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 a network of ever larger and more costly research organizations, and struggled to find agreement on findings about climate to guide policy-makers. An intergovernmental panel of climate scientists established in 1988 (the IPCC) began to issue comprehensive reports. In a 1992 Rio de Janeiro convention, nations promised to avoid "dangerous climate change" and set up a framework for many following conferences. A 1997 Kyoto meeting negotiated a modest first attempt to limit greenhouse gas emissions. But developing countries and the United States refused to participate, and the outcome was wholly insufficient. Meanwhile scientists organized their research in international coalitions of unprecedented size and complexity. Their work was now oriented *toward informing the IPCC's reports, which every half-decade grew more unequivocal and more dire. Driven by these findings, a 2015 Paris meeting won pledges from essentially all the world's governments to cut their emissions. The pledges were strengthened in 2021, but much more work would be needed to avert catastrophe. (NOTE: this essay describes relationships among scientists and only sketches the complex history of negotiations at higher governmental levels. There is a separate essay on the United States Government, which was central in international affairs.*)

THE FIRST INTERNATIONAL ORGANIZATIONS - GLOBAL DATA: THE IGY AND WORLD WEATHER WATCH - GLOBAL RESEARCH PROGRAMS (1960S) - CONFRONTING ENVIRONMENTAL CHANGE (1970S) - FROM RESEARCH TO POLICY - VILLACH, 1985 - INTERNATIONAL RESEARCH EXPANDS (1980S) - SEEKING ENVIRONMENTAL AGREEMENTS - DEMOCRACY AND POLICY ADVICE (1980S) - THE RISE OF THE IPCC (1990S) - THE 1995 IPCC REPORT AND KYOTO - CONTROVERSY AND DIPLOMACY - ATTEMPTS TO RESTRICT EMISSIONS (EARLY 2000S) - THE 2007 IPCC REPORT AND THE WORLD'S RESPONSE - TOWARD A POLICY CONSENSUS (2010-)

"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

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

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, and Stalin grudgingly agreed to admit an American team (before they could set up their stations, Japan surrendered).[1]

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.

The First International Organizations

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."[2] In the second half of the 19th century, meteorologists got together in a series of international congresses, which led to the creation in 1879 of an *International Meteorological Organization*. Run mainly by the directors of national weather services, the organization encouraged the spread of meteorological stations and the exchange of weather data. It made ceaseless efforts at standardization—it was of limited value to exchange data if different nations measured temperatures, for example, at different times of day. Since the organization had no official status in any nation, and depended on voluntary and haphazard contributions, its efforts were often ignored. By the 1930s the leaders recognized their effort needed some sort of official status with governments, and they began to explore possible mechanisms.[3]

Meanwhile scientists who were interested in climate also met one another, along with 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

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[1] Yoder (1997). For a historical summary of science-government-international relationships from the 1960s forward see Howe (2014).

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

[3] Edwards (2010), pp. 51-59. For a summary history of global temperature measurements see IPCC (2021a), Section 1.3.1.

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. To mention only oceanographers, their research expeditions could scarcely function without permission to resupply at foreign ports.[1]

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 toward military ends. Some of those who worked for cooperation hoped 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, 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

[1] Greenaway (1996), pp. 48-50 & *passim*; Ismail-Zadeh and Joselyn (2019). In 1998 ICSU rebranded itself as the International Council for Science, and in 2018 as the International Science Council (ISC).

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—that is, one to which each nation appointed an official representative. 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 Victor A. Bugaev, a leader of the Soviet Union's meteorology office, and Harry Wexler, the director of research at 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—computer modeling, greenhouse gas measurements, satellite observations, and more—from the 1940s until his untimely death in 1962, as he astutely organized research and directed funds.[3]

Global Data: The IGY and World Weather Watch

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.

The IGY with its unprecedented funding was energized by a mixture of altruistic hopes and hard practical goals.[4] Scientists expected in the first place to advance their collective knowledge and

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

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

[3] For the general history of meteorological organization see Zillman (2018); for the WMO and climate in particular see Zillman (2009); for Wexler see Fleming (2016).

[4] See Needell (2000), chapter 11. Standard, although superficial, accounts of the IGY are Chapman (1959); Sullivan (1961); Greenaway (1996), ch. 12.

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 did.

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 as an 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 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.

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

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 after the U.S. launched a satellite that could watch the entire globe's weather from orbit, but only if its data could be checked against 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, give a window into the Soviet Union's scientific programs, and justify the principle of sending satellites over other nations' territories (which would be crucial for gathering military intelligence). 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.[1]

The first step would be world-wide gathering and exchange of data. The WMO eagerly took up the proposal, forming a "task force" consisting of exactly two men, Bugaev and Wexler. They quickly organized 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.[2]

The World Weather Watch and the WMO had reached the status of what specialists in international relations call an "international regime." Indeed they are paradigmatic of such regimes, prominent among the examples that J.G. Ruggie gave in a classic 1975 paper on the need to restructure international institutions to deal with the ever greater scope of scientific and technological developments. In defining for the first time the term "international regime," viz., as

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[1] Kristine Harper as quoted in Doel (2002); Edwards (2010), p. 223; 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.

[2] Edwards (2004). Fleagle (2001), pp. 57, 97.

"a set of mutual expectations, rules and regulations, plans, organizational energies and financial commitments, which have been accepted by a group of states," Ruggie highlighted the coordination among national weather bureaus.[1]

The WMO succeeded because it tied together preexisting national systems with technical standards and guidelines for communication. As Edwards points out, "It marked the successful transfer of standard-setting and coordinating powers from national weather services to a permanent, globalist intergovernmental organization... a genuinely global infrastructure." The actual work was not carried out by a single hierarchical, coordinated bureaucracy, but by individual national agencies. What tied them together was not authoritarian control, but a set of norms for behavior and rules of procedure that had been worked out over the centuries within the scientific community.[2]

Global Research Programs (1960s)

ICSU, determined not to be left out, decided to join the WMO in organizing global meteorological research. As a union of independent, mostly academic, scientific groups, ICSU often took a different view of affairs than the WMO, the U.N.-administered confederation of governmental agencies. 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.[3]

The chair of GARP's organizing committee during its crucial formative years 1964-1971 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

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[1] Ruggie (1975), pp. 570-72.

[2] Edwards (2010), pp. 242, 250; on the WMO and World Weather Watch as an "international regime": Ruggie (1975), pp. 571-72.

[3] Perry (1975), p. 661; Conway (2008).

