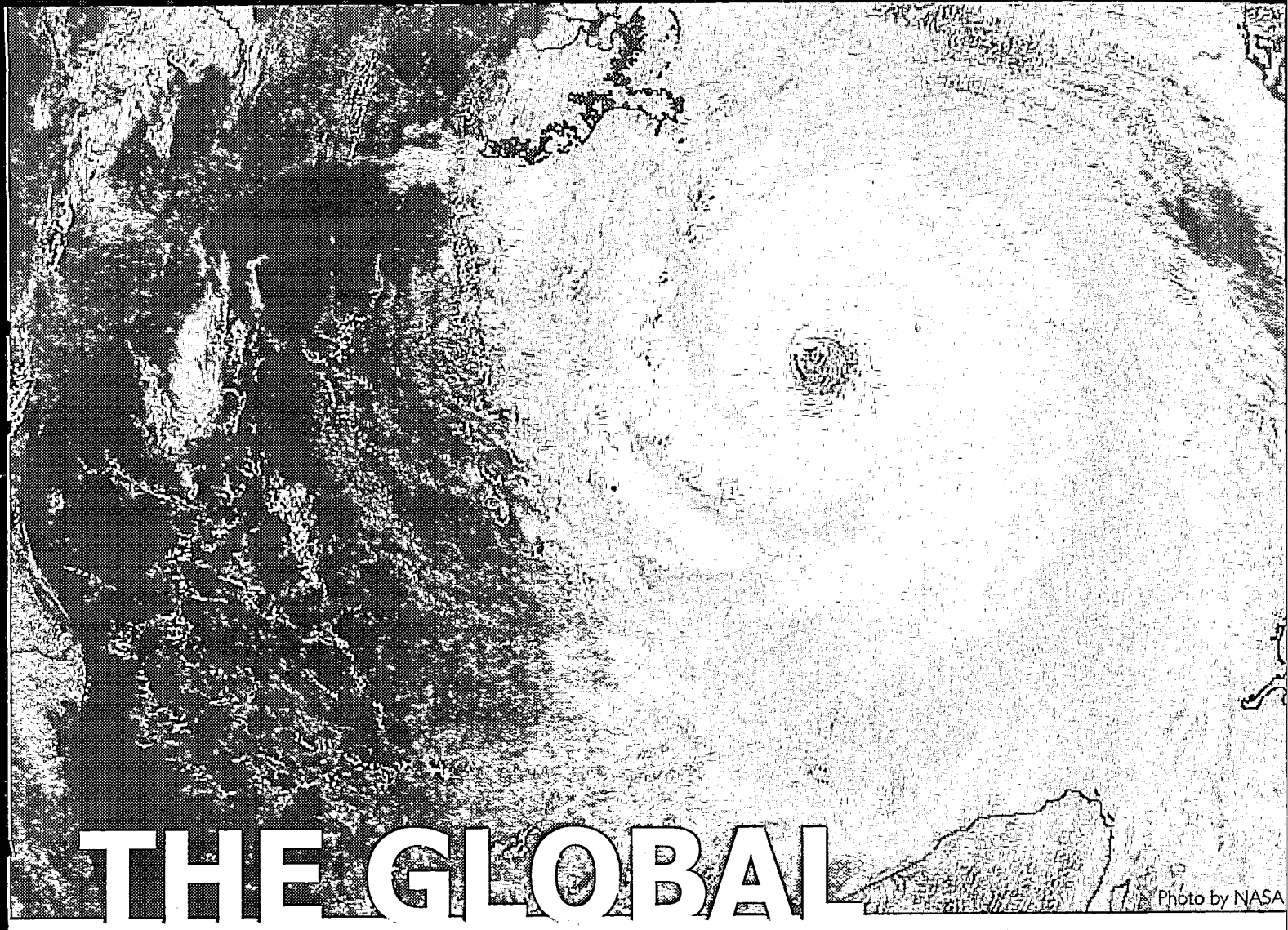

Photo by NASA

THE GLOBAL WARMING CRISIS

BY STUART JORDAN

THE EVIDENCE IS OVERWHELMING that the Earth's surface is warmer today than it was a century ago. As for why this is so, research by thousands of scientists strongly suggests that the cause is the largely uncontrolled and still increasing release of anthropogenic (human-caused) greenhouse gases. Yet there remain a few scientists who oppose these conclusions, claiming that either the evidence for significant global warming is unreliable or that, granting the problem, the sources are natural cycles over which we have little or no control.

