Global Climate Change and the Making of a Report to the President of the United States

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In the spring of 2001, the White House asked the National Academy of Sciences (NAS) to conduct a study on the reality and seriousness of climate change. The request was unusual in two respects. First, the White House does not routinely make requests of the NAS; requests typically come from federal agencies, state governments, and corporations. Second, the amount of time the White House gave the NAS to conduct the study was very small. When Bruce Alberts received the request from White House staff and told them that the normal turnaround time for an NAS study was between nine and twenty-four months, he was shocked when they responded, “How about three weeks?” Bruce and his confidantes inside the NAS really did not know what to do, so they did not accept the request at first—but the situation turned around very quickly during the first week of May. Bruce asked me if I would chair the panel to do the study—a panel that had yet to be created. I said, “Yes, it’s worth a try.” Others agreed: all of the people we asked to serve on the committee, including

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Commentator F. Sherwood Rowland and speaker Ralph J. Cicerone (both, UC Irvine).

Professor Rowland, were willing to drop what they were doing in order to participate.

Our study report responded to thirteen direct questions from the White House. Part of the deal was that we were to give the White House a briefing before the report was released so that they could factor it into their views as soon as possible. After the document had been peer-reviewed anonymously by thirteen people, Professor Rowland and I went to the White House and delivered it, on time, early in June 2001. Two days before that, in a conference call, I gave the White House a very long briefing on the contents. Getting to that point was really a story in itself—in some ways a dramatic and tense one.

We didn't know at the time that the White House was preparing to take its position on the Kyoto Protocol. The United Nations had established a framework convention on climate change in 1992, which was signed by the previous President Bush after an international meeting in Rio de Janeiro. One of the stated goals of that framework convention was to "prevent the dangerous manmade interference with the climate system." Over the subsequent eight years, a number of other international meetings were held, including one in December 1997 in Kyoto, where the framework convention became more specific as to what the signatory nations would have to commit to in limiting the emissions of various gases and other substances into the atmosphere. As I say, we didn't know that the new Bush administration, in May and June of 2001, was preparing to make its own decision. But we were told, just as we started this study that May, that we had been given an extremely short period of time because the president needed our report for a trip to Europe in June. As it turned out, he traveled to Sweden and Germany. Later that summer, the United States government withdrew from the Kyoto Protocol.

The study committee decided simply to respond to the questions from the White House without editorializing, to stay as close to the subject as we could, and to make no comments whatsoever about the political and economic aspects of climate change. And that is what we did.

The first question, which I will dwell on for a couple of minutes, was *"What is the range of natural variability in climate?"* That is a suitable and intelligent question, and it also has a practical impact. That is, if climate change is occurring, the next questions might be, Is it natural? Are there alternative ways to explain it besides simply blaming it on human activities? Another question was, *"Are the concentrations of greenhouse gases that contribute to climate changes increasing in the atmosphere?"* One question with some policy relevance was, *"How long does it take to reduce the buildup of greenhouse gases once they are in the atmosphere?"* Another was, *"Is climate change occurring and, if so, how?"*

Climate change has characterized Earth over its entire history. For example, an inland continental glacier—say, in the Peruvian Andes—consists of horizontal layers of ice formed by the annual deposition of snow, which becomes compressed. In certain formations, where the ice has been preserved, one can actually count the layers by drilling cylindrical cores out of the ice. More important, those samples can be brought into laboratories under freezing conditions and analyzed. There are a couple of places in Antarctica now where the ice cores represent four hundred thousand years of record—not only of past climate change but also of what was in the air at the time. Gases can be extracted from the layers, which makes it possible to reconstruct histories of the composition of the air and to determine what greenhouse gases were present. Of course, there is plentiful geological evidence of large periods of glaciation, when more than half of North America was covered by very deep glacier, and of other periods when Earth was much warmer. Certainly, climate change has occurred in the past, and the range of natural variability is reasonably large. We pointed that out in our report.