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 CO_2 and became an expert on the gas's chemical and biological operations. He was also one of the first scientists to study pollution from aerosols, showing that they had a significant cooling effect on the climate of entire regions. Yet when Bolin was chosen to organize GARP, it was less for his wide-ranging scientific savvy than for his exceptional skills in communicating and inspiring people. It helped that he was based in traditionally neutral Sweden, but it was more important that, as one colleague put it, Bolin was "a brilliant and honest scientist, who listened to and respected diverse views." Self-effacing and soft-spoken, as Bolin developed his diplomatic skills he would become the mainstay of international climate organizing efforts for the next quarter-century.[1]

Among Bolin's difficult tasks was getting people not only from different nations 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. 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 partly the computer modelers' demands for world-wide standardized data that drove 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.[2]

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.[3] 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,

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[1] Organizing committee: the Committee on Atmospheric Sciences; Bolin became Chair of GARP in 1967. For more on organizing GARP see Bolin (2007), pp. 20-23. Several short biographies and obituaries of Bolin may be found on the internet; the quote is from Bob Watson, "Bert Bolin (1925-2008)," *Nature* **451** (2008): 642.

[2] Edwards (2000a).

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

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.[1]

Confronting Environmental Change (1970s)

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 path-breaking 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). Breaking away from the environmental movement's usual local and regional concerns to focus on global problems, the lengthy SCEP and SMIC meetings were "bonding experiences as well as opportunities for scientific exchange."[2]

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. 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."[3]

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.

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

[2] Singer (1970) for Dallas 1968; Barrett and Landsberg (1975), p. 16; SCEP (1970); "bonding:" Edwards (2010), p. 361.

[3] 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.

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.[1] Heeding the report's recommendations, along with voices from many directions calling attention to other environmental problems, the Stockholm 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.[2]

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 wherever cumulus clouds billowed up. 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.[3] Increasingly in such studies, not only would one find teams from different nations cooperating, but even within a single team the individual members 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." The meetings included a special session of the U.N. General Assembly in 1974, which called on the WMO to carry out a study of climate change. Eager to take the lead in this newly prominent field, the WMO organized a number of conferences and working groups. In 1977 a panel of experts duly issued a report, reaffirming that global warming should be addressed. GARP planners too decided to give additional stress to climate research, making what one leader called a "belated, though earnest and sincere" effort to extend beyond traditional meteorology by bringing in oceanographers and polar researchers.[4]

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

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

[2] For government-level negotiations see Brenton (1994), ch. 3; also Hart and Victor (1993), p. 662; Fleagle (1994), p. 174. See UNEP's Web site at http://www.unep.org.

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

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

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.[1] (Some of the climate papers, however, presented important scientific advances.)

From Research to Policy

Despite growing public and scientific interest in climate change, the funding for research on the topic was now generally static in every nation. The number of PhD's granted in the sciences of the Earth, oceans and atmosphere, which had grown rapidly until the mid 1970s, leveled 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.[2]

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 nations a better chance of influencing international policy than domestic policy."[3] By the mid 1970s, when science officials in various nations became so concerned about climate change that they began to contemplate policy actions, they found sympathetic ears among officials engaged in United Nations activities. 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.

Scientists' demands for action led to a 1978 International Workshop on Climate Issues, held under WMO and ICSU auspices in Vienna. The participants laid plans for a pioneering World Climate Conference—the first of many. Their mode of organization was crucial, setting a standard for many later efforts. Participation would be by invitation, mostly scientists and some

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

[2] 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.

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

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 nations convened in a World Climate Conference in Geneva in 1979 (under the chairmanship of the invaluable Bob White) to examine the review papers and recommend conclusions. The experts' views were diverse, and they managed to reach a consensus only that there was a "serious concern that the continued expansion of man's activities"—in particular emissions of CO_2— "may cause significant extended regional and even global changes of climate." Effects were likely to become visible by the end of the century. Governments should therefore start preparing "to redirect, if necessary, the operations of many aspects of the world economy, including agriculture and the production of energy." And of course they called for more funding for research on climate change and its potential impacts.[1] 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. After SCOPE issued a report, when journalists at a press conference asked a leader of the work 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."[2]

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. 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* (ISCCP) 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.[3]

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[1] WMO (1979), pp. 1-2.

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

[3] Thompson et al. (2001); Jäger (1992), p. iii; Fleagle (1994), p. 176; Lanchbery and Victor (1995), p. 31. A detailed history of the ISCCP: Rossow (2022).

Up to this point the United States had dominated climate discussions, 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 exchanges became crucial. 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.

Villach, 1985

The most important initiative was a series of invitational meetings for meteorologists sponsored by all three organizations, with particular impetus from UNEP's farsighted director, the Egyptian biologist Mostafa Tolba. Beginning in 1980 the meetings gathered scientists for intense discussions in Villach, a quiet town in the Austrian Alps. A historic turning point was the 1985 Villach conference, where experts from 29 nations 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.[2]

It was Bolin who wrote the 500-page report of the Villach conference, quietly translating the group's scientific findings into a bold warning: "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 the report also took a more activist stance than scientists had normally taken. Brought together as individual researchers in their personal capacities, with

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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 (2005c), Pearce (2010) , pp. 34-37. Bolin: "Statement by the UNEP/WMO/ICSU International Conference," preface to Bolin et al. (1986), pp. xx-xxi.

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 the future as in the past. That was no longer a sound approach. Indeed the prospect of climate change demanded more than a passive response. Pointing out that "the rate and degree of future warming could be profoundly affected by governmental policies," the Villach report insisted that "Governments should take into account" the conference's conclusions "in their policies on social and economic development and control of emissions of radiatively active gases." As a specific first step they diffidently suggested "consideration of a global convention" to act against global warming. Climate science, in short, was no longer just a matter for scientists.[1]

The press took no notice, but Bolin, Tolba and others made sure that the Villach recommendations came to the attention of the international scientific leadership. As a practical result, 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. In particular, a workshop in Bellagio, Italy in 1987 included politicians and policy experts as well as scientists among its two dozen participants. They took a first stab at setting policy by proposing a target: the world should not warm up faster than 0.1 °C per decade (or, as some preferred, warm more than 2°C in total above the pre-industrial level). Some of those present began to lay plans for a major conference to be held the following year in Toronto.[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 had a firm base in his position as professor of meteorology at the University of Stockholm.

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

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[1] Bolin, *ibid*; UNEP/UMO/ICSU (1985). On Bolin's role see Fred Pearce, "Bert Bolin," *The Independent* Jan. 5, 2008, http://news.independent.co.uk/people/obituaries/article3310068.ece.

[2] Agrawala (1999a), Agrawala (1999b).

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

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."[1]

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 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."[2]

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 some 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.[3] 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.

International Research Expands (1980s)

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

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

[2] Boehmer-Christiansen (1994).

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

committees, panels, and working groups.[1] 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!" Pressed to study many immediate environmental concerns, the IGBP did not put climate change high on its list of priorities.[2]

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.

The most important early effort has been called the largest scientific experiment ever conducted: the First GARP Global Experiment, FGGE, pronounced "figgy." (An initial task of the organizers of such a collaboration is devising a usable acronym—a mode of naming that is emblematic of organizations with distinct if transient identities, stuck together from independent components.) During 1978-79 large numbers of aircraft, drifting buoys, ships, balloons and satellites made observations with the participation of some 140 nations. It took several years to process the data, but the result was standardized weather numbers covering the entire globe in a uniform grid for an entire year—exactly what computer teams needed as a reality check for their climate models.[3]

Other important examples of projects that gathered data internationally were the *Tropical Ocean and Global Atmosphere Programme* (TOGA), the *World Ocean Circulation Experiment* (WOCE), 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 under the auspices of the WCRP.[4]

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 and satellites, 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

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

[2] Bolin (2007), p. 39. Quote: Schneider (1987), p. 215.