This isn't a mere academic debate. The conclusions held by leaders in a variety of fields can't help but have a profound impact on social, political, and economic policy. Thus each side has expended considerable effort to convince the public, and through it the political establishment, of the validity of its stance. But because neither has been entirely successful, particularly in the United States, policies have been inconsistent and changeable, subject to partisan wrangling, corporate lobbying, and a general inadequacy of resolve.

The importance of the issue was most forcefully brought to the public's attention with Hurricane Katrina and Hurricane Rita. Their unusual severity, being among the strongest ever recorded in the Gulf of Mexico, reminded a number of network newscasters of recent scientific reports predicting an increase in hurricane severity.

For example, the article "Extreme Weather: Is Global Warming to Blame?" in the May/June 2005 *E/The*

Environmental Magazine quoted Ruth Curry, a Woods Hole Oceanographic Institute research specialist, saying, "Sea surface temperatures all over the tropics are running 1.8 to 3.6 degrees above normal. This is due to global warming." The article's author, Jennifer Vogel, noted the relevance of this: "While ocean and atmospheric circulation is the engine of a hurricane, heat is the fuel." Her summation makes it all plain: "The general scientific consensus on climate change and hurricanes is this: Hurricanes won't necessarily become more frequent, but they will become more intense."

This view was further supported by Massachusetts Institute of Technology climatologist Kerry Emanuel, writing in the July 2005 issue of *Nature*. He reported research suggesting that violent storms originating in the Atlantic and Pacific since 1970 have increased in intensity and duration by approximately 50 percent.

With global warming, hurricanes are becoming not only more severe but also more frequent.

But on August 2 the National Oceanic and Atmospheric Administration raised its 2005 Atlantic Ocean hurricane forecast, predicting eighteen to twenty-one tropical storms: nine to eleven of which would become hurricanes and between five and seven expected to reach major hurricane status. By October 9 the season had already yielded twenty tropical storms, eleven of which became hurricanes and five that were major. By contrast, a typical Atlantic storm year has only six hurricanes with two to three being major. That this is part of a new trend over recent years emerges from the NOAA's statement that "these very high levels of activity are comparable to those seen during August-November 2003 and 2004." The conclusion would seem to be that, with global warming, hurricanes are becoming not only more severe but also more frequent. And the mainstream media is paying attention.

In such a scientifically- and politically-charged atmosphere, more people need to become familiar with the scientific evidence and understand the nature of the debate so they can respond knowledgeably and communicate with policy makers in an informed way. Toward that end, this article aims to assess that weight of evidence to see if it is, in fact, sufficiently alarming to recommend more than cosmetic action. It will also review the debate itself to see where the trouble lies and what the political dimensions of the problem have become.

WHAT IS THE EVIDENCE THAT SIGNIFICANT GLOBAL WARMING IS OCCURRING?

If the summarized results of thousands of scientific studies that appear in the *Report of the Intergovernmental Panel on Climate Control-Climate Change 2001, The Scientific Study*, hereafter referred to as the IPCC 2001 report, are valid, the answer is unambiguously that significant global warming is occurring. Yet there are still a few dissenters in the scientific community, albeit a small minority. As a result, it will be necessary to examine the evidence and the arguments on both sides.

Climate scientists define global warming as the measured increase in the mean Earth surface temperature over a specified time interval. The most reliable data are properly averaged over land and ocean surfaces, statistically weighted according to the density of measurements within each equal-area element. The final averaging is done for the entire surface of the globe.

So, according to the IPCC 2001 report, the Earth's surface has warmed by approximately 0.6 degrees Centigrade over the twentieth century. That is approximately one degree Fahrenheit. The warming hasn't been uniform over the globe, however. In general it has been greater over the land than the oceans and, probably for that reason, greater over the northern hemisphere than the southern. This isn't surprising given the greater thermal inertia of the oceans due to the high heat capacity of water. There is also some speculation that the greater industrial activity, hence greater greenhouse gas emission, in the northern hemisphere may have contributed. However, because the main greenhouse gases are well mixed—staying in the circulating atmosphere for a long time—this effect may be small or even negligible.