As to whether concentrations of greenhouse gases are increasing, the answer, of course, is yes. For 45 years, Professor Charles Keeling and colleagues from several organizations have measured the amount of carbon dioxide in the air in various locations around the world. Professor Keeling started his own work on this topic in 1957 in Hawaii, and the record shows a continuous increase of atmospheric amounts of carbon dioxide. Beginning in the late 1950s, the carbon dioxide levels were 310 to 312 parts per million, on average, with beautiful seasonal cycles that tell us a great deal about photosynthesis and respiration on the entire planet, as well as the global cycling of the nutrient element carbon. Over the 45-year period that followed, levels of carbon dioxide—the principal human-caused greenhouse gas—increased to 370 parts per million. Scientists have also measured past methane amounts by using dated ice cores. Since 1800, with the start of the Industrial Revolution, one sees a dramatic rate of increase in the amounts of carbon dioxide, methane, nitrous oxide, and even sulfur (which is not a greenhouse gas) in the air. The record of sulfate deposited in ice cores actually helps us to unravel whether current climate change is due to human activity or to something natural. The question of whether concentrations of greenhouse gases are increasing was the easiest one the White House asked, because we have tons of high-quality data collected by many scientists over the past 40 years. We also know that the carbon dioxide increase in the past century is 75 to 80 percent due to our burning of fossil fuels—that is, fuels that contain carbon (e.g., oil, wood, coal, natural gas, petroleum)—and about 20 to 25 percent due to the deforestation of basically tropical lands, mostly for agricultural purposes. The deforestation not only causes the wood to be burned; it also causes a loss of organic matter that had accumulated in the soil over thousands of years, which becomes oxidized and is released to the atmosphere in the form of carbon dioxide.

In the case of methane, we have determined that on an annual basis, roughly one-third of the amount present in the air comes from completely natural sources that have been producing methane more or less steadily for thousands of years. But two-thirds of the methane emitted annually is under human control or at least human influence. For example, large amounts of methane are released out of both ends of domesticated cattle. Natural gas distribution, coal mining, municipal landfills, and rice agriculture are other sources. That atmospheric methane levels have increased by more than a factor of two since the Industrial Revolution reflects the extra added human input compared with what was previously totally natural.

It was harder to answer this question: *"Is climate change occurring and, if so, how?"* We analyzed

Left to right: Jack Peltason (UC Irvine), Suzanne Peltason, Mari Choper, J. Hillis Miller (UC Irvine), and Jesse Choper (UC Berkeley).

temperature measurements taken over the past 120 years all around the world, over land and ocean, at all points—probably about 200 million observations of temperature at Earth's surface, taken from ships and weather stations. Very dramatic upward excursions of air temperatures have occurred in the past 20 years. There was warming from about the beginning of the twentieth century until around 1940. Then there was a slight cooling until the year 1975, and rapid warming afterwards, with a total excursion of about six-tenths of a degree Centigrade, or one degree Fahrenheit, of warming over the past century. This is one measure of climate change, but in reality, the variables of climate that we should really be concerned about are not average temperatures. The variables that will affect us and all life around us are extreme temperatures, extreme drought, extreme storms—not average temperatures. Nevertheless, the average temperature measure leads to other questions: Given that there has been this kind of warming over the past hundred years, are greenhouse gases causing climate change? By how much will temperatures change over the next hundred years, and where?

A very interesting question posed by the White House was this one: *"Has science determined whether there is a safe level of greenhouse concentrations?"* After a few days, I realized that the reason for that question was that the intention of the United Nations framework convention was to prevent dangerous levels of greenhouse gases. It turns out that we cannot give a very clear answer to this question. Depending on the amount of climate change and its rapidity, greenhouse gases could reach levels that would endanger poor countries and island nations far earlier than modern industrial societies. Nations that are well equipped with technology, that have the ability to foresee the change, and that have the capital and the scientific and technological ability to take mitigating action (e.g., providing the right kind of irrigation for agriculture, or levies against seawater intrusion in water-treatment plants, as in New Orleans) can accommodate a certain amount of climate change if it happens slowly enough.

The Sun itself may be changing. In the past twenty years, the global average temperature has risen rather quickly—faster than at any other time in the previous hundred years. The temperature increase and the rate of this change are so large that many scientists began to think, a few years ago, that they were probably due to human activities; the rate of change pretty much repeats what was predicted from the greenhouse gases. But it is still possible that the rise in temperature may be a natural effect of some kind. The most likely natural explanation would be a change in output from the Sun during the past twenty years, but we must also consider that the past twenty years is the first period of time in which humans have measured the output of the Sun carefully enough to be able to tell whether it is changing. Judith Lean and her colleagues at the Naval Research Laboratory have reported an extremely precise set of measurements. They found that the Sun's total output varied over an eleven-year cycle, as people thought it did, and that after twenty-two years, the Sun's output returned to the level at which it had started. In fact, it was slightly lower, but insignificantly so. Thus, any suggestion that the warming of the past twenty years has a natural cause—especially increasing output from the Sun, the best hypothesis that people had invented—is simply not tenable. Scientists are now facing the reality of human-caused warming and grappling with the question of what will happen in the future.