[3] Edwards (2010), pp. 244-46, 250.

[4] For links for history of the WCRP since about 1980 see https://www.wcrp-climate.org/about-wcrp/about-history, and for WOCE see Thompson et al. (2001).

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."[1]

Seeking Environmental Agreements

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 urgent. 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 elaborate computer modeling to connect acid rain with economic scenarios for power generation.[2]

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 chlorofluorocarbons (CFCs), staving off further deterioration of the ozone layer. The agreement was conceived primarily to protect human health and vital ecosystems, and later studies showed it had indeed averted global biological catastrophe. (Moreover, CFCs are potent greenhouse gases, and decades later scientists realized that restricting them had also averted a disastrous acceleration of global warming.) The people who had begun to worry about global warming hoped that the precedent set by the Montreal Protocol could serve as an example for negotiations to restrict greenhouse gas 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

[1] O'Riordan and Jäger (1996), p. 2.

[2] Brooks and McDonald (2000).

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 AGGG's 1987 Bellagio workshop with an assist from Gro Brundtland, the dynamic Prime Minister of Norway (the first woman to hold that post) and a few other environment-minded world leaders. Sponsored by UNEP and WMO plus the government of Canada, Toronto was a meeting by invitation dominated by scientist experts—not official government representatives, who would have had a much harder time reaching a consensus. There were a few ministers among the 300 attendees, notably Brundtland, but most nations were represented by relatively junior people.

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. Immediate action was needed, they said, to negotiate an "international framework convention" as a condition for national legislation. That was the Montreal Protocol model: set targets internationally, and let governments come up with their own policies to meet the targets. Some participants did not wish to step beyond strictly scientific findings into the realm of politics, but the conference set these hesitations aside: their report declared that by 2005 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 by 2005 the world's emissions had risen more than a third *above* the 1988 level.)[1]

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—a 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 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 most of the money was only relabelled or taken from other programs). Thatcher was the first major world leader to take a determined position.

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[1] WMO (1989); Lanchbery and Victor (1995), pp. 31-32; Bolin (2007), p. 48; Jäger (1992), p. v; Agrawala (1999b), pp. 115-16. On all this, see also Brenton (1994), O'Riordan and Jäger (1996) and Franz (1997).

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.

Democracy and Policy Advice (1980s)

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."[3] 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,

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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] Fleagle (1994), p. 179.

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 tiny 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."[1]

Policy-makers concerned about climate looked for a way to supersede the AGGG with a new kind of institution. The principal impetus came from the United States government, where the Environmental Protection Agency, the State Department and others were pushing for an international convention to restrict greenhouse gases. 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. The U.S. administration, along with some other governments, were also wary of control by the WMO or any other body that was part of the United Nations structure. Better to form a new, fully independent group under the direct control of representatives appointed by each government—that is, an intergovernmental body.[2]

Responding to this pressure from the United States and others, 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 in the hands 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. The AGGG was not formally abolished. But within two years that small body ceased to meet, as most of the world's climate scientists were drawn into the IPCC's processes.

Note that contrary to widespread assumptions, the IPCC was not an organ of the United Nations (which only provided administration), nor was it the creation of liberals. While formally the joint creation of UNEP and WMO, in practice the IPCC operated as an independent body, answering not to the UN but to delegates appointed by national governments. Its principal architect was the conservative Reagan administration.

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[1] Agrawala (1999a), p. 166, also Agrawala (1999b). For the AGGG and policy in this period in general see Randalls (2010), pp. 599-601.

[2] See Bolin (2007), p. 47; Houghton with Tavner (2013), ch. 13; Agrawala (1999b) ,p. 176-77; Pearce (2010), p. 38; Hecht (2014), p. 785. On IPCC structure see Kutney (2014), pp. 17-31.

In an initial meeting where delegates hammered out rules of procedure, American lobbyists affiliated with fossil fuel interests brazenly advised petro-states like Saudi Arabia and Nigeria. In the end the IPCC was allowed to issue reports only if the wording was accepted by essentially all the world's leading climate scientists plus the consensus of every participating government without exception. The requirement was unusual—decisions under the Montreal Protocol, for example, could be made by a two-thirds majority. The IPCC's constitution should have been, and was intended to be, a recipe for paralysis.

Diplomats with a solid education in history might have recalled the *liberum veto* of early modern Poland, whereby a single nobleman could halt any action by the national assembly. The veto, exploited by foreign agents who could always find a nobleman in need of cash, was a major factor in the eventual dissolution of the Polish state. However, "consensus" has a subtly different meaning to scientists, a meaning honed over centuries. Unlike a Polish nobleman, a scientist cannot raise an objection by right of ancestral status; a credible reason is required. And nearly all the delegates to the IPCC were scientists. If a small nation had no climate scientist, it could appoint someone from, say, the weather service—someone with a commitment to the mores of the scientific community.[1]

By 2001 the panel would turn its procedural restraints into a virtue: whatever it did manage to say would have unimpeachable authority. In the teeth of opposition from the immensely powerful fossil fuels industry and its many allies, the IPCC would issue what was arguably the most important policy advice any body has ever given, calling for nothing less than a wholesale restructuring of the world's economies and ways of living. Whether or not governments paid heed, in fulfilling its declared purpose of providing advice the IPCC has rightly been considered a remarkable success.

From the 1980s forward the world saw a proliferation of international conferences and other institutions dealing with environmental problems and policies (and many other issues). Among these the IPCC was exceptional in the scope of its mission and effort—but not in its methods and outcome. The requirement for consensus, and the procedures and mores that could make the requirement workable, were built into the decision-making of many other new international regimes that employed scientific research to address environmental problems. A survey by political scientists found that in general these regimes have been surprisingly effective.[2]

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[1] Consensus does not involve a formal unanimous vote. For a rule or report to be approved requires only silence, a reluctance to stand up and (as the Poles had it) exclaim, "I do not approve!" See Joanna Depledge, "Guest Post: The Challenge of Consensus Decision-making in UN Climate Negotiations," CarbonBrief.org (March 5, 2024), online at https://www.carbonbrief.org/guest-post-the-challenge-of-consensus-decision-making-in-un-climate-negotiations/.

[2] Breitmeier et al. (2006), pp. 231-32.

Most people were scarcely aware that all these international initiatives 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—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] The democratization of international politics was the scarcely noticed foundation upon which the IPCC and its fellow organizations took their stand.

