THIS IS THE TEXT OF AN ESSAY IN THE WEB SITE *"THE DISCOVERY OF GLOBAL WARMING"* BY SPENCER WEART, HTTP://WWW.AIP.ORG/HISTORY/CLIMATE. **JUNE 2007**. HYPERLINKS WITHIN THAT SITE ARE NOT INCLUDED IN THIS FILE. FOR AN OVERVIEW SEE THE BOOK OF THE SAME TITLE (HARVARD UNIV. PRESS, 2003).

International Cooperation

By the very nature of climate, scientists had to study it across national boundaries. Already in the 19th century, meteorologists formed occasional international collaborations and simple coordinating bodies. From the 1950s onward these expanded into ever larger and more elaborately organized global programs involving thousands of experts. The programs chiefly studied daily weather, not climate. But when research pointed to the possibility of global warming, it raised scientific questions that could only be addressed through international cooperative studies, and policy questions that required international negotiations. Scientists elaborated the network of research organizations, and struggled to work out a consensus of reasonably certain conclusions about climate to guide policy-makers. In the 1980s, international conferences and new types of scientific groups began to shape the agendas of governments to a degree that had little precedent in other areas of world politics. The 1997 Kyoto Protocol, which went into effect in 2004, was a first step toward limiting greenhouse emissions. (There is a separate essay on the United States Government, which was central in international affairs.)

"The climatic world is one world even if politically we are not."
— *Reid Bryson*[1]

At the 1945 Potsdam Conference where Allied leaders planned how to end the Second World War, the President of the United States pressed the dictator of the Soviet Union about weather stations. Truman was worried about the coming American invasion of Japan. This operation, twice the size of the June 1944 Normandy landings, would be launched in winter. The Normandy invasion had succeeded not least because of meteorology. The Germans had expected nothing to happen in the prevailing bad weather, but Allied meteorologists, with better data on conditions to westward, had spotted a break in the storms. Now Truman demanded weather data from Siberia. Stalin grudgingly agreed to admit an American team (before they could set up their stations, Japan surrendered).[2]

Meteorology had become a concern at the highest levels. And as people were learning, weather is inescapably international, flowing each day between nations. Still, one could not expect presidents and dictators to give sustained attention to the technicalities of weather data. Negotiations were generally left to mid-level diplomats. They in turn had to rely on their national meteorological experts for advice on what should be done. To a degree not often found in international affairs, scientists wrote the agenda for action.

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[1] Bryson testimony, May 26, 1976 United States Congress (95:1) (1977), p. 217.

[2] Yoder (1997).

Meteorologists of different nationalities had long cooperated in the loose informal fashion traditional for all scientists, reading one another's publications and visiting one another's universities. But already for nearly a century they had been reaching beyond that. As a leading meteorologist later remarked, "One of the unique charms of geophysical science is its global imperative."[1] In the second half of the 19th century, meteorologists got together in a series of international congresses, which led to the creation of an *International Meteorological Organization*. Scientists who were interested in climate also met one another, among specialists concerned with many other subjects of geophysical research, in an *International Union of Geodesy and Geophysics* which was established in 1919. It became known as the IUGG—one of the first of countless acronyms that would infest everything geophysical and international. Specialties relevant to climate included meteorology, oceanography, and volcanology, each represented within the IUGG by a semi-autonomous association. There were a number of similar unions that fostered cooperation among national academies and scientific societies, sponsoring a variety of committees and occasional grand international congresses, gathered under the umbrella of the *International Council of Scientific Unions* (ICSU). The IUGG, along with an association of astronomers, was the first of these unions. For geophysicists needed international cooperation for their research more than most other scientists did.[2]

The IUGG with other groups in ICSU organized sporadic programs of coordinated observations. The leading example was an International Polar Year (1932-33), carried out in cooperation with the International Meteorological Organization. Scientists arranged all these matters, involving diplomats only where absolutely necessary.

None of these organizations did much to advance research on climate. Up through the mid-20th century, climatology was mainly a study of regional phenomena. The climate in a given region was believed to be set by the sunlight at the particular latitude, along with the configuration of nearby mountain ranges and ocean currents, with the rest of the planet scarcely involved. Classifying foreign climates was useful chiefly to serve imperialist plans for colonies—advising what crops could be grown profitably in a given region, perhaps, or what places were suitable for disease-prone "white" settlers. However, climatology textbooks did feature diagrams of the entire globe, divided into climate zones by temperature and rainfall. Hopes for a fundamental science of climate pushed climatologists toward a global perspective, as they drew on data compiled by people of many nationalities.

The Second World War greatly increased the demand for international cooperation in science, and not only among military allies. For many of those who worked for cooperation, the aim was to bind peoples together by invoking interests that transcended the self-serving nationalism that had brought so much horror and death. The postwar years saw the creation of the United Nations, the Bretton-Woods financial institutions, the first tentative steps toward European Union, and many other multilateral efforts. When the Cold War began it only strengthened the movement,

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[1] Smagorinsky (1970), p. 25.

[2] Greenaway (1996), p. 48 and passim.

for if tens of millions had recently been slaughtered, nuclear arms could slay hundreds of millions. Creating areas where cooperation could flourish seemed essential. Science, with its long tradition of internationalism, offered some of the best opportunities.

Fostering transnational scientific links became an explicit policy for many of the world's democratic governments, not least the United States. It was not just that gathering knowledge gave a handy excuse for creating international organizations. Beyond that, the ideals and methods of scientists, their open communication, their reliance on objective facts and consensus rather than command, would reinforce the ideals and methods of democracy. As the political scientist Clark Miller has explained, American foreign policy makers believed the scientific enterprise was "intertwined with the pursuit of a free, stable, and prosperous world order."[1] Scientists themselves were still more strongly committed to the virtues of cooperation. For some, like oceanographers, international exchanges of information were simply indispensable for the pursuit of their studies. To many the free association of colleagues across national boundaries meant yet more: it meant advancing the causes of universal truth and world peace.[2]

Study of the global atmosphere seemed a natural place to start. In 1947, a World Meteorological Convention, negotiated in Washington, DC, explicitly made the meteorological enterprise an intergovernmental affair. In 1951, the International Meteorological Organization was succeeded by the *World Meteorological Organization* (WMO), an association of national weather services. The WMO soon became an agency of the United Nations. That gave meteorological groups access to important organizational and financial support, and brought them a new authority and stature.

We should pause a moment to recognize that behind these bland acronyms stood real humans, crafting the organizations and maintaining them through countless hours of delicate negotiations and memo-writing. The WMO, for example, owed much to cooperation between the Soviet Union's Victor A. Bugaev and Harry Wexler, chief of the United States Weather Bureau. Let us commemorate Wexler here as a particularly outstanding example of that seldom recognized but essential figure, the scientist - bureaucrat - administrator - diplomat. A close look reveals his hand pulling switches behind the scenes in many parts of the story of climate science, from the 1940s until his untimely death in 1962, as he organized research and directed funds with judicious care.

All the organizational work for weather prediction did little to connect the scattered specialists in diverse fields who took an interest in climate change. A better chance came in the mid 1950s, when a small band of scientists (Wexler, for one) got together to push international cooperation to a higher level in all areas of geophysics. They aimed to coordinate their data gathering and—no less important—to persuade their governments to spend an extra billion or so dollars on research. The result was the *International Geophysical Year* (IGY) of 1957-58.

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[1] Miller (2001), p. 171 and passim.

[2] See e.g., Hamblin (2002), p. 14.

The IGY with its unprecedented funding was energized by a mixture of altruistic hopes and hard practical goals.[1] Scientists expected in the first place to advance their collective knowledge and their individual careers. The government officials who supplied the money, while not indifferent to pure scientific discovery, expected the new knowledge would have civilian and military applications. The American and Soviet governments further hoped to win practical advantages in their Cold War competition. Under the banner of the IGY they could collect global geophysical data of potential military value. Along the way they could gather intelligence about their opponents, and meanwhile enhance their nation's prestige. Others found the Cold War an inspiration in a reverse sense, hoping that the IGY would help set a new pattern of cooperation between the rival powers—as indeed it would.

The launching of the Soviet *Sputnik* satellite in October 1957, and the American space shots that followed, were officially announced as cooperative scientific experiments under the IGY umbrella. Technically the rocket launches had more to do with spy satellites and the threat of bombardment with ballistic missiles. Yet on a deeper level, both global surveillance and intercontinental warfare forced people to see the planet as a whole. It is a moot question whether, in a more tranquil world, governments would have spent so much to learn about sea water and air around the globe. For whatever motives, the result was a coordinated effort involving several thousand scientists from 67 nations.

Climate change ranked low on the list of IGY priorities. The IGY's official reports scarcely noticed many meteorological subjects, for example computer modeling. But with such a big sum of new money, there was bound to be something for topics that happened to be related to climate. Highly important work was done under IGY auspices. For one thing, a young scientist studied the level of carbon dioxide gas (CO_2) in the atmosphere, and found it was rising. Without the IGY funding, this crucial warning signal might have been delayed a decade or more. Meanwhile a permanent scientific presence was established in Antarctica, and ice drilling began in Greenland, leading toward a demonstration that ice cores held a record of the history of climate. If the first artificial satellites were launched largely from Cold War motives, they had a grand potential for monitoring the Earth's air and seas in the spirit of the IGY. No less important, spending all that IGY money pushed meteorologists, oceanographers and other Earth scientists to coordinate their work, at both the national and international levels, to an extent that had been sadly missing until then. The field of geophysics rose to a new level of strength and cohesion—a mature international community. *The difficulties of bringing together the diverse topics involved in climate change are described in a supplementary essay on Climatology as a Profession.*

The effort still fell far short of gathering the kind of data from around the globe that would be needed to understand the atmosphere well. For example, even at the peak of the IGY there was only one station reporting upper-level winds for a swath of the South Pacific Ocean 50 degrees

[1] Standard although superficial accounts are Chapman (1959); Sullivan (1961); Greenaway (1996), ch. 12.

wide—one-seventh of the Earth's circumference.[1] The lack of data posed insuperable problems for atmospheric scientists, in particular those who hoped to build computer models that could show a realistic climate, or even just predict weather a few days ahead.