Of particular concern is the rapid temperature rise over the last quarter of the twentieth century. The observations reviewed in the IPCC 2001 report show that the 1990s was the hottest decade on record and the year 1998 the hottest year since reliable temperature measurements were made. Reliable direct temperature measurements carry the record back into the

erature measurements carry the record back into the nineteenth century. And with the use of well-established indirect methods, it has been maintained that this decade was probably the hottest over the last thousand years.

One might think this weight of evidence for global warming is so overwhelming that the only remaining issue would be to establish the cause. However, a few additional issues need to be examined. While none of these suggest that global warming in the twentieth century didn't occur, there is still some controversy over the details of the rise. The curve of increasing surface temperature in the twentieth century shows a definite increase in the first part of the century, then an extended plateau over the years 1940 to 1975, and finally the rapid increase already discussed. Scientists ask why there were thirty-five years of no significant measured temperature rise during a mid-century period of increasing emission of anthropogenic greenhouse gases. Though industrial aerosol emissions that could have balanced the effect of the greenhouse gases were also increasing during this period, no satisfactory answer has yet emerged.

There is another problem that involves climate modeling. The best current general circulation models have predicted that tropospheric temperatures at heights in the atmosphere of a few kilometers should track surface temperatures. But measurements show little warming at these tropospheric levels, in disagreement with the models. Current work at the Goddard Institute for Space Science suggests that the discrepancy might be corrected by a better treatment of still poorly understood aerosols, plus dynamical processes that connect the troposphere with higher-lying atmospheric layers, but a definitive explanation hasn't yet emerged.

This is why it's important to always keep in mind that final answers to many important questions relating to global warming don't yet exist. Science isn't a collection of proved certainties: a factor often used as a reason for doing practically nothing, as if any action taken before all questions have been definitively answered is premature. But if the weight of evidence suggests a problem is both real and likely to become more serious with time, most reasonable people would say that doing nothing is the height of folly. Therefore, notwithstanding the aforementioned uncertainties, there remains the fact that an enormous body of well-calibrated observations supports the unambiguous rise in global surface temperature.

HOW SERIOUS ARE THE CONSEQUENCES OF GLOBAL WARMING?

Understanding the consensus of the scientific community, it remains necessary to ask if the likely harmful effects of global warming sufficiently outweigh the probable benefits of policies that might have harmful economic consequences. Furthermore, we need to ask about the likely *positive* effects of global warming? Might the news be good rather than bad?

There is some truth in this latter idea. Moderate global warming will enhance the agricultural productivity over parts of the globe. Climate models haven't advanced to the point of yielding accurate predictions of the detailed effects on all regional climates, but all of the more sophisticated models, in agreement with observations, predict that warming is greatest at the higher northern latitudes. Thus, for example, it seems probable that large areas of Russia and Canada could become more productive as the Earth's surface warms, though this could be offset by insufficient regional rainfall, currently difficult to predict.

In addition, increasing the growth rate of plants increases the rate at which the major greenhouse gas, carbon dioxide, is removed from the atmosphere through photosynthesis, while the rate of beneficial oxygen released also increases. This has been confirmed experimentally in areas of new forest growth and annual agricultural production, which, because of the rapid growth rate of young plants, is more beneficial from the above standpoint than an old-growth forest where overall growth rates have greatly subsided.

But are these benefits likely to significantly offset the known harmful effects of global warming? Let's review the negative consequences.

Perhaps most disturbing is sea-level rise. Water expands with increasing temperature, causing the sea level to rise accordingly. The best evidence from observations gives a mean global sea-level rise over the twentieth century of at least one foot, corresponding to the approximately one-degree Fahrenheit mean global temperature rise. Many of the world's glaciers are also retreating and very few are growing. If greater warming should induce significant melting of the West Antarctic Ice Sheet (anchored in the ocean below sea level) or, worse, a significant part of the Greenland Ice Cap, the rise in sea level could exceed twenty feet or more. The effect on major coastal cities, if warming

continues, is likely to become significant by the end of the twenty-first century and will be disastrous or even catastrophic if the warming exceeds moderate increases of a few degrees Fahrenheit.