The effect was visible in all areas of human endeavor, but it often came first in science, internationally and democratically minded since its origins. Indeed the procedures and mores of the scientific community are historically inextricable from the development of a cosmopolitan, egalitarian civil society.[2] From the seventeenth century forward a community of savants flourished in Europe and across the Atlantic, men and a few women who wrote letters to one another for public discussion, frequently on scientific subjects—a community named, for good reason, the "Republic of Letters." And from the seventeenth century forward, it was scientists more than anyone who met as equals in their clubs and societies, often with foreign associates present. Week by week they hammered out rational understandings as they sought agreement on the validity of the latest theories and experiments. This spirit was taken up in the Enlightenment salons, Freemason lodges, and other venues where scientists and foreigners were welcomed and honored—institutions that played a central role in the spread of republicanism in the eighteenth and early nineteenth centuries.[3] Scientists were not so much borrowing procedures from modern democracy as collecting on a loan they had made centuries earlier.

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

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

[2] Nyhart and Broman (2002).

[3] Jacob (2006), pp. 41-44, 134; Jacob (1991); Ferris (2010).

fisheries, panels of scientists were becoming a new voice in world affairs.[1] 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 scientific influence on policy matched dreams held by liberals since the nineteenth century. It awoke corresponding suspicions in the enemies of liberalism.

The Rise of the IPCC (1990s)

Global warming was now firmly in place as an international issue. In many nations it was hotly debated in national politics. The scientific community itself was taking up the topic with greater enthusiasm than ever. Conferences proliferated, demanding time from researchers, government officials, and environmental and industry lobbyists. As one conference delegate put it, a "traveling circus" of greenhouse effect discussions 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.[2]

International diplomatic negotiations to reduce greenhouse gas emissions were launched in a Ministerial Conference that brought representatives from 66 nations and various international organization to Noordwijk, the Netherlands in 1989. Most of the representatives hoped for an agreement that would do for CO_2 what the Montreal agreement had done for ozone. Drafts called for freezing emissions by the year 2000, followed by reductions. However, greenhouse warming did not yet command the universal scientific consensus that had formed quickly for the ozone danger. Nor was there dramatically visible proof like the "ozone hole" images to sway the public. Above all, vastly greater economic and political forces were in play. The Republican administration in the United States, friendly to fossil fuel lobbyists and dedicated to the ascendant neoliberal ideology that rejected any regulation of industry, refused to consider a deadline on restraining emissions or any other significant commitment. Britain, Japan, and the Soviet Union followed the American lead. The Noordwijk conference limped to an end with a declaration that the industrialized countries should stabilize greenhouse gas emissions "as soon as possible." That moved diplomacy forward (any sentence that is agreed to matters), but it did nothing to actually hold back global warming.[3]

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 policy-makers what to do 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

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

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

[3] Rich (2019); Bodansky (1994), see pp. 65-66; Ungar (1995).

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.

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. Following a proposal by UNEP's Tolba, three of these set to work simultaneously. Working Group I—the one principally covered by these essays—would assess the physical science of climate change; groups II and III would address respectively impacts of climate change and policy responses. Unlike the First World Climate Conference, the Villach meetings, and the workshops of the Advisory Group on Greenhouse Gases, this was a large-scale, prolonged, and explicitly policy-oriented 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 contributing their time as volunteers 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. As political scientist Shardul Agrawala remarked, this "peer review was ad hoc, based more on a tradition of scientific conduct and trust than on any political norms." It was much like the process of reviewing articles submitted to a scientific journal, although with far more reviewers. Another political scientist put it in more general terms: the work of the IPCC was in accord with "the rules, norms and procedures that govern science at large."[1]

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

[1] Agrawala (1999b), p. 204; Skodvin (2000), p. 157.For arguments over a rejected Soviet Union approach championed by M. Budyko see Doose (2022).

all. The elaborate IPCC process, however, had educated many bureaucrats and officials about the climate problem, and most were ready to act.[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. Even so, complete deadlock was avoided only by accepting the Working Groups' summaries as they stood. The prestige of the scientists, as scientists, was strong enough to give the authors an effective veto power over attempts to water down statements until they were meaningless.[2]

The result was not "mainstream" science so much as conservative, lowest-common-denominator science. The conclusions were neither the findings of scientific experts nor the political statements of governments—they were statements that the scientists agreed were scrupulously accurate and that the governments found politically acceptable. So when the IPCC finally announced its conclusions, 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, as it turned out) that it would take another decade before they could be confident that the change was caused by the greenhouse effect... by which time it would be that much harder to arrest the warming. Drawing on computer studies, the panel thought that by the middle of the next century the world might find itself warmer by anywhere between 1.5 and 4.5°C (roughly 2.5 to 8°F). Much would depend on whether people acted to reduce emissions. In the worst case, the so-called business-as-usual scenario, emissions "will result in a likely increase in global-mean temperature of about 1°C above the present value by 2025 [this actually happened around 2017] and 3°C before the end of the next century." 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.[3]

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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; Bolin, (2007), *passim*.

[2] Skodvin (2000), p. 160

[3] Jäger (1992); Leggett (1999), pp. 9-28; Lanchbery and Victor (1995); Kerr (1990); IPCC (1990a), "likely increase:" IPCC (1990d), p. 63.

The report did not silence the scientists who held that global warming was unlikely. The IPCC consensus, hammered out through a wearisome 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 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. 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 nations, 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 consistently rejected 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 to produce a

[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).

compromise, formalized as the *United Nations Framework Convention on Climate Change* (FCCC). Future world climate conferences, like the landmark Kyoto Conference of 1997 described below, were formally "Conferences of the Parties" of the FCCC. In these conferences formal decisions would be made by consensus in a plenary of all parties, that is, all nations that signed the treaty—essentially all the world's nations. When the rules of procedure were negotiated in 1994, some proposed that in the absence of a consensus, decisions could be reached by a three-quarters majority. But Saudi Arabia and other states that relied on fossil fuels insisted that, as in the IPCC, no formal conclusion could be reached if even a single party objected.

The Framework Convention included targets for reducing emissions, but the central point was a solemn promise to work toward "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The convention was signed at Rio by more than 150 states. However, its evasions and ambiguities (just what was "dangerous anthropogenic interference"?) left governments enough loopholes so they could avoid 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. The Rio meeting and the FCCC inaugurated an era of great hopes for solving the climate problem.[1]

A historian of the negotiations leading to the Framework Convention thought it "remarkable that it was achieved at all," given the scientific uncertainties and the huge potential economic stakes. He ascribed much of the success to the strength of the physical-science report from the IPCC's Working Group I. The scientists' report had "seized the intellectual high ground from the moment it was published," undercutting efforts by the United States and others to claim that uncertainty called for delays.[2]

The 1995 IPCC Report and Kyoto

The IPCC had established a cyclic international process. Roughly twice a decade, the panel 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 in a Conference of the Parties,

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[1] Mintzer and Leonard (1994); Kutney (2014), pp. 8-13; Jamieson (2014), section 2.3, q.v. for a history of the entire Rio diplomatic process. UNEP Information Unit on Climate Change, "The Second World Climate Conference," 1993, online at https://unfccc.int/resource/ccsites/senegal/fact/fs221.htm. Full consensus required: Vihma (2015), see also J.D. Werksman, "Procedural and Institutional Aspects of the Emerging Climate Change Regime: Improvised Procedures and Impoverished Rules?" Foundation for International Environmental Law and Development (1999), draft online at https://www.ucl.ac.uk/cserge/Werksman.pdf. For historical summaries of science-government-international relationships from the 1960s to 2013 see Howe (2014) and Hecht (2014).