Conversations among mid-level officials, and a 1961 report from the U.S. National Academy of Sciences, brought the problem to the attention of the American government. A solution was at hand in the satellites that were being launched into orbit to watch the entire globe, but they had to be backed up by ground-level observations. President John F. Kennedy saw an opportunity to improve his administration's standing with the U.S. public, who were skeptical of the value of his ambitious plans for spacefaring. The government also had in mind the Cold War arguments that had favored the IGY — launching an international research program could improve the nation's prestige abroad, and give a window into the Soviet Union's meteorological programs. Addressing the United Nations General Assembly in 1961, Kennedy called for "cooperative efforts between all nations in weather prediction and eventually in weather control." The President mentioned that one result would be "a better understanding of the processes that determine the system of world climate," but the primary goal he offered was the traditional one, improved weather predictions.[2]

The first step would be world-wide gathering and exchange of data. The WMO eagerly took up the proposal and promptly launched a World Weather Watch using balloons, satellites, and so forth. The Watch has continued down to the present as the core WMO activity. It has served weather forecasters everywhere, scarcely impeded by the Cold War and other international conflicts—a radiant demonstration of how science can transcend nationalism (even when the original motives included a strong nationalist component). Among the most important, and most obscure, jobs of the meteorologists was to agree on standards for exchanging data: how many times a day should a station measure the wind, for example, and at what times, and exactly how? As historian Paul Edwards has pointed out,"Global standards were blocked by both perceived national interests and the sheer inertia of existing practices." The standardization gradually achieved by the World Weather Watch capped more than a century of difficult negotiations, and formed the essential foundation for everything that the world's scientists would eventually be able to say about climate change.

Meanwhile the ICSU, determined not to be left out, decided to join the WMO in organizing global meteorological research. The union of independent, mostly academic, scientific groups and the UN-administered organization of governmental agencies often took a different view of

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[1] Lorenz (1967), pp. 26, 33, 90-91, ch. 5 passim.

[2] Kristine Harper as quoted in Doel (2002); Harlan Cleveland, "Keeping Up with Technology," Address to National GeoData Forum, Nov. 2, 2001, online at www.chaordic.org/res_geodata.html. Kennedy, address before the General Assembly of the United Nations, September 25, 1961, online at http://www.jfklibrary.org/HistoricalResources/Archives/ReferenceDesk/Speeches/JFK/003POF03UnitedNations09251961.htm. Thanks to Bob Henson for correcting this reference.

affairs. Their negotiations were ponderous and sometimes frustrating. Nevertheless in 1967 the two organizations managed to set up a *Global Atmospheric Research Program* (GARP). The program's primary goal was better weather forecasting, but the organizers, with an eye on the steadily rising curve of atmospheric CO_2, meant to study climate too. The organization was inevitably complex. An international committee of scientists would set policy, helped by a small full-time planning staff in Geneva. Panels of specialists would design individual projects, while boards of government representatives would arrange for funding and other support. Also necessary was an additional layer: national panels to guide the participation by each individual nation (for the United States, the group was appointed by the National Academy of Sciences).

Already by 1973 the observing system for GARP and the World Weather Watch was in place — seven satellites, four of them built by the United States and one each by the Soviet Union, the European Space Agency, and Japan. Evidently the organizational complexities were not a hindrance but an advantage, at least in the hands of people who knew how to work the system.[1]

The chair of GARP's organizing committee during its crucial formative years 1968-1971 was a Swedish meteorologist, Bert Bolin. He had started his career with the arcane mathematics of atmospheric circulation, working with top experts like Carl-Gustav Rossby and Jule Charney. He won a high reputation by devising equations for weather prediction computers, first in Princeton and then back in Stockholm. In 1957, shortly before Rossby died unexpectedly, he encouraged Bolin to turn to geochemistry—a study whose importance had suddenly been raised by the discovery that the greenhouse effect might become a serious matter. Bolin went to work on carbon dioxide and became an expert on its chemical and biological operations. He also did a bit of pioneering work on the influence of aerosols. Yet it was less for his wide-ranging scientific savvy that Bolin was chosen to organize GARP, than for his unusual ability to communicate and inspire people. Developing outstanding diplomatic skills, he would be a mainstay of international climate organizing efforts for the next quarter-century.

Among Bolin's difficult tasks was getting people not only from different countries but from different geophysics fields to find a common language. The central activity of GARP was coordinating international research projects, which gathered specialized sets of data on a global scale, complementing the routine record-keeping of the World Weather Watch. Historian Paul Edwards has pointed out that such networks of measurement became essential in the modern world's process of "globalization." Few recognized how powerfully these networks pressed people to communicate, cooperate, and establish standards.

The process was never straightforward, for great heaps of raw data are meaningless in themselves. As Edwards points out, raw data must be standardized by processing it through layers of computation. These computations are inescapably based on particular theoretical ideas. What ultimately emerges is a picture of "the world" as represented by a computer model. (After all, it was mainly the computer modelers' demands for world-wide standardized data that drove

[1] Standards: Edwards (2004). Fleagle (2001), pp. 57, 97; Perry (1975), p. 661; Conway (in press).

agencies to create measurement networks in the first place.) Then, to an extent rarely noticed, the summary information sets agendas for policy-makers. The World Weather Watch and other meteorological programs were pioneers in the process, but during the last quarter of the 20th century, measurement networks ranged into many other fields of economic and social life, from trade figures to disease statistics.[1]

GARP itself, while including research on climate, was aimed more at meteorology. Global climate, one scientist recalled, "was considered a very subordinate field compared with synoptic forecasting, atmospheric research, and so forth." Some even questioned whether the WMO should continue work in climatology at all.[2] But in the late 1960s an environmental movement was everywhere on the rise, and officials could no longer ignore global changes. As a first step, in 1969 the WMO's Commission for Climatology established a working group on climate forecasts. Meanwhile the WMO itself passed a resolution calling for global monitoring of climate and atmospheric pollutants, including CO_2. Climate was also among the many topics addressed by a *Scientific Committee on Problems of the Environment* (SCOPE), established by ICSU officials in 1969 as an international framework for collecting environmental data and for related research. The SCOPE committee, aware of the CO_2 greenhouse problem, promoted the first extensive studies of how carbon passes through bio-geochemical systems.[3]

Climate scientists met one another in an increasing number of scientific meetings, from cozy workshops to swarming conferences. The first significant conferences where scientists discussed climate change included the topic as just one of several "Global Effects of Environmental Pollution," to quote the title of a two-day symposium held in Dallas, Texas in 1968. This pathbreaking symposium was followed by a month-long "Study of Critical Environmental Problems" (SCEP) organized at the Massachusetts Institute of Technology in 1970. All but one of the participants at MIT were residents of the United States, and some felt that environmental issues demanded a more multinational approach, particularly to meet the need for standardized global research programs. This led directly to a second, more comprehensive gathering of experts from 14 nations in Stockholm in 1971, funded by an assortment of private and government sources. The Stockholm meeting focused specifically on climate change—a "Study of Man's Impact on Climate" (SMIC).[4]

The exhaustive SMIC discussions failed to work out a consensus among scientists who felt greenhouse gases were warming the Earth and those who felt pollution from particles was cooling it. Nevertheless, all agreed in issuing a report with stern warnings about the risk of severe climate change. Among other things, the reviewers noted the possibility that warming would melt polar ice, which would reduce the Earth's reflection of sunlight and thus accelerate the warming.

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[1] Edwards (2000a).

[2] Taba (1991), p. 106.

[3] Greenaway (1996), pp. 176-82.

[4] Singer (1970) for Dallas 1968; Barrett and Landsberg (1975), p. 16; SCEP (1970).

With such unstable feedbacks at work, the climate could shift dangerously "in the next hundred years," the scientists declared, and "as a result of man's activities."[1]

What should be done? Like almost all scientists at the time, the SMIC experts called mainly for more research, to determine how serious the problem really was. They recommended a major international program to monitor the environment, much larger and better integrated than the scattered efforts of the time, as well as more research with computer models and so forth.

The SMIC meeting had been organized specifically to prepare for a pioneering United Nations Conference on the Human Environment that was held the following year, again in Stockholm. The SMIC Report was "required reading" for the delegates.[2] Heeding the report's recommendations, along with voices from many directions calling attention to other problems, the U.N. conference set in motion a vigorous new *United Nations Environment Programme* (UNEP). From this point forward, gathering data and other research on the climate was a concern—although only one among many—of the U.N.'s environmental activities.[3]

Meanwhile the GARP committee set up a series of internationally coordinated large-scale observations of the oceans and atmosphere. As usual the main goal was improved short-term weather prediction, but as usual the findings could also be useful for climate studies. The best-known of these projects was the GARP Atlantic Tropical Experiment (GATE, an acronym containing an acronym!). The aim of the exercise was to understand the enormous transport of moisture and heat from tropical oceans into the atmosphere where cumulus clouds formed. As one participant boasted, GATE was "the largest and most complex international scientific undertaking yet attempted." In the summer of 1974, a dozen aircraft and 40 research ships from 20 nations made measurements across a large swath of the tropical Atlantic Ocean, along with a satellite launched specially to linger overhead.[4] Increasingly in such studies, not only would one find teams from different nations cooperating, but also the individual members within a single team might come from a half dozen different nations.

While these studies proceeded through the early 1970s, the world public's climate anxieties were jumping higher as savage droughts and other weather disasters struck several important regions. The Secretary-General of the WMO took note of "the many references to the possible impacts of climatic changes on world food production and other human activities at various international meetings," including both a special session of the U.N. General Assembly and a World Food Conference in 1974. The WMO resolved to take the lead in this newly prominent field, organizing an increased number of conferences and working groups on climate change. GARP

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[1] SCEP (1970); Matthews et al. (1971); Wilson and Matthews (1971), pp. 125-29, quote on p. 129; for the history, Barrett and Landsberg (1975), pp. 16-17.