There will be many other damaging effects of sea-level rise. The global ocean-circulation "conveyor belt" is known to be highly sensitive to temperature and salinity, resulting in so-called thermohaline circulation. Some observations suggest that the Gulf Stream, on which northwestern Europe is critically dependent, may be slowing down due to the reduced density of Arctic seawater. This water is becoming fresher from the more rapid melting of the Arctic Ice Sheet and is thus less density driven to sink into the deep ocean, providing a major driving force for the circulation at high northern latitudes. Sea-level rise will also flood many coastal wetlands critical to certain human activities and many forms of wildlife. While tough-minded "realists" may scoff at the importance of songbirds in the United States, they need to consider the role these birds play in controlling insect pests. Flooding the low-lying swamps of southern Louisiana will ensure a precipitous drop in the numbers of insectivorous migrating songbirds that are critically dependent on this area for food after their long spring migration back to North America.

Many other damaging effects of global warming are known with near certainty. Warming increases the incidence of pathogens responsible for many human and animal diseases. Warming induces changes in weather patterns, with increasing evidence (as mentioned above) that we can expect more violent storms. Moreover, there has been a spate of recent, unusual weather extremes in Europe, from deadly heat waves (in which over 30,000 people died in 2003) to tumultuous rainstorms in southeastern Europe, to forest fires in Portugal, to drought throughout Iberia. And warming means that a smaller fraction of the Earth's surface will be covered by snow and ice, which reflect sunlight more effectively than other land and sea surfaces. This increased absorption of sunlight sets in motion an unstable process that further enhances global warming.

Anyone interested in learning the huge number of harmful effects of global warming is encouraged to examine the IPPC 2001 report. For it is almost certain that the harmful effects will greatly outweigh the possible benefits, with many highly damaging effects already occurring.

IS HUMAN ACTIVITY THE CHIEF CAUSE OF GLOBAL WARMING TODAY?

It is often noted by critics of the current consensus that many natural processes might contribute to global warming and that one or more of them may be the dominant driver or drivers. It is therefore necessary to look at this claim and see if it holds up.

Examination of the mean global temperature curve for the northern hemisphere over the past millennium does reveal a fluctuating temperature of as much as 0.4 degrees Centigrade *before* the twentieth century. That is a sufficiently large fraction of the approximately 0.6 degree rise during the twentieth century to induce some scientists to speculate that even the recent rise, though unprecedented for the rate of change over this millennium, may have been caused by a long-period internal mode of the climate system, or by small long-term changes in the solar radiation.

It is true that not all internal modes of the climate system are well understood. However, I am aware of no evidence for any mechanism of this kind that has been studied at length in the refereed literature *and* which appears likely to produce long-term global warming. Instead, this possibility remains an unsubstantiated if interesting speculation.

This brings us to the sun, my primary area of expertise. A major effort has been underway in the National Aeronautic and Space Administration since 1979, and more recently in the European Space Agency, to obtain accurate measurements of the total solar irradiance (TSI), the flux of solar energy at the top of the Earth's atmosphere. One unambiguous result is that the TSI has varied by a small amount (no more than 0.1 percent) since 1979 over the well-known "eleven-year" solar cycle of sunspot activity. The TSI is measurably higher at solar maximum, when there are many sunspots, than at solar minimum, when there are few or none. However, this small increase in the solar flux, if simply "dumped" into the Earth's atmosphere as added heat, is insufficient to contribute to global warming. Furthermore, global warming doesn't exhibit a strong eleven-year cycle. Consequently, solar scientists have also looked for a change in the TSI over times longer than one eleven-year cycle. A recent increase should show up in the TSI measured at successive solar minima, when solar-cycle dependent processes that contribute to the TSI are largely absent. Unfortunately, the precision of the observations to date hasn't yielded a definitive result, though what evidence is available

suggests there is either no change between minima or a very small change that, viewed as heat introduced into the Earth's atmosphere, by itself couldn't explain the recent mean global temperature rise.

One must note that there are further possibilities for solar influence involving the effect of solar ultraviolet radiation on our upper atmosphere, and also possible small long-term changes in the solar interplanetary magnetic field at Earth, which influences comic-ray penetration and could indirectly affect cloud formation. These are subjects of ongoing research. Notwithstanding these many efforts, no strong suggestion has emerged that any of the known solar influences are playing a major role as global warming drivers.

The lack of a convincing argument based on solid research for any of the above hypotheses leads us to ask what we humans are doing that may be causing global warming. This leads naturally into an examination of anthropogenic greenhouse gases. Unlike the more speculative discussion of possible causes reviewed above, a very strong case can be made that carbon dioxide, in particular, is probably a significant driver, and could well be the dominant driver, of the current rapid rise in global mean surface temperatures.