[2] Brenton (1994), pp. 194-95.

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. There were more of them every year as concern about climate change spread in the scientific community, and each successive IPCC report had a much larger group of authors than the one before. This was driven not only by an increase in scientific research but also by political concerns in the broadest sense. The early IPCC was dominated by geophysicists and other physical scientists. But to many people, especially in developing countries, the problem of global warming involved not just physics but social and economic questions. It was the developed industrial countries that had dumped most of the extra CO_2 into the air. Developing countries like India, whose poverty and geography left them especially vulnerable to climate change, did not want scientists from the rich world to set the terms of the policy agenda.

Admitting its shortcomings, the IPCC reorganized itself. Although the world's attention continued to focus on the IPCC's Working Group I, which addressed the physical science, increasing funding and attention went to the other two Working Groups, which addressed the likely impacts of climate change and the policies needed to mitigate the damage, recruiting experts in fields ranging from epidemiology to economics. Meanwhile funds were raised to support scientists from developing countries. The first job was simply to pay for their travel to attend meetings, but gradually over the years many ways were found to increase not only their representation but their participation in research. In particular, each Working Group would be co-chaired by one scientist from a developed country and one from a developing country. There were some who complained that resources would be better concentrated in the established elite scientific institutions. But in the long run emissions would have to be restrained everywhere, and that meant every group had to be meaningfully engaged in the entire process.

Meanwhile in 1990 the governments of developing countries pushed the United Nations to create an International Negotiation Committee, a forum for policy questions that went beyond the subjects the IPCC scientists were supposed to address. The committee played a major role in working out positions for the 1992 Framework Convention on Climate Change; in 1995 it was replaced by a Secretariat of the FCCC. In 1995 yet another intermediary, a Subsidiary Body for Scientific and Technological Advice, was set up to help arbitrate between the worlds of science and diplomacy. This body, which eventually included representatives of nearly all the world's governments, argued out what the scientists' pronouncements really meant for policy-makers. That provided not only a forum to explore political differences, but a way to get the scientists to clarify their statements, and ultimately a certification of the reliability and significance of the IPCC's findings.

Non-governmental organizations, ranging from oil companies to Greenpeace, took an important part in the discussions. Industry lobbyists and environmental group staff members showed up at

the major conferences by hundreds and later by thousands, handing out reports and bending ears; their working papers were considered as seriously as the findings of state agencies. The most numerous and well-funded were representatives of industry, who in some meetings outnumbered the delegates from developing countries, working effectively to get their preferred language incorporated into conference documents. But nothing held more sway with the scientists than solid data or sound logic from any quarter. In the sometimes chaotic but thoroughly open debates, it was plain that every argument, from geophysical to moral, was on the table.[1]

The process is reminiscent of a phenomenon observed historically in the emergence of parliaments. Once a nominally representative body has been created, over decades or centuries it will enlarge its representation. This helps it to acquire prestige—and ultimately some degree of power over decisions.

Meanwhile the scientific experts pored over a great variety of evidence and calculations. 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 and completed just in time for its 1995 report, 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.

Another arduous process of analysis, discussion, negotiation, and lobbying occupied 400 expert scientists, joined by representatives not only of governments but of every variety of non-governmental interest. Warned by the close approach to deadlock in 1990, in 1993 the IPCC adopted a formal approach to its crucial summary statements: each would have to be approved, line by line, by consensus at a plenary session of the Working Group. In 1995 the IPCC announced its conclusions to the world. While acknowledging many uncertainties, the experts found, first, that the world was certainly getting warmer. And second, that the warming was probably not entirely natural; the pattern of actual warming was a telling "fingerprint" of greenhouse heating. (They added, almost parenthetically, that abrupt and unwelcome climate surprises might be in store.) The report's single widely quoted sentence said, *"The balance of evidence suggests that there is a discernible human influence on global climate."*

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[1] On all the preceding: Bolin (2007), pp. 96-97 & *passim*; Houghton (2008); Miller (2004), esp. pp. 50, 58-60; Dahan-Dalmedico (2008), pp. 73-74, 78; Agrawala (1999b), pp. 212-13 & *passim*; Pearce (2010), esp. p. 108; Andresen & Agrawala (2002); Estrada-Oyuela (2009); Kutney (2014), see pp. 34-41 for developing countries; Karen Savage and Mat Hope, "Global Climate Coalition: Documents Show How a Fossil Fuel Lobby Group Manipulated UN Climate Negotiations," Climate Liability News, April 25, 2019, online at https://www.climateliabilitynews.org/2019/04/25/global-climate-coalition-gcc-un-climate-change .

The weaselly wording showed the strain of political compromises that had watered down the original draft. The representatives, meeting at a Conference of the Parties in Madrid, had needed a day and a half to hammer out the final sentences in hostile debates. It was after midnight, and the official translators had gone home, when Bolin suggested replacing "appreciable" with "discernible." The exhausted representatives burst into applause; the gavel came down as the Saudi delegate, who spoke for the oil industry, at last raised no objection. For all its qualifications the message was unmistakable. "It's official," as *Science* magazine put it—the "first glimmer of greenhouse warming" had been seen.[1]

The conclusion was widely reported in the news media, setting off a raucous debate over every nuance of the report. A main author of the Working Group I report, Benjamin Santer, came under vicious personal attack for making editorial changes—which he had done in obedience to the established procedures. The IPCC responded by revising its procedures, formalizing the editorial process with additional "review" editors. It was an example of the flexibility that made the panel unusually effective as an international organization.

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.)[2] 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.[3] The IPCC process deliberately mingled science and politics until they could scarcely be disentangled.

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[1] Kerr (1995b); IPCC (1996a); see also interim report, IPCC (1992); on the process see Bolin (2007), pp. 112-13, 127-28; Stevens (1999), ch. 13; Gelbspan (1997), ch. 5; Edwards and Schneider (2001), pp. 236-40; Schneider (2009), pp. 137-41; Houghton with Tavner (2013), ch. 15; a narrative account: Weart, "Madrid 1995: A Sentence to Change the World," *Reports of the National Center for Science Education* **40**, no. 4 (Fall, 2020), p. 13, online at https://ncse.ngo/sites/default/files/pdfs/REPORTS40_4links.pdf.