[2] "required:" Kellogg and Schneider (1974), p. 121; see Kellogg (1987).

[3] Hart and Victor (1993), p. 662; Fleagle (1994), p. 174. See UNEP's Web site at http://www.unep.org.

[4] Robinson (1967); Fleagle (1994), pp. 170-73; GARP (1975); Perry (1975), quote p. 663.

planners too decided to give additional stress to climate research, making what one leader called a "belated, though earnest and sincere" effort to bring in oceanographers and polar researchers.[1]

Nevertheless, the study of long-term climate change remained a relatively minor topic, even while studies of short-term weather flourished. A rapid rise in publications on climate change had begun in the 1950s. That did not mean a great deal, for the starting level had been negligibly small. In 1975, only about 75 scientific papers were published world-wide on any aspect of the subject, and the rate of increase was sluggish compared with some "hot" fields of science.[2] (Some of the climate papers, however, presented important scientific advances.)

Despite growing public and scientific interest in climate change, the funding for research on the topic was now generally static in every country. The number of PhD's granted in the sciences of the Earth, oceans and atmosphere, which had grown rapidly until the mid 1970s, levelled off. The same thing was happening in most fields of science during the economically stagnant 1970s. But climate science had special problems because it lacked a committed sponsor. Funding was dispersed among numerous private organizations and relatively small and weak government agencies. An example of the problems was the struggle to sustain a Climatic Research Unit that Hubert H. Lamb established in 1971 at the University of East Anglia in England. One of a very few institutions dedicated to climate research, the Unit would make pathbreaking studies of climate history, but its funding from the government was trifling. Only a scramble to secure grants from various private foundations allowed the work to move forward.[3]

Climate scientists had little chance to get access to policy-makers. If they convinced their contacts among lower-level officials that climate change posed a problem, these officials themselves had scant influence with the higher reaches of their governments. The best opportunities lay elsewhere. As one scholar commented, "national research had in many countries a better chance of influencing international policy than domestic policy."[4] By the mid 1970s, when science officials in various countries became so concerned about climate change that they began to contemplate policy actions, they found sympathetic ears among officials in United Nations organizations. One notable example was Robert M. White, who in his position as head of the U.S. Weather Bureau, and afterward of the agency responsible for all government meteorology and oceanography (NOAA), was his nation's official representative to the WMO. Already in the early 1960s, Bob White had been one of the founders of the World Weather Watch. Now in all his official capacities he pressed for cooperative research on climate change, using American government commitments to influence WMO and vice versa.

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[1] WMO (1975), p. ix; Perry (1975), pp. 66-67.

[2] Stanhill (1999), reading from graph on p. 396, see also Stanhill (2001), Fig. 2, p. 518.

[3] Publications: Geerts, (1999), p. 64. Lamb (1997), pp. 199, 203-04. Other institutions at the time were the Institute for Environmental Studies founded in 1970 under Reid Bryson at the University of Wisconsin (incorporating a Center for Climatic Research that Bryson had created in the 1950s), and Budyko's Main Geophysical Observatory in Leningrad.

[4] Nolin (1999), p. 138.

Scientists' demands for action led to a 1978 International Workshop on Climate Issues, held under WMO and ICSU auspices in Vienna, where the participants organized a pioneering World Climate Conference. Their mode of organization was crucial, setting a standard for many later efforts. Participation was by invitation, mostly scientists and some government officials. Well in advance, the conference organizers commissioned a set of review papers inspecting the state of climate science. These were circulated, discussed, and revised. Then more than 300 experts from more than 50 countries convened in Geneva in 1979 to examine the review papers and recommend conclusions. The experts' views about what might happen to the climate spanned a broad spectrum, yet they managed to reach a consensus. In a concluding statement, the conference recognized a "clear possibility" that an increase of CO_2 "may result in significant and possibly major long-term changes of the global-scale climate." This cautious statement about an eventual "possibility" was scarcely news, and it caught little attention.

Conferences and other international bodies shied away from any statement that might seem partisan. Scientific societies since their outset (that is, since the foundation of the Royal Society of London in the 17th century) had explicitly held themselves apart from politics. This tradition was doubly strong in international science associations, which could not hope to keep cooperation going if they published anything but facts that all agreed upon. Every word of key statements was negotiated, sometimes at great length. When journalists at a press conference asked a leader of SCOPE what he thought governments should do, he replied, "They should read the report." When the journalists said, "Okay, but what next?" he replied, "They should read it again."[1]

The most influential work of those who attended the 1978 Vienna conference was structural. Besides organizing the 1979 Geneva meeting, they called for a climate program established in its own right, to replace the miscellaneous collection of uncoordinated "meteorological" studies. The government representatives in the WMO and the scientific leaders in ICSU took the advice, and in 1979 launched a *World Climate Programme* (WCP) with various branches. These branches included groups that coordinated routine global data-gathering, plus a *World Climate Research Programme* (WCRP). The WCRP was the successor to the portion of GARP that had been concerned with climate change. It inherited the GARP organization and logistics, including WMO administrative support plus its own small staff, and an independent scientific planning committee.[2] As in GARP, the new organization's main task was planning complex international research projects. For example, under WCRP an *International Satellite Cloud Climatology Project* collected streams of raw data from the weather satellites of several nations, channeling the data through a variety of government and university groups for processing and analysis. The vast data sets were stored in a central archives, managed by a U.S. government agency.

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[1] Greenaway (1996), p. 179, quoting F. Warner.

[2] http://ads.smr.uib.no/jgofs/Intro.htm#HISTORY; Thompson et al. (2001); Jäger (1992), p. iii; Fleagle (1994), p. 176; Lanchbery and Victor (1995), p. 31.

Up to this point the United States had dominated climate dicussions, as it dominated most scientific affairs while the rest of the world's advanced nations were digging out of the ruins of the Second World War. But now that the other economies and research establishments had recovered, international discussions began to dominate the discourse. The driving force, as one observer remarked, was "a small group of 'entrepreneurs,' who promoted what they viewed as global rather than national interests." Blurring the distinction between government officials and non-governmental actors, they organized a series of quasi-official international meetings which were increasingly influential.[1] Some of the meetings were formally sponsored by the WMO, others by ICSU or UNEP.

The most important initiative was a series of invitational meetings for meteorologists sponsored by all three organizations, with particular impetus from UNEP's influential director, Mostafa Tolba. Beginning in 1980 the meetings gathered scientists for intense discussions in Villach, a quiet town in the Austrian Alps. A major turning point was the 1985 Villach conference, where experts from 29 countries both rich and poor, representing a variety of widely separated fields, exchanged knowledge and argued over ideas. By the end of the meeting they had formed a prototype of an international climate science community, a community with a firm consensus. From their review of the evidence that had accumulated in the past half-dozen years (supercomputer models, the discovery that CO_2 levels had plunged during past ice ages, an observed rising of global temperature, a SCOPE assessment of the likely impacts of warming and so forth), the Villach scientists agreed that greenhouse gases could warm the Earth by several degrees, with grave consequences. But it was a more recent and surprising calculation that made "the biggest buzz of the conference." Methane gas and various other gases emitted by industry and agriculture, which were rapidly accumulating in the atmosphere but had attracted little attention until now, could have a collective effect on climate roughly equal to the effect of CO_2 itself. The climate changes that had been predicted to come when the level of CO_2 doubled, a century in the future, would in fact come on twice as fast—within their own lifetimes. "Suddenly the climate change issue became much more urgent," recalled Bolin, who supervised the meeting's scientific report.[2]

In their concluding statement, the Villach group boldly announced that "in the first half of the next century a rise of global mean temperature could occur which is greater than any in man's history." As usual, the scientists called for more research. But they also took a more activist stance than scientists had normally taken. Brought together as individual researchers in their personal capacities, with no official governmental responsibilities, they felt free to respond to the alarming conclusions that emerged from their discussions. In their concluding statement the Villach group pointed out that governments made many policies (building dams and dikes, managing farmlands and forests, etc.) under the assumption that the climate would be the same in

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[1] Bodansky (1997), quote at section 4.1.6.

[2] Ramanathan et al. (1985); on Villach see Franz (1997), quote (by J.P. Bruce), p. 16; see also Pearce (2005). Bolin: "Statement by the UNEP/WMO/ICSU International Conference," preface to Bolin et al. (1986), pp. xx-xxi.

the future as in the past. That was no longer a sound approach. Nor should government policies only respond passively to climate change. The Villach report pointed out that "the rate and degree of future warming could be profoundly affected by governmental policies," and called on governments to consider positive actions to prevent too much warming. Climate science, in short, was no longer just a matter for scientists.[1]

As a practical result of the Villach recommendations, in 1986 the WMO, UNEP, and ICSU jointly established an *Advisory Group on Greenhouse Gases* (AGGG). It was a small, elite committee of experts. For funding and advice, it relied largely on scientists and institutions that were already advocating policies to restrain climate change. The AGGG organized international workshops and promoted studies, aiming eventually to stimulate further world conferences. [2]

These U.N.-sponsored efforts were only one strand, although the central one, in a tangle of national, bilateral, and multi-national initiatives.[3] Countless organizations were now seeking to be part of the action. Of course, none of this work was actually done by abstract "organizations." It was made to happen by a few human beings. Among these Bert Bolin was the indispensable man, chairing meetings, editing reports, promoting the establishment of panels. Along with his exceptional personal abilities as a scientist, executive, and diplomat, Bolin benefitted from his position at the University of Stockholm in Sweden, traditionally neutral territory.