There is no disagreement over the occurrence of the greenhouse effect to which carbon dioxide contributes. If the relatively long-wavelength infrared radiation from the relatively cool (compared to the sun's emitting surface) Earth all escaped into space, the Earth would be approximately fifty degrees Fahrenheit cooler than it is. Therefore life as we know it is critically dependent on the greenhouse effect. The question becomes how much greenhouse effect is good for us. Carbon dioxide is a well-studied gas that readily absorbs Earth's infrared radiation and reradiates part of it back to the Earth, thus causing warming. We know that the concentration of carbon dioxide in our atmosphere has increased by more than 30 percent since the beginning of the industrial revolution and that this percentage is increasing rapidly today, especially as China and India industrialize. We also know that carbon dioxide is so well mixed in our atmosphere that once there it will remain for more than a century unless we actively remove it. Thus, to stabilize the concentration of carbon dioxide in our atmosphere and prevent ever more efficient greenhouse warming, we will need to reduce the emission of carbon dioxide *well below* current rates of production—unless some powerful new "sink" for removing the gas can be developed. Even doing that won't likely lead to a stable situation for several decades; this is because of the aforementioned mixing problem. Finally, the more carbon dioxide we put into the atmosphere, the more the water in this warmed-up atmosphere will appear in vapor form; and water vapor is the most effective greenhouse gas of all.

Taken together, one quickly sees why all quantitative estimates of the most effective driver of global warming reported in the IPCC 2001 report identify carbon dioxide as the strongest contributor. To summarize, the extensively studied and well-known greenhouse effects of carbon dioxide are so strong that, combined with its persistence in our atmosphere, we can reasonably conclude that the increasing atmospheric concentration of carbon dioxide from human activity is very likely the dominant driver of global warming, and the warming effects will probably become worse with time for several decades, even after the emission rate has subsided.

The Bush administration has given little more than lip service to the global warming problem.

There are other greenhouse gases that contribute to global warming. Methane is the most important of these, but nitrous oxides also contribute and their concentration is rapidly increasing. All these gases are well mixed and will remain in the atmosphere for many decades. Aerosols also play an important role in global warming, and the effect of most of them, especially the sulphates, is generally toward cooling, as we have learned from the effect of large volcanic eruptions. However, based on the best knowledge available today from a large scientific community, the net effect of all of the other contributors to global warming isn't comparable to the effect of the well-studied greenhouse gases, with anthropogenic carbon dioxide demonstrably the leading contributor.

THE POLITICAL DIMENSION

Any consideration of the political dimension of an issue that has the global character of this one demands that we grasp the extraordinary complexity of

the political challenge. There is seldom an easy path to effective action, even if the arguments favoring it are compelling. There will usually be those passionately devoted to the opposite viewpoint, even if the real source of their position is to maintain the status quo. These opponents are often articulate, and some of them hold positions of great influence. That is one problem faced by those who would take decisive action to address global warming today.

But there is another. As Paul Krugman reports in the August 5 issue of the *New York Times*, there exists "a sort of parallel intellectual universe" in the sciences. Back in 1978, neoconservative theorist Irving Kristol encouraged major corporations to direct their "philanthropic contributions to scholars and institutions who are likely to advocate preservation of a strong private sector." Thus conservative think tanks emerged, first in the area of economics and then in hard science—creating in Krugman's words, "a world of 'scholars' whose careers are based on toeing an ideological line, rather than on doing research that stands up to scrutiny by their peers." We see this clearly regarding the issue of global warming. Even though the scientific consensus is overwhelming, skeptical reports having the appearance of peer-reviewed research have led large segments of the public, as well as national leaders, to believe that global warming is a controversial idea.

I attended a presentation on the question of global warming at the Rayburn House Office Building in Washington, DC, in May 2002, shortly after the IPCC 2001 report became generally available. A booklet was passed out by its author, Dr. S. Fred Singer, bearing the title *The Kyoto Protocol is Not Backed by Science.* This booklet makes frequent reference to the IPCC 2001 report, which contains a graph of surface temperature versus time up to the year 2000 C.E. The booklet carries a similar temperature-time plot on page 30, but cuts it off in the 1980s, just *before* the most spectacular rise in the 1990s! In the caption to this latter plot it says:

> Note the rapid rise up to about 1940, likely the recovery from the "Little Ice Age" that followed the "Medieval Climate Optimum." Temperatures fell till about 1975, when there was a sudden jump, tied to changes in ocean circulation and other worldwide changes.