[2] A 1995 poll of 16 top American climate scientists asked them to suggest ranges that they felt roughly 95% certain about. The responses were mostly similar to the IPCC's range, although in some cases with higher upper limits. The modelers themselves may have been less confident. Morgan and Keith (1995), p. 470. {from GCM 115}

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

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. It 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 nations gradually reduce their emissions to 1990 levels. Most other governments, with Western European nations in the lead, demanded more aggressive action.

On the other hand, coal-rich China and most other developing countries demanded exemption from the regulations until their economies caught up with the industrialized ones. The demand had already been embedded in the 1992 Rio Framework as a principle of "common but differentiated responsibilities." Developed countries, which had emitted most of the greenhouse gases now in the atmosphere and profited from it, bore more responsibility than countries that could not imagine reaching prosperity without burning a great deal more coal. The greenhouse debate was increasingly entangled 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.

The key would be a combination of regulation with a free-market mechanism. Governments would set a cap on how much carbon a particular industry could emit. A company could continue to emit an extra amount by purchasing an "offset" or "carbon credit" from somebody who was emitting less, or was otherwise reducing the burden in the atmosphere. The method, known as "cap-and-trade," had already been applied in particular by Repbulican President George H.W. Bush in a successful program to control acid rain in the United States. Applying the method now to carbon emissions was only an initial experiment. The Kyoto agreement was supposed to terminate in 2012, presumably to be 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, 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]

Climate research itself needed better 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 that 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.

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 Western Europe—although science funding was tight there 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.)

Yet climate change was now widely recognized as a deeply serious matter, and the one thing governments were willing to do about it was support research. The international community of climate researchers—and they were now a genuine community embracing many different specialties—was climbing steeply in numbers and funding. The trend would continue for decades, supporting countless research projects. By now nearly all significant research involved multiple authors, more often than not from different nations.

Controversy and Diplomacy

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.

Financial and industrial interests no longer presented 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

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[1] Christianson (1999), pp. 254-58, 263-68; Oberthür and Ott (1999); Stevens (1999), pp. 300-07. On the US Senate's Byrd–Hagel resolution rejecting Kyoto in advance see Aklin and Mildenberger (2020). 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] Trenberth (1999).

theorists had predicted. 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.[1]

Opposition remained powerful. Under the prevailing legal and political systems, 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 easily found 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.[2]

The difficulties overwhelmed the next major international Conference of the Parties, held at The Hague in late 2000. Representatives from 170 nations 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. In the negotiations that crafted the IPCC's third report, a consensus of scientists coalesced under the chairmanship of environmental scientist Robert Watson, a frank advocate of policies to reduce greenhouse emissions. Answering all the objections posed by skeptics and industry lobbyists, the report bluntly concluded that the world was rapidly getting warmer. In fact, 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." (I have italicized the crucial words, agreed on only after weary hours of debate.) Cautious scientists no longer had to rely on computers predicting future global warming—they could see it. Ever since the 1960s, experts had been saying that if greenhouse warming was real, its "signal" would emerge from the "noise" of random weather fluctuations around the start of the coming century. And here it was. Different types of observations on land, in the oceans, and in the upper air all produced "fingerprints" showing that greenhouse gas emissions, and nothing else, were raising world temperatures with unprecedented force. (See the section on "fingerprints" in the essay on "The Modern Temperature Trend".)

Meanwhile, 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

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[1] Leggett (1999).

[2] Oberthür and Ott (1999), p. 300.

reports, whose ambiguous language about risk and probability 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 might 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 come after 2070 unless the world took action. 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 pre-industrial 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; the actual warming 2001-2021 would be 0.22°C per decade). 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 European representatives placated their powerful Green parties by insisting on a strict regime of regulation. That approach found no effective political backing in the United States and a few other nations, which insisted on market-friendly mechanisms. That would be a system of licenses to permit a company to emit some amount of CO_2 in exchange for removing an equivalent amount of emissions elsewhere, for example by saving a forest from destruction. Europeans exclaimed that it would be unfair for the world's biggest emitters to wriggle out of actual cutbacks. Nor could the parties agree on how to calculate

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[1] IPCC (2001a), 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. See note on "likely" in the essay on General Circulation Models, On the criticism see Giles (2002), and on the scheme for meeting it, Moss and Schneider (2000); Schneider (2009), pp. 148-53,Schneider (2010), pp. 436-41. For negotiations see Petersen (2006). {from GCM n. 115}

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

an equivalence, when scientists had little solid knowledge of how forests and soils emitted or absorbed greenhouse gases. The negotiations collapsed amid acrimony.[1]

Hopes for strong measures in the near future were entirely crushed 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. Moreover, the U.S. administration, suspecting that Watson's environmentalism had biased the panel's reports, insisted that he be denied another term as chair of the IPCC. Watson's hard-driving, forthright ways had ruffled many feathers, leaving him vulnerable. The majority of delegates, particularly from developing countries, voted for Rajendra Pachauri, a mild-mannered economist from India.[2]

Yet whatever happened to the IPCC, many responsible government officials and business leaders saw that 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."[3]

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 negotiated a compromise agreement for implementing the Kyoto Protocol. What made this breakthrough possible was at the same time the agreement's greatest flaw, the absence of the U.S. government from the entire process. The stated goal of the remaining nations 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 gas level 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 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.[4]

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[1] See media reports and Babiker et al. (2002).

[2] Bolin (2007), p. 186; Walker (2007).

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

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

Attempts to Restrict Emissions (Early 2000s)

To put the Kyoto Protocol into effect required ratification by nations that made 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), in October 2004 the government did ratify the treaty under pressure from Western Europe. 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 carbon emissions credits to polluters, who might find that buying credits was cheaper than reducing their own emissions.

In 2003 the nations of the European Union had struck an agreement to roll back their emissions. 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.[1] All these European initiatives attracted scant attention in the United States.

The Bush Administration's adamant hostility to the Kyoto Protocol, and its general rejection of international climate negotiations and restraints on industry, was one of the first and most persistent causes of a widening 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.[2]

In February 2005 the Kyoto Protocol went into effect with 141 signatory nations. Everyone agreed that there were many problems with the treaty, which was only a first step that would do little by itself to forestall global warming. 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 U.S. agencies, was now

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

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

almost the only major government entity denying the problem. At a major international meeting convened in Montreal, the American representatives angered everyone by refusing to cooperate and walked out at the eleventh hour. Coaxed back, they would agree only 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 2005 the European Union's Emission Trading System went into effect,. It was a "cap-and-trade" scheme that required permits for carbon emissions, issued a limited number of permits, and set up a market for trading them. As the world's first major effort to regulate greenhouse gases, it suffered all the problems of a pioneer. 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. 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. By 2012 European permits had again fallen to nearly that level, for the supply of permits kept climbing as nations issued generous carbon credits to their industries. The complex system proved to be vulnerable not only to political pressure and lobbying but many other kinds of gaming.