Judging by probable estimates made by the Intergovernmental Panel on Climate Change (IPCC)—a group of about a thousand scientists who have been working over the past ten years to assess our state of knowledge—we can expect to see higher maximum temperatures and more hot days over nearly all land areas, with higher minimum temperatures and fewer cold days and frost days over all land areas. There will probably be a warming of the centers of the continents and an earlier drying out of soils after snow melts in the spring in

Left to right: Albert Bennett (UC Irvine), Kimball Romney (UC Irvine), Pauline Skyrms, and Brian Skyrms (UC Irvine) with speaker Ralph J. Cicerone.

agricultural belts in North America, Canada, and Russia. These projections are based on physical reasoning as well as computer models. What is likely to happen over the next hundred years, assuming a "business as usual" environment in which we continue to increase our rate of fossil fuel consumption and methane production? The IPCC predicts that by the end of the next century, the temperature increase will be somewhere between five and a half degrees Centigrade on the high side and about two degrees Centigrade on the low side, depending on the number of people in the world, as well as such factors as their fuel use, lifestyles, and levels of affluence.

Our report to the White House was very difficult to write because there are so many uncertainties and we do not yet know how to predict climate change in enough detail. We started with simple statements that we were able to make in direct answer to the questions posed, and we qualified our other statements. Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise—but we cannot rule out that some significant part of these changes is also a reflection of natural variability.

As you know, the Bush administration decided to end its participation in the Kyoto Protocol. I think that was a mistake because we have lost our influence to modify the treaty and because we are forfeiting future markets in energy technologies, among other reasons. We found out, in the process of preparing our report and during some summer testimony in the House and Senate, that the members of the administration, both in the White House and in the Cabinet, are divided on how to address humankind's impact on climate change. Some of them are taking this issue very seriously and, I believe, want the administration to stay involved internationally. Several other individuals moved in the opposite direction and took President Bush with them. They have all looked at the situation very carefully; they simply disagreed with each other.

F. Sherwood Rowland

On the morning of June 6 last year, half an hour before we were scheduled to brief the State Department on our National Academy of Sciences report on "The Science of Climate Change," we were looking closely at the just-arrived printed version of the document, and we noticed that a certain paragraph wasn't quite right. So we sent the report back for reprinting with the revisions, and the State Department briefing was conducted without any accompanying printed material. Then, after lunch, just before Ralph and I were to go over to the White House with the final report, a reporter for the *New York Times* called the NAS press office to request an advance copy before the press conference scheduled for the following morning. He was told, "No, you can't have it. That's our policy." However, the reporter had already learned that a briefing for members of Congress was going to happen immediately after the White House session, and he said, "If I don't get a copy from you, I'll have one from Congress by five o'clock this afternoon, and you won't have to worry about a press conference tomorrow." Of course, he would certainly have obtained a copy by that route. So that afternoon, while other committee members and I briefed the congressmen, Ralph was not with us. Instead, he was talking with the *Times* reporter and with other journalists who had been calling. The lead story on the front page of the *New York Times* the next morning revealed the conclusions that Ralph has just talked about here: that global temperatures are rising, and that human activities are among the most important causes of this phenomenon.

In my short commentary, I want to emphasize the importance of discriminating between the greenhouse effect and its enhancement. Many people think that the whole concept of the greenhouse effect is controversial, but it is not. Its existence and its causes are both understood and accepted in the scientific community. Current discussions center on how much the greenhouse effect may be increased during the coming decades, not on its validity.

The amount of solar energy that reaches Earth has to be balanced closely, on a day-to-day basis, by an equal amount of energy escaping from Earth. When scientists talk about global warming, they are concerned about a one- to three-degree temperature increase accumulated over the next fifty years—an imperceptible daily imbalance between the incoming and outgoing energies. The total energy radiated by both the Sun and Earth is basically determined by the surface temperature of each, as are the wavelengths of the emitted radiations. The energy emitted by the Sun as a consequence of its surface temperature of 5,800 degrees Kelvin is given off chiefly in the visible wavelengths corresponding to the colors red through violet, and in the invisible wavelengths of the near infrared and of the ultraviolet. The energy leaving Earth is emitted at much longer wavelengths in the far infrared, as determined by our surface temperature of about 57 degrees Fahrenheit, or 287 Kelvin.

The amount of energy absorbed by Earth is determined by the intensity of energy emission from the Sun, the distance of Earth from the Sun, and the albedo of Earth—the portion (about 30 percent) of the solar radiation that is reflected from Earth back into space without absorption. A straightforward calculation can be performed of the needed temperature for Earth's surface for the emission of an equivalent amount of far infrared energy if the

President Patricia Meyer Spacks (University of Virginia), Executive Officer Leslie C. Berlowitz, and Western Center Cochairs Walter Fitch (UC Irvine) and John Hogness (University of Washington) at a meeting of the Western Center Executive Council, held prior to the Stated Meeting.

additional assumption is made that *all* of this far infrared radiation escapes directly to space. When this calculation is performed, the needed surface temperature for Earth is 0 degrees Fahrenheit, far below the actual circumstance. The 57-degree difference between this calculated temperature of 0 degrees Fahrenheit and the actual average Earth temperature of 57 degrees Fahrenheit is the natural greenhouse effect. The reason for this large discrepancy is well understood: not all of this terrestrially emitted infrared radiation actually escapes to space. And the cause of this blockage of infrared escape is the presence in the atmosphere of the greenhouse gases.