I am unaware of any refereed scientific paper that would make such sweeping categorical statements on effects spanning a millennium. Until backed by serious research, such claims are unconfirmed speculations.

One more feature of the booklet is worth noting. In a paragraph on page 10, which argues that temperature observations since 1979 are in dispute, there appears the sentence, "It is likely therefore that the surface data (from poorly distributed land stations and sparse ocean measurements) are contaminated by the local warming effects of 'urban heat islands' acting on weather station thermometers (HTCS, 13)." The HTCS is a book by the same author, not a refereed scientific paper. And if the most recent temperature measurements had been so badly compromised—a conclusion with which many distinguished observers would stoutly disagree—those made at earlier dates to which I refer for comparisons were certainly much worse. Most significant of all, the IPPC 2001 report, on page 106, carries the following summary of many scientists who have studied the urban heat island effect *in detail* and whose work appears in the refereed literature.

Clearly the urban heat island effect is a real climate change in urban areas, but is not representative of larger areas. Extensive tests have shown that the urban heat island effects are no more than about 0.05 degrees Centigrade up to 1990 in the global temperature records used in this chapter to depict climate change.

The reader is encouraged to compare the above two direct quotes. Hopefully policy makers will compare the things they are told in science-policy briefings with the published consensus of working scientists. There are, after all, good reasons why almost all scientists are convinced that the evidence strongly supports the position that significant global warming is occurring, that the recently measured rate of global surface temperature rise is cause for serious concern, and that anthropogenic greenhouse gases, especially carbon dioxide, are likely the chief drivers of the current disturbing mean global temperature rise.

TOWARD A SOLUTION

Given all this, what can be done? Unfortunately, at this moment, there seem to be no technologically workable schemes for removing enough carbon dioxide from the atmosphere to make a measurable difference.

This leaves us with the challenge of finding some politically practicable way to reduce greenhouse gas

emissions. But it is an awkward truth that when most U.S. senators were asked informally in 2000 if they would support the Kyoto Protocol should President George W. Bush send it to the Senate for ratification, the overwhelming majority, Democrats as well as Republicans, said they could not. (Since that time, some new terms have been included in the Protocol to facilitate the admission of China and India, so this situation may have changed.) The reason for the liberals' surprising reply is clear. Many studies, not all by conservatives, suggest that full compliance with the terms of the Kyoto Protocol would likely lead to a deep American recession. For those willing to run this risk, sober reflection on the consequences of the economic collapse of 1929 and the subsequent worldwide depression with all its political and ultimately military consequences is certainly in order.

That said, what *can* be done, in particular by our own country? I have no new ideas for the solution, nor have I to date discovered any valid ones proposed by others. Nevertheless, in agreement with a large number of scientists who have given this issue considerable thought, there is one unambiguous statement I would make. Independent of the issues raised by the Kyoto Protocol, and given the weight of evidence that the problem of global warming is serious and fraught with dire consequences, failure to do anything at all and instead to promote "business as usual" is downright criminal.

Yet I see little evidence that the Bush administration has given more than lip service to the problem, though that could be changing. It is one thing to weigh alternatives and implement compromises that reflect the complexity of the problem; it is quite another thing to do nothing, especially if doing nothing is just a way of securing support from certain industries that exacerbate the problem.

There are, after all, things that can be done. Reopening a serious international dialogue, and not just saying a few good words, would be a useful if inadequate start. Not every problem must be solved before the weight of evidence becomes so compelling that certain initial steps become almost mandatory. We already know how to make more fuel-efficient automobiles, yet no national policy has surfaced to accomplish this. The scientific and engineering communities are the ones best suited to identify the scientific research that is still needed and the technical projects that show the greatest promise. These issues should be decided by them and not the politicians. Once solutions look promising, as a few already do, industry will be all too ready to jump in, for at that stage there is money to be made. And only a fool would underestimate human ingenuity when given a proper incentive, or the strength of American industry once the boiler is lit under it.

The important thing is to get started doing some of these things in earnest, and not for us to stick our head in the sand doing business as usual until the water comes in over our eyelids. If we wait long enough, it will. ⊞

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