GLOBAL WARMING: QUO VADIS?

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Global warming is with us, and there is an urgent need for the world community to confront it. This, at least, is the popular conception garnered from the media and from a sheaf of conference reports. The same sources tell us that international relations and international law must be totally reorganized to deal with this impending threat.

This paper takes a different view. We argue that the international community is in danger of becoming a victim of its own hysteria. We outline the current state of knowledge about global warming and conclude that the fears of the world community have very little foundation in scientific fact.

The greenhouse effect, which was first described by Arrhenius nearly a century ago, refers to the process by which water vapor, carbon dioxide and other trace gases trap reflected solar radiation and warm the atmosphere. While there is no question about the existence of this effect—without it, the earth would have the same climate as the moon—there is considerable debate about the seriousness of an enhanced greenhouse effect arising from human contributions of greenhouse gases to the atmosphere.

Since the Industrial Revolution, the level of carbon dioxide in the atmosphere has increased by about 25 percent, largely as a result of the consumption of fossil fuel. About half of this increase has occurred over the last thirty years. The levels of other greenhouse gases, such as methane, chlorofluorocarbons, and nitrogen oxides, have also been increasing in recent years and now account for nearly half the added absorptive effect. A simple extrapolation indicates that sometime within the next century the level of greenhouse gases, expressed as carbon dioxide equivalent, will reach twice its preindustrial level. A similarly crude calculation indicates that the radiative effect of this doubling corresponds to a global warming of around 2-3°C. On geologic time scales, a warming of this magnitude occurring over a period this short would represent a substantial climate change.

The climatic effects of global warming might include an increase in precipitation, an increase in sea level, and changes in storm climate. Like the warming itself, which would be greater over continents and at high latitudes, these changes would not be uniform over the globe. Certain ecosystems, such as forests, might have difficulty adapting to rapid warming.

This broad picture has been known to atmospheric scientists for at least 50 years and, despite periodic cries from the wilderness, has attracted almost no attention. During 1988, however, this changed dramatically, thanks in part to the confluence of four events. Three of these events were climatological:

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heavy summer floods in Bangladesh, a hot, dry summer in the United States, and a large tropical storm in the Caribbean. The fourth event was the testimony of Dr. James Hansen on June 23, 1988, before the Senate Energy Committee. Hansen, a respected NASA scientist, told the committee that the earth had warmed significantly over the past century, that with a high degree of confidence this warming could be attributed to an enhancement of the greenhouse effect, and that unless something was done to stop the warming, the weather would get very bad indeed.

Hansen's remarks were picked up and amplified to the point of distortion by environmental activists, politicians, bureaucrats and journalists. They described a post-greenhouse hell of submerged coastal cities, desertifying grain belts, super-hurricanes, and millions of environmental refugees streaming out of the low-lying lands of Africa and Asia to impose their misery on neighboring states. The culprit in this impending disaster? Industry. More specifically, American industry, aided and abetted by short-sighted government policies that squander natural resources, suppress new technologies, and tempt developing nations down the road to environmental ruin.

There was something about this Manichean tale, repeated with a breathtaking disregard for the true complexities, that resonated throughout the world. Nearly two years later, it is still difficult to believe the reaction that followed. Perhaps the best measure of this reaction was the acceptability of the claim that global warming represents a threat second only to thermonuclear war—a claim that, even if true, illustrates just how enormous the gap between first and second place can be. More importantly, by the end of 1989 the US Congress was considering a dozen bills addressing the problem of global warming—including one ambitiously called the Global Warming Prevention Act. At the international level, an epidemic of conferences and commissions issued remarkably similar manifestos calling for a massive and immediate response. Meanwhile, the Intergovernmental Panel on Climate Change, which has been delegated responsibility for formulating this response, appears to be headed for a treaty-making initiative regardless of the conclusions of its own scientific working group.

Science reacts slowly to non-scientific events. By the time the first skeptical voices were raised, global warming as Armageddon was widely accepted as fact. Slowly, however, the scientific tide has turned—not against global warming, to be sure, but towards a more reasonable discussion of what is known, what is uncertain, and what should be done.

Climate Models

While the qualitative relationship between atmospheric composition and temperature is known from theory, it is clear that to "get the sign right" is not enough to guide policy-makers. To provide more detailed information about the timing, magnitude, and regional distribution of global warming, climatologists have turned to large-scale numerical models. From these models, fairly specific scenarios of the greenhouse world have been produced. To the non-specialist, it may seem that scientific results based on tens of millions of dollars of computing costs must be accurate. Unfortunately, as climate modelers are the first to point out, this is not the case.

If the earth were dry, it would be relatively easy to predict the climatic effect of a change in atmospheric composition. Unfortunately for climate modelers (and fortunately for humankind), most of the earth's surface is covered with water, and water vapor is a major constituent of the lower atmosphere. To a great extent, the response of this water will determine the climatic effects of changes in atmospheric composition.