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. Over the next decade a movement developed for a different attack on the climate problem—what most economists recommended, a simple tax on emissions. Of course, it was hard to persuade people to accept a new tax. Perhaps the tax could be made palatable if the revenue was used to reduce taxes that were even more unpopular, or paid out directly to citizens ("tax-and-dividend")? If even that could not win public approval, governments would have to find ways to make cap-and-trade schemes do their job.[1]

The 2007 IPCC Report and the World's Response

In the first months of 2007, the IPCC issued its Fourth Assessment Report (FAR, later AR4). Most of the world's climate scientists had taken a hand in shaping the conclusions. In two rounds of review, what one of the participants called "a painstaking process of self-interrogation," the editors had individually considered more than 30,000 comments. The effort meant serious sacrifices. Scientists had to set aside their chosen profession of pushing into the unknown in order to work out what they could agree was known. "It drives you absolutely crazy," one of them said. "You fly to distant places; you stay up all night negotiating; you listen to hundreds of sometimes silly interventions. You go through so many mundane things to produce the big picture."[2]

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[1] The tax should in principle reflect the "social cost of carbon," but estimates for that varied widely. At any rate the IPCC's 2007 report estimated that setting permits at $50 per ton would go far toward reducing global emissions. The 2018 Nobel Prize in Economics bestowed on William Nordhaus signaled the profession's endorsement of his work advocating a carbon tax.

[2] Both quotes: Hans Joachim Schellnhuber in Walter Gibbs and Sarah Lyall, "Gore Shares Peace Prize for Climate Change Work," *New York Times,* Oct. 13, 2007.

Computer modelers in particular had devoted much of their work for half a dozen years to producing results specifically tailored for the IPCC 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 human: what economic and political path of technology and emissions regulation would the world follow? Teams ran their models through a set of scenarios that described a range of future world emission rates—just one of the areas where the research effort was increasingly structured by the IPCC process itself.

Pachauri, the economist the U.S. government had promoted to chair the IPCC, had become as worried about global warming as the scientists, and his shy manner concealed a passionate energy. Under his skillful leadership the panel reached a consensus that was tighter and more dire than ever. The range of temperatures the modelers predicted for the end of the century had not changed much since the 2001 report, with a best guess 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 for doubled CO_2 —likely 4.5°C, but with a small but all too real possibility that global temperature could soar as high as a cataclysmic 6°C. That would be a serious risk if, contrary to the IPCC's baseline assumption, the world continued to burn fossil fuels at an accelerating rate with no restraints. And whatever happened in the 21st century, the following century would be hotter still.

Scientists did feel much more certain about a couple of things. First, 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 thawing of permafrost, and changes in the ranges of countless animal and plant species. And second, it was nearly certain that human emissions were partly responsible for these ever worse changes.[1]

However ominous that was, observers increasingly remarked that the IPCC statements could have been even stronger. The requirement for consensus that governments had imposed on the IPCC from the outset meant that expressions of divergent views were mostly confined to informal discussions; in the Panel's formal pronouncements, any debate was invisible or at best relegated to the ponderous technical reports that few read. Everyone might agree that impact X would be *at least* as bad as Y. But the process by its very nature muffled those experts, whether a minority or even a majority, who worried about eventualities that were uncertain but potentially far worse. For example, plausible speculations that ice sheets could surge rapidly into the oceans were omitted from the 2007 report's conclusions about sea-level rise. Since 1990 the climb in both sea level and temperature had been at about the upper limit of what previous IPCC reports had thought likely.

Conventionally one would say the IPCC, by refusing to emphasize the more extreme possible changes, had been soberly conservative. But if being "conservative" means concentrating on the most serious risks (as people do, for example, when buying fire insurance or budgeting for military forces), a range of projections that was overall too low was the reverse of conservative.

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

What if the world warmed up more than, say, 5°C? After all, the IPCC could not rule that out, even under the baseline scenario of gradually imposed controls on emissions. 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 possibilities at the high end of the uncertainty range, in an attempt to appear moderate and '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 grueling plenary session where political appointees revised the crucial "Summary Report for Policymakers" until not one of them raised an objection. 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 as usual from Saudi Arabia, now as in the past representing the interests of all who wished to sell fossil fuels without restraint, and from China, representing the developing countries that intended to burn more and more fuel as their industries grew.

An example was another long debate over a statement that humanity was causing the observed warming: how certain was that? The British delegation, supported by many scientists, insisted that it was "extremely likely"—to be precise, at least 99% certain—that humans were responsible. But in the end the delegates could only agree to report that this 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] The wrangling did not mean much for the making of policy. Everyone, or at least everyone who was not wedded to an outdated and unscientific opinion, now understood that only big policy changes could avoid the risk that warming would rise to intolerable levels.

The IPCC leaders made this entirely clear in November when they published a Synthesis of the 2007 reports. The panel was now better known and better respected for sharing a Nobel Peace Prize with Gore, and the authors ventured to describe the risks plainly. With CO_2 in the atmosphere rising a percent each year at an accelerating rate, we were likely, for example, to put a quarter of the world's species at risk of extinction. Still more likely would be, for example, "disruption of... societies" by storm floods. Less certain but no less important, there could be "abrupt or irreversible" impacts. For example, "sea-level rise on century time scales cannot be excluded." If greenhouse gas levels kept rising unrestrained, well beyond twice the pre-industrial

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[1] IPCC (2007b); Pearce (2007b); Rahmstorf et al. (2007); Hansen (2007); Yohe and Oppenheimer (2011); Oppenheimer et al. (2019), p. 165. On procedures there is a large and growing social science literature, with valuable information and ideas floating amid a jumble of academic theories, for review see Beck and Mahoney (2018). The "different planet" phrase was developed by James Hansen, e.g., Hansen, (2006), see his website, http://www.columbia.edu/~jeh1/. "Downplayed:" Pittock (2006). See Brace et al. (2013).

[2] IPCC (2007a). 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.

level, we were likely to see a radical impoverishment of many of the ecosystems that sustain our civilization.[1]

Meanwhile, additional IPCC reports by economists and social scientists explained that action to forestall all this was feasible with current or easily developed technologies. The cost, they agreed, would be far less than the cost of the damage from global warming. In fact the world's governments were spending hundreds of millions of dollars a year to *subsidize* fossil fuels. Indirect subsidies, like the cost of illness and death caused by coal pollution, amounted to five trillion a year. Devoting those funds instead to lessening emissions, for example funding mass transit to replace automobiles, would bring many benefits even aside from retarding global warming. But governments were stingy, even for the relatively cheap work of climate research and development of sustainable technology.[2] *Note that these essays do not cover the complex history of debates over the economics of climate change and policies to address it.*

In the now familiar cycle, the world's governments were obliged to respond to the IPCC's findings. Convening at Bali in December 2007, delegates continued their heated arguments over equity between developing and developed countries and so forth. Emotions ran high amid threats of trade sanctions and boycotts. As the long and acrimonious sessions neared their deadline, the head of the conference dissolved in tears and had to be led away. A last-minute obstruction by the U.S. delegation provoked booing and hissing. The delegate for Papua New Guinea raised cheers when he told the U.S., "If for some reason you are not willing to lead, leave it to the rest of us. Please—get out of the way." In a striking demonstration of the power of public opinion and the pull of consensus for democracies, the U.S. did get out of the way. The final Bali agreement was, inevitably, weak and ambiguous. But it sketched out a path for future negotiations that could, with enough will, yield serious results.[3]

The 2007 report had barely been issued when a few experts began to warn that global warming was arriving at a faster pace than the panel had anticipated, highlighting how the IPCC had habitually underplayed uncertain dangers. The report had been based on evidence published in peer-reviewed journals through about 2005, and most of the science published in the next few years was discouraging. The world's CO_2 emissions were rising at the upper limit of what the IPCC had thought likely; new data and better theories showed that tropical forests and oceans were rapidly becoming less able to take some of the CO_2 out of the atmosphere; emissions of other greenhouse gases like methane were rising at a frightening rate; newly-discovered feedback mechanisms mostly worked in the wrong direction, and on and on.