Villach and other world conferences, along with similar consensus-building studies on climate change carried out in the 1980s by national bodies such as the U.S. National Academy of Sciences, crystallized a set of beliefs and attitudes among climate scientists. Science writer Jonathan Weiner reported after a series of interviews, "By the second half of the 1980s, many experts were frantic to persuade the world of what was about to happen. Yet they could not afford to sound frantic, or they would lose credibility." Any push for policy changes set the scientists against potent economic and political forces, and also against some colleagues who vehemently denied the likelihood of global warming. The scientific arguments became entangled with emotions. "They were so worried about the changes they saw coming, and the difficulty of persuading the world," Weiner noticed, "that they sometimes caught themselves rooting for the changes to appear... it was hard to know how to feel."[4]

Human motivation is never simple, and behind the emotional commitment of scientists lay more than dry evaluation of data. Adding to their concern about global warming was the normal desire of people to perceive their own field as vitally important, with the corollary that funds should be generously awarded for their work and for their students and colleagues. An important minority took their case directly to the public, but most scientists felt more comfortable sending rational appeals through channels to government officials. The scientists found allies among

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[1] Bolin, *ibid*.

[2] Agrawala (1999).

[3] Some elements are covered by Pomerance (1989), pp. 265-67.

[4] Weiner (1990), p. 79.

administrators in national and international bureaucracies, persuading many that the world faced a serious problem. That reinforced the normal inclination of officials to extol the importance of their areas of responsibility and to seek greater budgets and broader powers. Whenever evidence suggests that something needs to be done, those who stand to profit from the doing will be especially quick to accept the evidence and to argue for policy changes. As the political scientist Sonja Boehmer-Christiansen argues, "Calls for environmental regulation were generally attractive to environmental bureaucracies," and attention to global warming "allowed national bodies to expand their influence." As for politicians, by speaking to public concerns for the environment they could mount "a world stage on which to indulge in global green rhetoric."[1]

To sort through the human motives and determine what policy actions were truly needed, the only reliable guide would be rigorous scientific conclusions—which would require more research.. While a few scientists and officials tentatively proposed policy changes, many more were pushing for better international research projects. Although ICSU's SCOPE program had produced some useful work, such as reports on the global carbon cycle, that was barely a beginning.[2] The WCRP's work was likewise useful, but as an organization under the supervision of the WMO (which is to say, the heads of national weather services), the WCRP was naturally preoccupied with meteorology. All this was too narrow for the scientists who were taking up the new "climate system" approach, which was building connections among geophysics, chemistry, and biology. They decided they needed a new administrative body.

Spurred especially by U.S. scientists acting through their National Academy of Sciences, around 1983 various organizations came together under ICSU to develop an *International Geosphere-Biosphere Program* (IGBP). Starting up in 1986, the IGBP built its own large structure of committees, panels, and working groups.[3] The drawback, as one climate scientist pointed out, was a feeling that "an IGBP should be in the business of measuring or modeling everything at once from the mantle of the Earth to the center of the Sun!"[4]

The WCRP remained active in its sphere, launching international collaborations in meteorology and related oceanography. Like the IGBP and other international scientific programs, the WCRP had no significant funds of its own. It was a locus of panels, workshops, draft reports, and above all negotiations. Scientists would hammer out an agreement on the research topics that should get the most attention over the next five or ten years, and who should study which problem in collaboration with whom. The scientists would then go back to their respective governments, backed by the international consensus, to beg for funds for the specific projects.

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[1] Boehmer-Christiansen (1994).

[2] Bolin et al. (1979); Bolin (1981).

[3] National Academy of Sciences (1986); International Council of Scientific Unions (1986); Fleagle (1994), p. 195.

[4] Schneider (1987), p. 215.

In each case one of the organizers' first difficulties was to find a meaningful and pronounceable acronym—a mode of naming emblematic of organizations with distinct if transient identities, stuck together from independent components. Important examples of projects that gathered data internationally under the WCRP were the *Tropical Ocean and Global Atmosphere Programme* (TOGA), the *World Ocean Circulation Experiment*, and the *Joint Global Ocean Flux Study* (JGOFS, which surveyed the carbon in the world's oceans). Scheduled to run through the mid 1990s, these were complex institutions, coordinating the work of hundreds of scientists and support staff from a variety of institutions in dozens of nations.[1]

Two participants described the developments of the 1980s as a "revolution" in the social structure of climate science. The field was propelled to a new level not only by great improvements in scientific tools such as computers, but equally by great improvements in international networking thanks to cheap air travel and telecommunications. "Huge teams of highly skilled people can review each other's work, perform integrated assessments, and generate ideas" far better than the mostly isolated individuals of earlier decades, they pointed out. "A steady diet of fresh scientific perspectives helps to maintain regular doses of funding, helped in turn by an endless round of conferences."[2]

Research impelled a major policy breakthrough in the late 1980s, although not for climate. International public concern over damage to the protective stratospheric ozone layer, and scientific work coordinated by UNEP, led to policy discussions beginning in 1982. The result was a Vienna Convention for the Protection of the Ozone Layer, signed by 20 nations in 1985. This document was only a toothless expression of hopes, but it established a framework. The framework became useful when the discovery of an "ozone hole" over Antarctica shocked officials and the public, showing that the problem was already upon us. In the epochal 1987 Montreal Protocol of the Vienna Convention, governments formally pledged to restrict emission of specific ozone-damaging chemicals.

This was not the first international agreement to restrict pollution in response to scientific advice. One notable example was an Antarctic Treaty, regulating activities on the polar continent, inspired by the IGY and signed back in 1959. More to the point, in 1979 the nations of Western Europe had adopted a Convention on Long-Range Transboundary Air Pollution. This pledged them to limit their sulfate emissions, which scientists had proved was the cause of destructive acid rain. The aim was to restrain coal burning in, say, Britain so it would not kill forests in, say, Germany. Later, more nations and other chemicals were added to the agreement. The convention led to the establishment of an international scientific project to study the problem, complete with

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[1] For history of the WCRP since about 1980, see http://www.wmo.ch/web/wcrp/about.htm#history, for JGOFS, see http://ads.smr.uib.no/jgofs/Intro.htm#HISTORY, and for WOCE, Thompson et al. (2001).

[2] O'Riordan and Jäger (1996), p. 2.

elaborate computer modeling to connect acid rain with economic scenarios for power generation.[1]

The Montreal Protocol set an even higher and stricter standard for international cooperation and national self-restraint. Over the following decade it had wonderful success in reducing emissions of CFCs, staving off further deterioration of the ozone layer. Although important for protecting human health and vital ecosystems, this did little to hinder climate change. (CFCs are only one of many greenhouse gases, and some of the chemicals that industry substituted for CFCs were themselves greenhouse gases). However, the people who had begun to worry about global warming hoped that the precedent set by the Montreal Protocol could set an example for negotiations to restrict greenhouse gase emissions. Industrial groups and ideologues had vehemently opposed this sort of regulation as an insufferable economic drag. But in regulating CFCs, as in regulating the sulfate emissions that caused acid rain and in a variety of other environmental issues, a few years of experience showed that market-oriented mechanisms could be devised to do the job surprisingly cheaply. Indeed, over the long run the restrictions brought a net *savings* to the global economy.

The success at Montreal was followed up the next year, 1988, in a "World Conference on the Changing Atmosphere: Implications for Global Security," nicknamed the Toronto Conference. The planning came out of the workshops initiated by the 1985 Villach conference. Toronto was a meeting by invitation of scientist experts—not official government representatives, who would have had a much harder time reaching a consensus. The Toronto Conference's report concluded that the changes in the atmosphere due to human pollution "represent a major threat to international security and are already having harmful consequences over many parts of the globe." For the first time, a group of prestigious scientists called on the world's governments to set strict, specific targets for reducing greenhouse gas emissions. That was the Montreal Protocol model: set targets internationally, and let governments come up with their own policies to meet the targets. By 2005, said the experts, the world should push its emissions some 20% below the 1988 level. Observers hailed the setting of this goal as a major accomplishment, if only as a marker to judge how governments responded (it would turn out that in 2005 the world's emissions were slightly *above* the 1988 level.)[2]

The Toronto Conference attracted much publicity, and politicians at the highest level began to pay attention to greenhouse gases. It helped that the Conference was held during the summer of 1988, when exceptional heat and drought caused much public concern in the United States—the nation whose cooperation was indispensable for any effective agreement. But officials were also impressed by the insistent warnings of leading scientists. In the United Kingdom, Prime Minister Margaret Thatcher—trained as a chemist and one of the few prominent politicians able to fully understand her briefings by scientists—gave global warming official standing when she

[1] Brooks and McDonald (2000).

[2] WMO (1989); Lanchbery and Victor (1995), pp. 31-32; Jäger (1992), p. v. On all this, see also O'Riordan and Jäger (1996) and Franz (1997).

described it as a key issue in a September 1988 speech to the Royal Society. She showed she meant it by increasing the funding for climate research (although as elsewhere, most of the money was relabelled or taken from other programs). Thatcher was the first major world leader to take a determined position. Attention from the politically powerful "Greens" in Germany and elsewhere in continental Europe added to the issue's legitimacy. One immediate consequence was a 1989 meeting in Hanover, Germany where twenty environmentalists from Europe and the United States discussed ways to work together. The result was the Climate Action Network, a loose coalition of non-governmental organizations. (Within two decades the network was exchanging information and coordinating strategy among more than 360 NGOs around the world.)[1] Meanwhile, the media increasingly hinted that any catastrophe in the news, from droughts to floods to polluted seas, might be due to human interference with climate. What had begun as a research puzzle had become a serious international public concern and a diplomatic issue.

The policy debates required answers to questions even more intractable than the scientific ones. What would global warming mean for the economy and for society, and what should (or could) governments do about it? These questions pushed climate scientists toward what some called a "holistic" approach, interacting with many other fields.[2] Experts in agriculture, economics, and so forth began to build rough numerical models, addressing questions such as how farming and forestry would react to a rise of temperature or to a rise of fuel taxes. Predictions would also have to figure in possible increases in weather disasters, in tropical diseases, and much else. The results of the studies were far from reassuring.