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The hydrosphere responds to warming in two ways critical to the magnitude and timing of global warming. First, increased evaporation puts more water vapor into the atmosphere in the form of clouds. Cloudiness is an extremely important climatic process, in some cases acting to warm the earth's surface through a greenhouse effect and in other cases acting to cool it by reflecting solar radiation back into space. The latter process appears to dominate in today's climate, but it is not known whether this will continue under greenhouse warming. One illustration of the great sensitivity of temperatures to clouds is that, by changing slightly the way in which cloudiness is treated, the global warming predicted by the British Meteorological Office climate model was reduced in 1989 from around 5°C, among the highest predictions, to less than 2°, among the lowest.

The second response of the hydrosphere to warming is that the upper layer of the ocean warms up. This storage of heat in the ocean determines the timing of the atmospheric warming. Until recently, models of the ocean were very simple ("hokey" is the word used by climate modelers). In particular, these models made no allowance for an oceanic response to the warming of its upper layer. More recently, improved ocean models suggest that changes in ocean circulation may delay further the warming by redistributing heat.

There are other problems with climate models, many resulting from limitations imposed by computing power. For example, the ocean and the atmosphere are uncoupled in these models. Also, the spatial resolution of the models is too coarse to account for small-scale processes including clouds and ocean eddies—not to mention certain geographic features such as Florida and Japan. The impacts of warming on sea level and storm climate are not provided by the models and must be inferred from other information.

Not all model improvements can be counted on to reduce or delay the predicted warming. In some models, improving spatial resolution appears to increase the predicted warming. The point is that our best guess about future climate almost certainly will change as our understanding of climate processes and our computing ability improve, and that we must recognize this in choosing an appropriate response. Perhaps the best example of this is the evolution of opinion regarding the likely response of sea level to global warming. As recently as 1980, serious consideration was given to the possibility of an 8-meter rise in sea level in response to global warming. By early 1989, this number had been reduced to around one meter. By the end of 1989, a further revision brought this number down to 0.3 meter. This evolution can be understood as the normal progress of science, and we should keep in mind that this progress is likely to continue in all aspects of the global warming problem.

The limitations of climate models were known long before 1988. In particular, the current generation of climate models was not intended to be used for forecasting decades ahead. Instead, these models were intended to be used as research tools, to help climatologists understand the intricate connections and feedbacks in the climate system. For example, through the use of one such model, climatologists were able to determine that the drought of 1988 was caused by natural oceanographic events in the Pacific that, like the flooding in Bangladesh and Hurricane Gilbert, had nothing to do with greenhouse warming. To base a national energy policy on long-range climate predictions from these models is a little like basing a strategic defense initiative on the more realistic Tom Swift novels.

One measure of a model's ability to forecast future climate is its ability to reconstruct historic climate. Because we are interested in forecasting perhaps a century ahead, it makes sense to focus on climate reconstructions over the past century. Current models indicate that there should have been an accelerating global warming of more than 1 degree centigrade over the past century in response to changes in atmospheric composition, with most of the warming in the Northern Hemisphere and at high latitudes. To assess the accuracy of these reconstructions, and to gain further understanding of the climate of this and the next century, climatologists have turned to historic data.

Climate Data

It is only over the last 140 years or so that instrumental temperature data have been available for a large number of locations. There are many problems with these data, including incomplete spatial coverage (particularly over the Southern Hemisphere and the oceans) and changes in measurement methods. A more serious problem is that temperature data at many locations contain a localized warming component due to urbanization.

Great efforts have been made to address these problems and to construct global temperature records from these data. In general terms, these global records show an irregular warming beginning around 1880 and amounting to around 0.5° since then.

Is this warming in agreement with model reconstructions? We believe that it is not, although there is some disagreement over the seriousness of the mismatch.

First, even if all the historic warming is attributed to an enhancement of the greenhouse effect, it is still well below that predicted by models. In fact, there are good reasons to believe that some, if not all, of the historic warming represents a natural recovery from the Little Ice Age that culminated in an anomalously cool 19th century. If this is the case, then the mismatch between the models and the data is even greater.

Second, the temporal pattern of the warming is not consistent with model predictions. Most of the historic warming occurred between 1880 and 1940. Since 1940, there has been no overall warming, although the 1980s exhibited renewed warming. By contrast, the model predictions suggest that the rate of warming should have increased through time.

Third, the spatial distribution of the warming is not consistent with model predictions. Perhaps the most striking example of this inconsistency is the absence of warming or changes in precipitation over the continental United States since 1880. Certainly, the United States covers only a small part of the earth's surface, and conclusions about global climate should not be drawn too lightly from this. On the other hand, it is striking that the model predictions fail in perhaps the only large area for which sufficient high quality data are available to make this kind of careful assessment.

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Broadly speaking, the discrepancies between the model predictions and the data can be explained in two ways (that are not mutually exclusive). First, the models may overstate the true sensitivity of temperature to changes in atmospheric composition. Second, the behavior of the data may reflect processes—such as external variations in solar output and volcanic activity or internal variations typical of complex, interacting systems—that have masked greenhouse warming. Although it is not yet possible to distinguish between these explanations, the implications are clear. If it is the former, then, to some extent at least, the heat is off. If it is the latter, then we cannot count on these processes to suppress greenhouse warming indefinitely.

