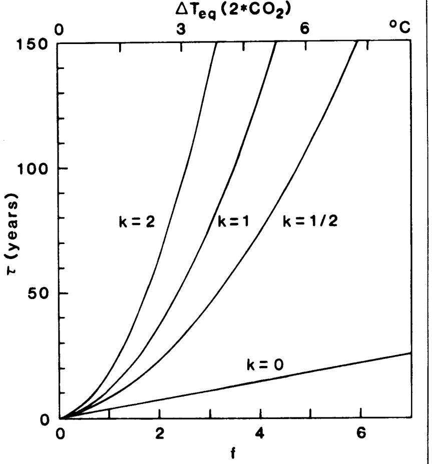
"Either way, it's not surprising that we haven't convincingly detected the CO_2 warming yet," says climatologist Syukuro Manabe at the Geophysical Fluid Dynamics Laboratory at Princeton (N.J.) University. Wigley and others have estimated that the temperature has increased by about 0.6°C over the last 100 years in the Northern Hemisphere. There is, therefore, no way to tell at present whether this value reflects a small warming on a short time scale or is just the beginning of a much larger, long-range temperature rise. Moreover, researchers are not even certain that the 0.6° jump is a direct result of CO_2 and greenhouse gases, since there are natural climatic fluctuations of about the same magnitude. In any event, the recent studies work against earlier arguments that future warming will be far less severe than had been projected since the earth had not warmed up much in the last century.

Since the observed temperature changes are not large enough and have not occurred over a long enough time for researchers to accurately infer climate sensitivity values, many scientists would like, at least, to reduce the uncertainties plaguing the climate models. The most serious problem at the moment centers on how to model clouds. Clouds can cool the planet by reflecting solar radiation back to space, but because they contain water vapor, which is a greenhouse gas, they can also enhance warming. Which of these effects wins out — as the increasing CO_2 levels



Hansen et al./SCIENCE

A large part of the ultimate warming (ΔT_{eq}) due to CO_2 added to the atmosphere since 1850 probably has not yet occurred. Above, the amount of the warming still to come depends on the climate sensitivity (f), for which the most plausible values run from about 1 to 4. Below, the time it will take for the ocean surface to warm to its final, equilibrium value depends very strongly on f and on k, the oceanic diffusion coefficient (in square centimeters per second). The larger the sensitivity of the climate, the greater the ultimate warming and the longer the delay time. Similarly, high values of k imply that more layers of the ocean are heated, so that it takes a longer time for the ocean surface to come to its equilibrium temperature. In the figures, ΔT is the temperature change since 1850 and the top scales denote the equilibrium temperatures calculated for a doubling of CO_2.



change the temperature, water content, optical properties and altitude of the clouds — is the subject of much debate. In addition, the mathematics are such that a small change in the theoretical effect of clouds can have a large impact on the outcome of the models.

Another weak spot in modeling efforts is the treatment of oceans, which can absorb and sequester heat in their deeper layers, thereby delaying surface warming. In their

Continued on p. 174

Continued from p. 170

recent papers, Wigley, Schlesinger and Hansen's group used a simple, one-dimensional model in which heat diffuses from a well-mixed upper ocean layer to the underlying zones. They found that the easier it is for the heat to diffuse, the greater the volume of water that must be heated, and the longer the response time.

Stephen H. Schneider and L. Danny Harvey at the National Center for Atmospheric Research (NCAR) in Boulder, Colo., say they have improved on this model by adding to it the advection or sinking of water at the poles and the upwelling of water elsewhere. Using their model in a numerical study, they obtained a response time two to three times shorter than with the diffusion model alone, they say.

The real ocean, of course, is far more complex than either of these models. "It will probably be another 10 years or so before a realistic three-dimensional model of the ocean is made," says Robert E. Dickinson at NCAR. Adds Schneider, "Most of us are atmospheric types and we're doing oceanography because we can't talk the oceanographers into solving the problems we need. But we're not doing the best that could be done."

There are many more research and data needs — every scientist has his or her favorite list. In coordinating an upcoming series of "state of the art" reports on the CO_2 problem, Fred Koomanoff, director of CO_2 research at the Department of Energy in Germantown, Md., hopes to sort through these lists and clarify what is and is not known about the greenhouse effect.

"We have to do better than we've done before we can go to the policy makers," he says. "I feel very strongly that we have a 10- to 12-year window before we might have to set into motion a change if there's going to be a change. The urgency that I feel right now is a research urgency."

Schneider says he's heard scientists contend for a long time that they have 10 more study years. "It's not a scientific issue of how long we have to study," he argues. "It's a value judgement — all a matter of how much change you fear and how much you are willing to gamble." He would like to see more programs focusing on how to adjust to the effects of greenhouse warming, such as developing new crop strains and exploring alternative energy sources. Others have stressed the need for studying the international consequences of the greenhouse effect, since some countries — like Canada and the Soviet Union, which suffer from severe winters — may benefit from the warming while others will not.

"We are performing an experiment on ourselves at a faster rate than we're understanding it," concludes Schneider. "To go into the future with no preparation strikes me as foolhardy, like anyone who goes out on the road without insurance." □