The steep climb of concern in scientific, public, and official circles did not translate into any exceptional increase of funding in the 1980s. Particularly in the United States, the world's largest source of money for research, the Reagan administration instinctively disbelieved all claims supported by environmentalists. Moreover, during the 1980s most of the industrialized countries, from the United States through Western Europe to the Soviet Union, slowed the rate of increase of their research spending. With jobs in research scarcer than applicants, students were not attracted to the grueling labor of winning a Ph.D. Nevertheless, climate change managed to attract an increasing number of students and grants, rising at least as rapidly as other important fields of science in the 1980s. After stalling in 1970-1975 the annual number of scientific papers published on climate change world-wide began again to rise in a fairly smooth exponential, more than doubling each decade.[3]

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[1] Nolin (1999) discusses the general trend of policy in Germany, the Netherlands, Sweden, and the U.K. 1970s-1997; for Germany, see Beuermann and Jäger (1996). Steve Waddell, "The Climate Action Network: Civil Society Tackling Global Negotiations," Global Action Network Net (Jan. 2003), http://www.gan-net.net/pdfs/can.pdf.

[2] Jones and Henderson-Sellers (1990), p. 9.

[3] From 76 papers in 1975 to 447 in 1997, Stanhill (1999).

Climate research remained quite a small field of science in the 1980s. Whereas any substantial sub-field of physics or chemistry counted its professionals in the thousands, the number of scientists dedicated full-time to research on the geophysics of climate change was probably only a few hundred worldwide. (If you included every scientist competent to at least comment on some aspect, including such fields as biological responses to climate change, it would still be not much above a thousand.)[1] Since these climate scientists were divided among a great variety of fields, any given subject could muster only a handful of true experts.

What role could the international climate science community, so small and fragmented, play among the mighty political and economic forces that were coming to bear on climate policy? The existing scientific organizations, however well-crafted to coordinate research projects, seemed incapable of taking a stand in policy debates. As one knowledgeable observer put it, "Because WCRP was seen as largely the vehicle of physical scientists, while IGBP was viewed largely as the vehicle of scientists active in biogeochemical cycles, and because both WCRP and IGBP were seen as scientific research programs, neither seemed to afford the venue that could generate the necessary confidence in the scientific and policy communities."[2] Events like the Toronto Conference were all very well, but a report issued after a brief meeting could not command much respect. And it did not commit any particular group to following up systematically.

The Advisory Group on Greenhouse Gases (AGGG) set up in 1986 had served well in keeping the issue in the forefront through activities like the Toronto Conference. However, the group lacked the official status and connections that could give their recommendations force. Besides, they had little money to spend on studies. The AGGG's reliance on a few private foundations, and its connections with outspoken environmentalists, raised suspicions that the group's recommendations were partisan. An even more fundamental drawback was the group's structure, in the traditional model of a tight, elite committee. As one policy expert explained, "climate change spans an enormous array of disciplines, each with their own competing schools of thought... Seven experts, even with impeccable credentials,... could not credibly serve as mouthpieces of all these communities."[3]

Policy-makers concerned about climate looked for a way to supersede the AGGG with a new kind of institution. Conservatives in the United States administration might have been expected to oppose the creation of a new and prestigious body to address climate change. But they feared still more the strong environmentalist pronouncements that the independent scientists of the AGGG were likely to stimulate. Better to form a new group under the control of government representatives.

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[1] Estimate of 200 to 300: Gee (1989). The IPCC study in 1995, aiming at comprehensive international inclusion, had about 500 "authors" and over 500 "reviewers" who submitted suggestions..

[2] Fleagle (1994), p. 179.

[3] Agrawala (1999), p. 166 (this is a particularly penetrating study).

Responding to all these pressures, in 1988 the WMO and UNEP collaborated in creating an *Intergovernmental Panel on Climate Change* (IPCC). Unlike earlier conferences, national academy panels, and advisory committees, the IPCC was composed mainly of people who participated not only as science experts, but as official representatives of their governments—people who had strong links to national laboratories, meteorological offices, and science agencies like NASA. The IPCC was neither a strictly scientific nor a strictly political body, but a unique hybrid. This met the divergent needs of a variety of groups, especially within the United States government, which was a prime stimulator for the action. The AGGG was not formally abolished. But within two years this small body ceased to meet, as most of the world's climate scientists were drawn into the IPCC's processes. The panel would fulfill its creators' hopes, becoming a pivotal player in policy debates.

Most people were scarcely aware that these international initiatives all relied on a key historical development—the world-wide advance of democracy. It is too easy to overlook the obvious fact that international organizations govern themselves in a democratic fashion, with vigorous free debate and votes in councils. Often, as in the IPCC, decisions are made by a negotiated consensus in a spirit of equality, mutual accommodation, and commitment to the community process (these are seldom celebrated but essential components of the democratic political culture). If we tried to make a diagram of the organizations that deal with climate change, we would not draw an authoritarian tree of hierarchical command, but a spaghetti tangle of cross-linked, quasi-independent committees.

It is an important but little-known rule that such organizations were created mainly by governments that felt comfortable with such mechanisms at home, that is, democratic governments. Nations like Nazi Germany, Communist China, and the former Soviet Union did little to create international organizations (aside from front groups under their own thumb), and participated in them awkwardly. Happily, the number of nations under democratic governance increased dramatically during the 20th century, and by the end of the century they were predominant. Therefore democratically based international institutions proliferated, exerting an ever stronger influence in world affairs.[1] This was visible in all areas of human endeavor, but it often came first in science, internationally minded since its origins. The democratization of international politics was the scarcely noticed foundation upon which the IPCC and its fellow organizations took their stand.

It worked both ways. The international organization of climate studies helped fulfill some of the hopes of those who, in the aftermath of the Second World War, had worked to build an open and cooperative world order. If the IPCC was the outstanding example, in other areas, ranging from disease control to fisheries, panels of scientists were becoming a new voice in world affairs.[2] Independent of nationalities, they wielded increasing power by claiming dominion over views about the actual state of the world—shaping perceptions of reality itself. Such a transnational

[1] Weart (1998), pp. 264-65. On consensus, see p. 61.

[2] Miller (2001), esp. pp. 212-13.

scientific influence on policy matched dreams held by liberals since the nineteenth century. It awoke corresponding suspicions in the enemies of liberalism.

After 1988

Global warming was now firmly in place as an international issue. In many countries it was hotly debated in national politics. The scientific community itself was taking up the topic with far greater enthusiasm than ever. Conferences proliferated, demanding time from researchers, government officials, and environmental and industry lobbyists. As one conference delegate put it, the "traveling circus" of the greenhouse effect debate had begun. In the early 1980s, there had been only a few conferences each year where scientists presented papers on climate change, but in 1990 there were about 40, and in 1997 more than 100.[1]

Hopes that the Toronto agreement would do for CO_2 what the Montreal agreement had done for ozone soon dwindled. Greenhouse gases could not command the strong scientific consensus that had quickly formed for the ozone danger. There was no dramatically visible proof, like the "ozone hole" images presented to the public. And vastly greater economic forces were at stake. [2]

Most informed people understood by now that the climate change issue could not be handled in either of the two easiest ways. Scientists were not going to prove that there was nothing to worry about. Nor were they about to prove exactly how climate would change, and tell what should be done about it. Just spending more money on research would no longer be a sufficient response (not that governments had ever spent enough). For the scientists were not limited by the sort of simple ignorance that could be overcome with clever studies. A medical researcher can find the effects of a drug by giving a thousand patients one pill and another thousand patients a different one, but climate scientists did not have two Earths with different levels of greenhouse gases to compare. Our neighbor planets Mars and Venus, one with almost no gases and the other with an enormous amount, showed only lethal extremes. Scientists could look at the Earth's own climate in different geological epochs, but they found no record of a period when CO_2 was injected into the atmosphere as rapidly as was happening now. Or they could build elaborate computer models and vary the numbers that represented the level of gases, but critics could point out many ways the models failed to represent the real planet. These hardly seemed convincing ways to tell the civilized world how it should reorganize the way everyone lived.

Of course, people make all their important decisions in uncertainty. Every social policy and business plan is based on guesswork. But global warming was still invisible. It would not have become an issue at all except for scientists. Somehow the scientists would now have to give the world practical advice—yet without abandoning the commitment to strict rules of evidence and reasoning that made them scientists in the first place.

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[1] Chambers and Brain (2002); "circus:" McGourty (1988).

[2] Ungar (1995).

The Intergovernmental Panel on Climate Change, inevitably under the judicious chairmanship of Bert Bolin, established itself as the principal source of scientific advice to governments. The IPCC's method was to set up independent Working Groups to address the various issues. Unlike the First World Climate Conference, the Villach meetings, and the workshops of the Advisory Group on Greenhouse Gases, this was a large-scale and explicitly intergovernmental undertaking. The IPCC worked hard to draw nearly all the world's climate experts into the process through meetings, drafting of reports, and a great volume of correspondence.

Experts wrote working papers that drew on the latest studies, including some not yet published. These were debated at length in correspondence and workshops. Through 1989, the IPCC scientists, 170 of them in a dozen workshops, worked hard and long to craft statements that nobody could fault on scientific grounds. The draft reports next went through a process of review, gathering comments from virtually every climate expert in the world. The scientists found it easier than they had expected to reach a consensus. But any conclusions had to be endorsed by a consensus of government delegates, many of whom were not scientists at all.[1]

Among the officials, the most eloquent and passionate in arguing for strong statements were representatives of small island nations. For they had learned that rising sea levels could erase their territories from the map. Far more powerful were the oil, coal, and automobile industries, represented not only by their own lobbyists but also by governments of nations living off fossil fuels, like Saudi Arabia. The negotiations were intense. Only the fear of an embarrassing collapse pushed people through the grueling sessions to grudging agreement. Under pressure from the industrial forces, and obeying the mandate to make only statements that virtually every knowledgeable scientist could endorse, the IPCC's consensus statements were highly qualified and cautious. This was not "mainstream" science so much as conservative, lowest-common-denominator science. When the IPCC finally announced its conclusions, however, they had solid credibility.