There are two lessons to be learned from climate data. First, greenhouse warming, when it occurs, will be superimposed on a climate for which persistent natural variability is the rule. This complicates the detection of greenhouse warming considerably and explains why virtually no climatologist is willing to claim that this detection has occurred. Second, the failure of climate models to reconstruct historic climate brings into serious question the precision of forecasts of climate decades ahead.

POLICY

Perhaps the most surprising thing about the debate over the scientific aspects of global warming is that there is so little of it. The limitations of the models and the inconsistencies of their results with historic climate are well known. Virtually everyone agrees that the most likely outcome is some amount of warming. Virtually everyone also agrees that enormous uncertainty surrounds the timing, magnitude and distribution of the warming and its impacts on such natural occurances as the hydrologic cycle, sea level and storm climate. Similar uncertainty surrounds the impacts of climate change on human society and the costs and benefits of policies aimed at avoiding or mitigating the negative impacts. The real global warming debate is over how we should act in the face of this uncertainty.

The most activist position in this debate has undergone some evolution within just the past two years. In 1988, the implication was simply that, unless we respond immediately and decisively, life as we know it would end. As the uncertainties over future climate became more widely known, the argument became that the mere possibility of a climate catastrophe, however remote, justified an immediate and decisive response. More recently, as questions have been raised about the true impacts of global warming and as the costs of an immediate and decisive response became clearer, the argument became that an immediate and decisive response was justified for other reasons. What we have here is a policy in search of a problem.

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The problem of decision-making under uncertainty is one that we face every day and there is a well-developed, if unfortunately obscure, methodology for addressing it. Briefly, in choosing the type and level of response, this methodology calls for a balance to be struck between the costs and benefits, taking account of the uncertainties. The costs and benefits that go into this calculation are by no means restricted to monetary consequences but can incorporate matters of ethics, equity and risk preference. Just as an animal need not have read Darwin to participate in the process of natural selection, individuals, institutions and governments intuitively strike some version of this balance on a routine basis. Did you bring an umbrella to work today? Do you have medical insurance? Did you hide in the basement when Skylab was falling?

The problem of responding to global warming is sometimes portrayed in terms familiar to horseplayers: you take your pick, you put your money down and you wait to see what happens at the finish line. In fact, the best strategy is probably not to pick a single scenario of future climate and act once and for all as if it is certain to occur. A better portrayal—and one that horseplayers would envy—is one in which bets can be spread over different horses and the amounts can be adjusted to some extent even during the course of the race. Whatever response to global warming is made today, it is sure to change in the future as more facts emerge. This implies, of course, that mistakes will be made. But this is intrinsic to decision-making under uncertainty. Proceeding rationally is not the same thing as always being right.

There is also some confusion over the role of information in this exercise. We are often warned that, if we wait until all the uncertainties are resolved, then it will be too late to act. While it is true that the reduction of uncertainty comes at some cost, it is also true that this reduction has real value in the sense that it helps avoid policy errors. Recall the evolution in thinking about sea level rise. In other words, there is another balance to be struck between reducing uncertainty and postponing decisions. Moreover, the level of uncertainty should not only affect the timing of the response, but its nature as well. In whatever way the balance is struck, the key point is to recognize the uncertainty that remains and not to pretend it away.

Dealing with uncertainty is such a long-standing feature of human behavior that a well tested set of rules has evolved telling how to do so. One of these—"play it safe"—clearly favors the call for immediate action. Conservative choices that err on the side of safety are reasonable in the face of uncertainty. In effect, this implies assigning a greater penalty to underestimated of future hazards than to overestimates. Others, however, favor a more measured response. These include looking before you leap, not putting all your eggs in one basket and playing for time. In other words, get more information, diversify responses and put off fixed commitments.

It is also a misconception that the policy debate falls along familiar partisan lines. For example, there is much in the activist position that should worry liberal Democrats. Large-scale emission reductions and increases in automobile mileage standards may hurt working people through higher prices and increased unemployment. Gasoline taxes may be regressive. The diversion of government funds and attention may be felt by social and other environmental programs. There is also much in global warming that should worry conservative Republicans. Life in Orange County, for example, gets very uncomfortable under many greenhouse scenarios.

The selection of national and international responses to the threat of global warming is well underway. When this exercise is complete, the uncertainty over global warming may be so great, and the cost of a large-scale response may be so high, that the choice will be to do little for now. On the other hand, if the cost of a climate catastrophe, however remote a possibility, appears great enough, a large-scale reduction in emissions may be preferred despite the economic cost. The potential consequences of this exercise are so large that the international community should insist on a careful consideration of costs, benefits and uncertainties. Analysis along these lines has lagged well behind the floating cocktail party that passes for international environmental policymaking these days.

In closing, we admit that it may be naïve to view the debate over global warming as hinging on science. Like many people, we find much appeal in the notion that the natural world should be left alone and we regret that there are not stronger policies aimed at protecting the environment. Neither would our feelings be swayed much by scientific results suggesting that such policies provide little direct benefit to human beings. These are, however, personal feelings, and we would not attempt to foist them on others as scientific imperatives.