The important greenhouse gases are those atmospheric components which have three or more atoms per molecule: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and water (H_2O), plus others, such as the chlorofluorocarbon gases, or CFCs (CCl_2F_2, CCl_3F, etc.). Significant amounts of these gases entering the atmosphere arise from the activities of humankind. Each of these molecular forms has the ability to absorb some infrared radiation at particular wavelengths in the far infrared while remaining transparent to other nearby wavelengths. (For this reason, the infrared spectrum of a molecule can be used as a "fingerprint" of its presence.) When the infrared energy at some wavelengths fails to escape, the response of Earth is to warm up until the additional energy escaping through the transparent regions of the spectrum equalizes for the shortfall in the regions of radiation absorption. This interception of outgoing terrestrial radiation in the wavelengths associated with the individual greenhouse gases has been amply confirmed by Earth-orbiting nadir-focused satellites.

The question is not whether there is a greenhouse effect in the atmosphere; rather, it is how much that effect will be enhanced by the growing concentrations of carbon dioxide, methane, and other greenhouse gases. The amount of water vapor in the atmosphere is basically controlled by the temperature of the oceans: if greenhouse absorption by the other gases causes the surface temperature to begin to rise, this increase will cause more water to evaporate, raising its concentration in the atmosphere and trapping still more of the outgoing infrared radiation. This is an example of a positive feedback to the overall temperature increase. Other positive feedbacks occur when snow melts, exposing bare ground, and when floating ice melts, leaving a surface of open water in its place. In both instances, the substitution reduces the albedo over the affected region; less solar radiation is reflected to space, and more remains to warm the planet. The question for the coming century is whether the natural greenhouse effect of 57 degrees Fahrenheit will be enhanced through the additional accumulation of greenhouse gases, and by the actual magnitudes of the various feedback processes, to 59 or 60 or 63 degrees Fahrenheit. That quantitative question is more difficult to answer than the yes/no question of whether there is a greenhouse effect, which has already been answered in the affirmative.

Both Ralph's research group and mine have been much involved, over the years, in studying the atmospheric characteristics of methane—the second most important greenhouse gas after carbon dioxide. Ralph and his colleagues have established, for instance, that the methane that comes out of rice paddies when they are flooded escapes by coming up through the rice plant itself, going directly into the atmosphere rather than escaping as bubbles rising through the water. My research group started measuring globally the amounts of methane back in 1978 and has monitored the atmospheric composition since by sampling every three months at locations from Point Barrow, Alaska, to the southern tip of New Zealand. During the 1980s we found a rather steady increase of about 1 percent per year in the total amount of methane in the atmosphere. During the 1990s, however, the increase was more erratic, fluctuating over time scales of one or two years between an increase of 1 percent per year and no increase at all. We do not yet have a good understanding of all the causes for the fluctuations. My own hunch is that an important contributing factor was the collapse of the Soviet Union and thereby of the demand for its abundant resources of natural gas.

The last two decades have shown definite evidence that Earth is warming. The year 2001 was the second-warmest year in the long interval since

Academy Visiting Scholar Ann Marie Mikkelsen and her husband, Daniel Sharfstein, were introduced at the Stated Meeting.

temperatures have been widely enough measured geographically to provide a usable global average—a period of record that began about 1860 to 1870. The year 1998 was the hottest one in that record, and the 1990s have been the warmest decade, despite a two-year global temperature reduction caused early by the 1991 eruption of Mount Pinatubo in the Philippines. That volcanic explosion put enough sulfur into the stratosphere to form a layer of sulfuric acid that temporarily increased the planetary albedo, reflecting additional amounts of the incoming solar radiation to space for about two years. The total temperature increase since about 1860 has been slightly more than one degree Fahrenheit, with about half of this increase occurring over the past two decades.

I will close with just one other comment. Only a week or so before we delivered the report on global climate change to the White House, there was a very good chance that the consensus of the NAS committee was going to fall apart as a result of arguments and disagreements about particular points. The real feat that Ralph pulled off—getting everybody on board for the final version, as published—required a lot of hard work and careful persuasion on his part. The final production of a unanimous, successful report was a tribute to his chairmanship. All of us should be thankful that Ralph was the chairman of that committee.