Issued in 1990, the first IPCC Report concluded that the world had indeed been warming. Much of this might be caused by natural processes, the report conceded. The scientists predicted (correctly) that it would take another decade before they could be confident that the change was caused by the greenhouse effect. But the panel, drawing on computer studies, thought it likely that by the middle of the next century there could be a warming of somewhere between 1.5 and 4.5°C (roughly 2.5 to 8°F). The report specifically rejected the objection, raised by a small group of skeptical scientists, that the main cause of any observed changes was solar variations. The IPCC also drew attention to potent greenhouse gases other than CO_2, hinting at economically sound steps that the world might take at once to reduce future warming.[2]

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[1] The scientific conclusions were prepared by the Science Assessments Working Group, chaired (later co-chaired) by John Houghton. On the process see Houghton (1997), p. 158.

[2] Jäger (1992); Leggett (1999), pp. 9-28; Lanchbery and Victor (1995); Kerr (1990); IPCC (1990), see http://www.ipcc.ch/pub/reports.htm.

The report did not silence the scientists who held that global warming was unlikely. The IPCC consensus, hammered out through an exhausting cycle of negotiations among leading experts, offered no certainty. And no single statement, however tentative, could represent the views of all scientists on such a complex and uncertain matter. To find out what the entire community of climate experts felt, several different people conducted surveys in the early 1990s.

The responses suggested that most scientists felt their understanding of climate change was poor, and the future climate was highly uncertain—even more uncertain than indicated by the IPCC's report (at least as the news media described it). Nevertheless, a majority of climate experts did believe that significant global warming was likely to happen, even if they couldn't prove it. Asked to rank their certainty about this on a scale from one to ten, the majority picked a number near the middle. Only a few climate experts (perhaps one in ten) were fairly confident that there would be no global warming at all—although as they pointed out, scientific truth is not reached by taking a vote. Roughly two-thirds of the scientists polled felt that there was enough evidence in hand to make it reasonable for the world to start taking policy steps to lessen the danger, just in case. A considerable minority thought there was a serious risk that greenhouse warming could yank the climate into a seriously different state. On one thing nearly all scientists agreed: the future was likely to see "surprises," deviations from the climate as currently understood.[1]

The IPCC had written its report in preparation for a Second World Climate Conference, held in November 1990. Strongly influenced by the IPCC's conclusions, the conference wound up with a strong call for policy action. This induced the United Nations General Assembly to call for negotiations towards an international agreement that might restrain global warming. Lengthy discussions, arguments, and compromises led to draft documents and finally a 1992 gathering of world leaders in Rio de Janeiro—the United Nations Conference on Environment and Development, dubbed the "First Earth Summit." The great majority of countries, led by the Western Europeans, called for mandatory limits on greenhouse gas emissions. But the administration of President George H. W. Bush in the United States continued to reject any targets and timetables unless they were entirely voluntary and non-binding. No agreement could get far without the United States, the world's premier political, economic and scientific power—and largest emitter of greenhouse gases.

The American administration, attacked by its closest foreign friends as an irresponsible polluter, showed some flexibility and made modest concessions. Negotiators papered over disagreements

[1] Some of these polls were published only as summaries in bulletins. I have seen reports of polls by David Slade, 1989; by the "Global Environmental Change Report," vol. 2, no. 9 (11 May 1990); by Fred Singer and Jay Winston, 1991, for the Science & Environmental Policy Project; by the Gallup Organization for the Center for Science, Technology & Media, 1991; and by Thomas R. Stewart, Jeryl L. Mumpower, and Patricia Reagan-Cirincione for the Center for Policy Research of the Graduate School of Public Affairs of the State University of New York at Albany, 1991. Published surveys are Slade (1990) (esp. for degree of certainty and "surprises"); Chagnon et al. (1992); Morgan and Keith (1995) (a bit later, but particularly detailed); see also poll of a wider group of scientists, Anderson (1992).

to produce a compromise (officially, the "United Nations Framework Convention on Climate Change") which included targets for reducing emissions. It was signed at Rio by more than 150 states. The agreement's evasions and ambiguities left governments enough loopholes so they could avoid, if they chose, serious action to reduce greenhouse gases. Few governments did more than pursue inexpensive energy efficiency initiatives, avoiding any sacrifices for the sake of the climate. But the agreement did establish some basic principles, and it pointed out a path for further negotiation.[1]

The IPCC had established a cyclic international process. Roughly twice a decade, the IPCC would assemble the most recent research and issue a consensus statement about the prospects for climate change. That would lay a foundation for international negotiations, which would in turn give guidelines for individual national policies. Further moves would await the results of further research. In short, after governments responded to the Rio convention, it was the scientists' turn. Although they pursued research problems as usual, published the results for their peers as usual, and discussed the technical points in meetings as usual, to officialdom this was all in preparation for the next IPCC report, scheduled for 1995.

So the experts went back to work. They pored over a great variety of evidence and calculations, but what impressed them most was one bit of new science. Critics had heaped scorn on computer models of warming, pointing out that the models calculated that greenhouse gases should have caused about 1°C of warming in the past century, which was double what had actually been seen. New runs of the models, some done especially for the IPCC, now got results quite close to the actual trend of world climate, simply by taking better account of smoke and dust pollution. The basic greenhouse effect models had not been intrinsically flawed after all. Rather, the cooling effect of pollutants produced by human activity had temporarily obscured the expected greenhouse effect warming. Temperature data from around the world increasingly matched the specific patterns predicted by calculations.

After another arduous process of analysis, discussion, negotiation, and lobbying that involved some 400 expert scientists plus representatives of every variety of national and non-governmental interest, in 1995 the IPCC announced its conclusion to the world. While acknowledging many uncertainties, the experts found, first, that the world was certainly getting warmer. And second, that this was probably not entirely natural. The report's single widely quoted sentence said, "The balance of evidence suggests that there is a discernible human influence on global climate." The weaselly wording showed the strain of political compromises that had watered down the original draft, but the message was unmistakable. "It's official," as *Science* magazine put it—the "first glimmer of greenhouse warming" had been seen.[2] The conclusion was widely reported in the news media, reinvigorating public debate.

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[1] Mintzer and Leonard (1994).

[2] Kerr (1995a); IPCC (1996); see also interim report, IPCC (1992); on the process Stevens (1999), ch. 13; Gelbspan (1997), ch. 5; Edwards and Schneider (2001), pp. 236-40.

The 1995 IPCC report estimated that a doubling of CO_2, which was expected to come around the middle of the 21st century, would raise the average global temperature somewhere between 1.5 and 4.5°C. That was exactly the range of numbers announced by important groups one after another ever since 1979, when a committee of the U.S. National Academy of Sciences had published 3°C plus or minus 1.5°C as a plausible guess. Since then computer modeling had made enormous progress, of course. The latest scenarios actually suggested a somewhat different range of possibilities, with a warming as high as 5.5°C or so. But the meaning of these numbers had been hazy from the beginning—all they represented was what a group of experts found intuitively reasonable. The scientists who wrote the 1995 IPCC report decided to stick with the familiar figures of 1.5-4.5°C, rather than give critics an opening to cry inconsistency. In fact the meaning of the numbers had invisibly changed. The experts had grown a bit more confident that the warming would in fact fall within this range. (The report did not spell out just how confident they felt, however.)[1] The figures presented a striking case of an object on the border between science and politics, something that was at the same time fact and rhetoric.[2] The IPCC process deliberately mingled science and politics until they could scarcely be disentangled.

The IPCC's conclusions cast a long shadow over the next major conclave, the 1997 U.N. Conference on Climate Change held in Kyoto, Japan. This was a policy and media extravaganza attended by nearly 6,000 official delegates and thousands more representatives of environmental groups and industry, plus a swarm of reporters. Representatives of the United States proposed that industrial countries gradually reduce their emissions to 1990 levels. Most other governments, with Western European countries in the lead, demanded more aggressive action. Coal-rich China and most other developing countries, however, demanded exemption from the regulations until their economies caught up with the nations that had already industrialized. The greenhouse debate had now become tangled up with intractable problems involving fairness and the power relations between industrialized and developing countries. As a further impediment, the groups with the most to lose from global warming—poor people, and generations unborn—had the least power to force through an agreement. The negotiations almost broke down in frustration and exhaustion. Yet the IPCC's conclusions could not be brushed aside. Dedicated efforts by many leaders were capped by a dramatic intervention when U.S. Vice President Al Gore flew to Kyoto on the last day and pushed through a compromise—the Kyoto Protocol. The agreement exempted poor countries for the time being, and pledged wealthy countries to cut their emissions significantly by 2010. This was only an initial experiment. It was due to end in 2012, presumably followed by a better arrangement.

Much of the world public thought the arrangement was fair. But the Global Climate Coalition, an umbrella group representing a number of American and multinational industrial corporations, organized a lobbying and public relations campaign against the Kyoto treaty in the United States,

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[1] A 1995 poll of 16 top American climate scientists indicated that they felt roughly 95% certain about the ranges they proposed, which were mostly similar to the IPCC's range, although in some cases with higher upper limits. Morgan and Keith (1995), p. 470.

[2] van der Sluijs et al. (1998).

and Congress refused to take any action. That gave other governments an excuse to continue business as usual. Politicians could claim they advocated tough measures, casting blame on the United States for any failure to get started. Yet even if governments had taken up the Kyoto Protocol more aggressively, people on both sides of the debate agreed that it would have made only a start. It embodied so many compromises, and so many untested mechanisms for setting standards and enforcement, that the agreement could scarcely force a stabilization of emissions, let alone a reduction.[1]

International diplomacy is a gradual process. The most important task is to shift attitudes step by step. Next comes the work, no less slow and difficult, of devising mechanisms to put decisions into practice, for example, ways to measure national emissions and processes to adjudicate quotas. The mechanisms might be hollow at the start but they could slowly become meaningful.

The Kyoto proceedings showed that the people who denied any need for action on global warming were losing credibility. No longer did financial and industrial interests present a unified opposition. The first major industry to become worried had been the insurance business. In the early 1990s it endured mammoth losses as storms and floods increased, which (perhaps coincidentally) was just what global warming theorists had predicted. Perhaps scientists inside industrial firms meanwhile warned their superiors that the greenhouse effect predictions really could be correct. A breakthrough came in 1997 when John Browne, chief executive of oil giant BP Amoco, declared that global warming really might come to pass, and industry should prepare to deal with it. By the end of the 1990s, several other important companies had concluded that they should acknowledge the risk, and quit the Global Climate Coalition. Some began to restructure their operations so that they could flourish in a warming world with restrictions on emissions.[2]

Opposition remained powerful. The world's political system was such that people following "business as usual" did not have to prove that their practices were safe—it was up to critics to show unequivocal proof that a practice was dangerous. For a topic as complicated as climate change, people can easily find excuses to avoid altering their ways. Another layer of difficulty was added by the multitude of economic relationships and conflicts among many kinds of nations. A study of the politics concluded that "virtually no one involved in the negotiations is capable of grasping the overall picture of the climate negotiation process." That left the experts in a "complexity trap" of scientific and legal technicalities, with no clear and simple way forward.[3]

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[1] Christianson (1999), pp. 254-58, 263-68; Oberthür and Ott (1999); Stevens (1999), pp. 300-07. The official Web site of the U.N. Framework Convention is at http://www.unfccc.de. For Kyoto and post-Kyoto politics (especially in Australia) see Flannery (2006), chs. 24-26.

[2] Leggett (1999).

[3] Oberthür and Ott (1999), p. 300.

The difficulties overwhelmed the next major international conference, held at The Hague in late 2000. Representatives from 170 countries assembled to write the specific rules that might force reductions in greenhouse gases as promised at Kyoto. The proceedings were haunted by the third report of the IPCC (officially issued in 2001). Although the report was not yet completed, its main conclusions had been leaked to the delegates.

Again scientists had gathered in groups to sort through and debate a wide range of new scientific results, some not yet published. In the negotiations that crafted the IPCC's third report, the consensus of scientists coelesced, answering all the objections posed by skeptics and industry lobbyists. The report bluntly concluded that the world was rapidly getting warmer. Further, strong new evidence showed that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations." Above all, computer modeling had improved to the point where the panel could confidently conclude that future warming would be much greater still. Indeed the rate of warming was "very likely to be without precedent during at least the last 10,000 years." To meet criticism of earlier reports, whose ambiguous language had been only too politically convenient, after lengthy deliberation the panel explained what they meant when they said the warming was "very likely" unprecedented. They said it meant they believed there was a 90-99% chance that this was true.[1]

The worst-case scenario supposed that global emissions of CO_2 and restrictions on sulfate pollution might both rise faster than previous reports had considered. If that happened, the range of warming that the IPCC predicted for the late 21st century ran from 1.4°C up to a shocking 5.8°C (10°F). This range was not for the traditional doubled CO_2 level, which was now expected to arrive around midcentury, but for the still higher levels that would surely come after 2070. As one prominent scientist explained, "China's rapid industrialization has led to upward revision of predictions... While previously we thought in terms of doubling the strength of the CO_2 content of the preindustrial atmosphere, current thought is moving toward a tripling."[2] Eventually the level would move higher still, if not halted by self-restraint or catastrophe.

The IPCC delegates could not agree on a precise statement about the probability that warming would truly fall within the range 1.4-5.8°C. But they did say it was "likely" that the warming during the next few decades would be 0.1 to 0.2°C per decade. They defined "likely" as a 66-90% chance of being true. One approach to defining the meaning of such statements was to make a wide variety of computer model runs, and see what fraction fell within the announced limits. Later findings suggested a probable upper limit even higher than the IPCC's.[3]

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[1] IPCC (2001), for probabilities see pp. 1, 6, 8, 13, 527. The panel did not go into the question of what a given probability range meant, but one might treat it as a Bayesian initial estimate. On the criticism, see Giles (2002), and on the scheme for meeting it, Moss and Schneider (2000).

[2] Broecker (1997), p. 1586.

[3] Knutti et al. (2002).

Two decades of effort had not narrowed the range of uncertainty. That was partly because the geophysics of clouds and oceans and so forth was truly intractable, with complexities and uncertainties that stubbornly refused to allow precise numerical conclusions. Experts emphasized that they could not rule out climate "surprises" outside the range of their predictions. They also pointed out that whether we would get small temperature increases or huge ones depended most of all on future social and economic trends—it would depend on population growth, the regulation of soot from smokestacks, and so forth. Climate researchers had finally reached a point where the biggest uncertainty about the future climate did not lie in their science, but in what humans would choose to do.

At the conference in The Hague, continental Europeans, responsive to their powerful Green parties, insisted on a strict regime of regulation. That approach found no effective political backing in the United States, whose government insisted on market-friendly mechanisms. That meant a system of licenses which would permit a company to emit some amount of CO_2 in return for absorbing an equivalent amount elsewhere, for example by preserving a forest. Europeans exclaimed that it would be unfair for the world's biggest emitter to wriggle out of actual cutbacks. Nor could the parties agree on how to calculate an equivalence, when scientists had little solid knowledge of how forests and soils emitted or absorbed greenhouse gases. The negotiations collapsed. The final destruction of any chance for strong measures in the near future came in March 2001. The newly installed American President George W. Bush rejected any kind of regulation of the nation's CO_2 emissions, publicly renouncing the Kyoto Protocol.

Yet responsible government officials and business leaders knew they could not avoid the issue. In 2000 the *Economist* magazine, a free-market champion, reported, "Three years ago, most business groups were rubbishing the science of global warming... Now, even business has come to realize that global warming is a problem... Rather than cheering the collapse of the negotiations in the Hague, most business lobbies chastised ministers for not concluding a deal." Corporations needed "clear ground-rules for the green energy projects, clean-development schemes and emissions-trading initiatives on which they have been placing big bets." [1]

Most of the world's governments remained committed to taking some kind of action. At an international meeting held in Bonn in July 2001, 178 governments—but not the United States—negotiated a compromise agreement for implementing the Kyoto Protocol. Their stated goal was to return greenhouse gas emissions to roughly the 1990 rate within a decade. Scarcely anyone believed the world would really achieve that. And if somehow it did happen, at the 1990 rate of emissions the greenhouse gases in the atmosphere would still continue to rise. The Kyoto Protocol was evidently only a bare beginning for yet more difficult and far-reaching negotiations.

Global warming might require the international system to forge entirely new mechanisms of cooperation. Some questioned whether humanity could rise to the challenge. Most officials and many business leaders nevertheless felt it worthwhile to keep on developing regulation and

[1] Economist (2000), p. 20, see also p. 61.

monitoring mechanisms. The experience would be essential if the day came when dire need forced the world into a true commitment to halt global warming.[1]

Far-seeing people in fields ranging from forestry to municipal water supplies had begun to lay plans for a changed world. More and more experts were confident that they could find practical ways to keep climate change within tolerable limits without harming industrial efficiency. Cutting pollution and subsidies for fossil fuels might even strengthen the economy at once, as well as for posterity. Meanwhile people could brace for the climate changes that were already inevitable.

Climate research itself needed still more organization on a global scale. In the mid 1990s, WCRP designed a *Climate Variability and Predictability* project (CLIVAR) to pick up where TOGA, WOCE, and other efforts left off as they were completed. In 1995, a steering group drafted a scientific plan, and in 1998 delegates from 63 nations met in Paris to officially launch the project.[2] In the usual fashion, the groups convened under CLIVAR could not provide any money, but simply gave their stamp of approval to research plans which then had to get funds from national governments.

The money was not easy to come by. The United States, the world's principal supporter of climate research, was not generous to science overall in the 1990s. Among other deficiencies, American computer modelers suffered from a dearth of the most advanced machines. By the end of the decade, the lead in climate simulation had passed to Europe—although science funding was tight in Europe too. Meanwhile the collapse of the Soviet Union starved important efforts like their ice-drilling station in Antarctica. (The Russians managed to complete their probe with the aid of French funds and by trading some of their ice cores for American logistical support, but the reprieve was temporary.)

Funding nevertheless improved somewhat, overall. By the 1990s, climate scientists had established that their research deserved substantial support. The ratio of funding to needs, for a science whose practical consequences would not be seen for decades, was getting close to the level of high-energy physics and cosmology, if not yet as generous as the support for biomedical research, planetary space probes, and numerous other scientific and technical problems. Far from enjoying an easy ride, scientists warned there was an actual decline of observational networks in many parts of the world. Nobody knew exactly how much was being spent on climate research (a sign of the lack of international organization) but plausible estimates put it at three or four billion dollars a year at the end of the 1990s.[3]

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[1] Victor (2001) is an example of searching analysis from one of the many individual viewpoints.

[2] Trenberth (1999).

[3] Warnings: IPCC (2001), p. 11; funds: Stanhill (1999); Stanhill (2001), pp. 519-20.

Since the mid 1980s the number of scientific papers published on climate change had been doubling roughly every 11 years, to about 7000 per year in 2000 — a hundred times the number in the mid-1970s (moreover, the number of pages per article and of words per page had risen sharply). About half of these papers originated in the United States. The number of full-time climate researchers was likewise rising rapidly, reaching perhaps a thousand by the century's end. That might sound like a lot, yet it barely sufficed for a problem where the fate of entire populations would be swayed by dozens of different factors, each planetary in scope.[1]

In 2003, the European Union agreed to roll back emissions and instituted a trading scheme. British Prime Minister Tony Blair in particular gave personal priority to rousing the international community to take action against global warming. Meanwhile the world's second-largest reinsurance corporation, Swiss Re, voiced concern that companies could be vulnerable to lawsuits if they didn't take action to anticipate Kyoto-Protocol restrictions on emissions. In 2004 the company warned that within a decade, insurance companies could face tens of billions of dollars a year in extra costs due to climate change accelerated by human intervention.[2] All these European initiatives attracted scant attention in the United States.

To put the Kyoto Protocol into effect required ratification by nations with more than 55% of the world's CO_2 emissions, and with the United States refusing to join, only Russia could put the treaty into effect. After a long internal debate (in which some scientist-bureaucrats denied that their frigid country needed to worry about global warming), the government did ratify the treaty under pressure from West Europe in October 2004. Because of the post-Soviet crash of industrial production, Russia was still well below the emissions limits the protocol required. Russian companies hoped to sell unused emissions "credits" to polluters, who might find that buying credits was cheaper than reducing their own emissions.

In December 2004 a United Nations conference on climate change gathered in Buenas Aires. But the United States government blocked efforts to begin substantive discussions on further steps to limit greenhouse emissions. The conference, which lasted weeks and involved many nations (but was scarcely noticed in the American press), ended with only a weak agreement for limited and informal talks. The Bush Administration's adamant hostility to the Kyoto Protocol, and its general rejection of any restraint on industry for the sake of avoiding climate change, was one of the first and most persistent causes of a serious rift between the United States and its European allies. The divergence on climate policy also raised strains with Japan and vulnerable developing countries, both on the governmental level and in international public opinion (by 2006, polls were showing that the climate issue aroused world-wide hostility against the United States). Reflecting these strains, there were signs of political tensions resulting from government pressures within the IPCC itself—conflicts that we must leave to future historians to unravel.[3]

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[1] Stanhill (2001); Geerts (1999), pp. 639-40.

[2] Wall Street Journal, 7 May 2003; Reuters, 2 March 2004.

[3] See Gelbspan (2004), ch. 5; Flannery (2006), chs. 24-26.

In February 2005 the Kyoto Protocol went into effect with 141 signatory nations. Everyone agreed that there were many problems with the treaty, and that even if all the signatory countries lived up to their obligations—which would be difficult for some—it would do little to forestall global warming. The treaty had always been acknowledged as simply a first step. The aim was to get people started on working out systems for monitoring and controlling emissions and trading emissions credits, and to stimulate the invention and development of energy-saving devices and practices. This experience would be needed for the next round of negotiations, with a new treaty anticipated when the Kyoto Protocol reached its end in 2012. Stronger measures might then be called for, if it seemed at that time that global warming would have severe consequences.

The evidence for that was stronger every year. In June 2005, the science academies of the world's leading industrial and developing countries signed an unprecedented joint statement, declaring that "the threat of climate change is real and increasing," and calling on all nations to take "prompt action." The Bush White House (together with its appointees in other agencies) was now almost the only major government entity denying the problem. At a major international meeting convened in Montreal that December to discuss how to advance beyond the Kyoto Protocol, the American representatives angered everyone by refusing to cooperate, and walked out at the eleventh hour. Coaxed back, they would agree only to to participate in discussions that would require no commitment.

Nearly all the other nations settled down to serious work. They hammered out details of emissions trading mechanisms, and planned negotiations for what steps to take after the Kyoto agreement expired in 2012. In January 2005 Europeans adopted a scheme that required permits for carbon emissions, and set up a market for trading the permits. The system was so badly designed that the price of the permits at first soared to about 30 euros ($40) per ton of carbon and then abruptly crashed to almost nil. Meanwhile permits for emissions after 2007, when the regime was expected to tighten, recovered and climbed past 20. A parallel, non-obligatory carbon exchange in the United States set the price at about $4 per ton. In a perverse way these anomalies were exactly what the Kyoto negotiators had wanted, that is, experiments to find how particular policies worked in practice. The lessons they taught would guide the more rigorous policies that governments would need to shape.[1]

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[1] "...what should have been an exercise in setting rules for a new market became a matter of horse-trading about pollution limits, with powerful companies lobbying for the largest possible allowances... [in 2005] governments gave away (i.e., did not sell) pollution permits that amounted to more than the pollution companies were actually spewing forth... When it became clear, in April [2006], that most allocations were larger than actual emissions, the price of carbon halved almost overnight... some countries (Germany, France and Poland) have scattered permits around like confetti while a few (Britain, Ireland and Spain) have been sparing because they want to cut emissions. Companies in the second group are buying permits issued in the first, so the market is transferring resources from places that are using the scheme to curb pollution to those that are not." — "Charlemagne," *The Economist*, Nov. 18, 2006, p. 54. The IPCC's 2007 report estimated that setting permits at $50 per ton would go far toward reducing global emissions.

In the first months of 2007 the IPCC issued its Fourth Assessment Report. Most of the world's climate scientists had taken a hand in shaping the conclusions. In two rounds of review, the editors had individually considered more than 30,000 comments. Computer modellers in particular had devoted much of their work for half a dozen years to producing results tailored for the report. Different models still gave somewhat different results, for much remained unknown about complex processes such as the effects of aerosols in forming clouds. But the biggest source of uncertainty was how far humanity would restrain its production of greenhouse gases.

The range of temperatures the modelers predicted for the end of the century had not changed much since the 2001 report. Their best guess was still roughly 3°C of warming. They had grown more certain that we were very unlikely to get away with a rise of less than 1.5°C. The computer models did not agree so well on the upper limit — there was a small but all too real possibility that global temperature could soar to a disastrous 6°C (or even higher?). Whatever happened in the 21st century, the following century would be warmer still. *For a summary of predicted impacts of global warming, see the separate essay on Impacts.*

Scientists did feel much more certain about a couple of things. First, that serious effects of global warming were now plainly evident. Around the world they were seeing greater heat waves, more stormy rains and droughts, melting of ice and permafrost, and changes in the ranges of countless animal and plant species. And second, that humans were responsible for these ever worse changes.[1]

Observers increasingly noticed that the IPCC process by its very nature muffled those experts, whether a minority or even a majority, who worried about eventualities that were uncertain but potentially catastrophic. For example, plausible speculations that ice sheets could surge rapidly into the oceans were omitted from the official conclusions about sea level rise. Indeed since 1990 the climb in both sea level and temperature had been at about the upper limit of what previous IPCC reports had seen as likely. Conventionally one would say the IPCC had been soberly conservative by refusing to emphasize the more extreme possible changes. But if being conservative means concentrating on the most serious risks (as people do, for example, when budgeting for military forces), a band of projections that was overall too low had been the reverse of conservative.

What if the world warmed up even more than 6°C? After all, the IPCC was not entirely confident that it could not. Or what if, as some experts warned, even a 3°C rise could leave us with a radically "different planet"? As one geophysicist wrote in an open letter to his colleagues, "Up until now many scientists may have consciously or unconsciously downplayed the more extreme possiblilities at the high end of the uncertainty range, in an attempt to appear moderate and

[1] Meehl et al. (2007), section 9.6.4.

'responsible' (that is, to avoid scaring people). However, true responsibility is to provide evidence of what must be avoided."[1]

Alarming statements were still more repressed in the exhausting plenary session where political appointees revised the crucial "Summary Report for Policymakers" until they all could endorse it. Journalists reported that the delegation from the United States, while conservative in the conventional sense, played a more constructive role than in previous IPCC meetings. The most strenuous obstruction came from the Saudi Arabians, who now as in the past represented the interests of all who wished to sell fossil fuels without restraint, and from the Chinese, representing nations that hoped to burn ever more fuel as their industries grew.

An example was a long debate over how certain scientists could be that humanity was causing the observed warming. The British delegation, supported by many scientists, insisted this was "extremely likely" (that is, at least 99% certain), but in the end the delegates could only agree to report that it was "very likely" (between 90% and 99% certain; most media reported this as "90%" or "at least 90%" certain, understating the degree of certainty).[2] While this was a step up from the 2001 report's statement that human causation was "likely" (67% to 90% certain), the wrangling did not mean much for the making of policy. Everyone, or at least everyone who was not wedded to an opinion formed decades earlier, now understood that only human action could avoid a solid risk that the warming would rise to intolerable levels.

Additional IPCC reports by economists and social scientists explained that such action was indeed feasible with current or easily developed technologies. The cost, they agreed, would be far less than the cost of the damage from global warming. *Note that these essays do not cover the complex history of debates over the economics of climate change and policies to ameliorate it.*

Meanwhile more and more governmental and corporate entitites, in the United States as much as elsewhere, began to seek efficient ways to limit their emissions. Faced with international regulations, threats of legal action, and stockholder or public activism, they saw they must act soon or suffer crippling economic and social consequences.

"Climatology, even by the standards of science, has been distinguished by a remarkable degree of interdisciplinary and international cooperation. As the world continues to grapple with the profound issues posed by the CO_2 buildup, it could seek few better models of international cooperation than what we have already achieved."

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[1] Solomon (2007); Pearce (2007); Rahmstorf et al. (2007); Hansen (2007). The "different planet" phrase was developed by James Hansen, e.g., Hansen, (2006), see his website, http://www.columbia.edu/~jeh1/. Quote: Pittock (2006).

[2] IPCC (2007). For process, Zielinski (2007). News reports include James Kanter and Andrew C. Revkin in *International Herald Tribune*, Feb. 1, 2007, reports by Fred Pearce in *New Scientist,* Feb. 10 and March 10, 2007, and by Revkin in the *New York Times,* as well as reports in *Nature*, *Science* and other media, mostly available online.

— E.E. David, Jr. (President, Exxon Research & Engineering Co.), 1982[1]

> *What are the world's nations doing about global warming, what can they do, and what should they do? See my Personal Note and Links.*

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[1] David (1984), p. 5.