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[1] IPCC (2007f), pp. 12-13.

[2] The annual $5 trillion amounted to 6.5% of global GDP. IMF Survey Magazine, "Counting the Cost of Energy Subsidies," July 17, 2015, online at http://www.imf.org/external/pubs/ft/survey/so/2015/NEW070215A.htm. See footnote in Conclusions: Personal Note.

[3] See media reports in *Nature, New Scientist* (Fred Pearce), *The Economist*, etc. The statement of PNG delegate Kevin Conrad may be viewed on Youtube.com

Meanwhile, actual harms that could probably be traced to climate change were showing up around the world with increasing frequency. The ice pack in the Arctic Ocean was shrinking far more swiftly, and Greenland and Antarctica were melting more quickly, than most experts had thought possible. From prolonged droughts and heat waves to catastrophic floods to the disappearance of entire species, much appeared to be happening sooner than expected. In March 2009 an international consortium of eleven universities brought more than 2,000 experts to Copenhagen to evaluate what had been learned since the IPCC panels crafted their reports. The scientists' overall conclusion: "The worst-case IPCC projections, or even worse, are being realized."[1]

The next major Conference of the Parties, that is, signatories of the FCCC (nicknamed COP15 since it was their fifteenth meeting), was scheduled for Copenhagen in December 2009. Its goal was to forge a binding treaty to replace the Kyoto accord on its expiration in 2012. Negotiations leading up to the conference were called the most complex and difficult problem that diplomats had ever attempted.

Most developing countries continued to insist that the industrialized countries should take all responsibility for solving the problem—and also pay the world's poor enormous sums to handle the prospective damage from climate change. After all, as India pointed out, the United States was responsible for the lion's share of the greenhouse gases now in the atmosphere, and the average American continued to add twenty times as much every year as the average Indian. Americans replied: why should we restrict our emissions, if others did not? After all, China had passed the United States as the world's biggest emitter, and was building a new coal-fired power plant every week or so. But the U.S. delegation could not exert strong leadership, for the Senate had barely begun to consider the nation's target for its own future emissions, and if it ever did set rules they would surely be weaker than other nations were demanding.

When more than 120 heads of state descended on Copenhagen in the last days of the Conference, they found that the weary negotiators had resolved few of the issues. With chaotic demonstrations on the frozen streets outside and angry shouts on the convention floor, the process was lurching toward ignominious collapse. Late on the last day, the new U.S. President, Barack Obama, barged into a room where the Chinese had privately invited leaders from Brazil, India and South Africa to work out a joint position against any strong agreement. They had no choice but to welcome Obama, and the five nations negotiated a vaguely worded accord that kept the door open for future negotiations. The prospects for a legally binding treaty were more distant than ever. The only party to the talks that expressed complete satisfaction with the outcome was Saudi Arabia.[2]

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[1] Richardson et al. (2009). Quote: Katherine Richardson in Kintisch (2009). On the IPCC's conservatism see O'Reilly et al. (2012), and cf. pp. 717-19 on the IPCC processes in general.

[2] Tobias Rapp, Christian Schwägerl and Gerals Traufetter, "How China and India sabotaged the UN climate summit," *Der Spiegel Online*, May 5, 2010 at: www.spiegel.de/international/world/0,1518,692861,00.html; see Mark Lynas, "How do I know China wrecked the Copenhagen deal? I was in the room," *The Guardian*, Dec. 22, 2009

After the debacle, most negotiators gave up hope of keeping the rise of global temperature to less than 2°C above the pre-industrial level—a number that had been widely adopted since the 1990s, somewhat arbitrarily, as the threshold for the "dangerous anthropogenic interference with the climate system" that nations had pledged in Rio to avoid. (A decade later, computer studies would indicate that serious danger would begin at 1.5°C.) ("Pre-industrial" had no generally accepted definition. People tended to think of a time around the middle of the 19th century, but scientists could not specify mean global temperature back then precisely. Many published graphs showed mean global temperature in terms of the rise above the average for the period 1951-1980, a well-measured baseline but already several tenths of a degree warmer than a century before. Eventually most discussions used a rise above the 1880-1900 level, which if not really "pre-industrial" did precede the explosive rise of greenhouse gas emissions.)[1] Many nations followed the conference with pledges to reduce their emissions, in harmony with the hastily negotiated platitudes of the "Copenhagen Accord." But even if all the pledges were honored, they would not suffice to avert dangerous warming.

Nobody proposed to give up. The negotiations stumbled forward like an injured mountaineer who will not turn back. For example, at a 2011 Conference of the Parties in Durban, South Africa (COP17), tempestuous debates over what should follow resulted in an agreement to... keep negotiating. At a 2013 Conference of the Parties in Doha, the Kyoto Protocol was extended to 2020. The Protocol now covered only a minor fraction of the world's economies (mainly in the European Union), but it did keep alive the experiment with market-based mechanisms for managing emissions.

In practical terms, Kyoto was a failure. Although some nations lived up to their commitments, with Europe in particular substantially cutting its emissions, the result scarcely slowed the global

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http://www.theguardian.com/environment/2009/dec/22/copenhagen-climate-change-mark-lynas and articles in *The Economist* and other media.

[1] As early as 1975, economist William Nordhaus pointed out that global temperatures had not been more than two or three degrees higher for hundreds of thousands of years. William D. Nordhaus, "Can We Control Carbon Dioxide?" IIASA Working Paper WP-75-63 (June 1975), online at http://webarchive.iiasa.ac.at/Admin/PUB/Documents/WP-75-063.pdf. Randalls (2010) identifies the 1987 Bellagio AGGG workshop and a 1990 report to the AGGG (by Rijsberman & Swart) as critical points in the emergence of the 2°C limit. By the early 1990s many experts had come to believe, more by intuition than any formal scientific analysis, that beyond two degrees, civilization would enter an unprecedented, and probably dangerous, climate regime. In 1996 the European Commission's Council of environment ministers endorsed the 2° limit as their goal, and it was formalized internationally at a 2010 Conference of the Parties in Cancun. Some scientists had always held that anything above one degree would be seriously harmful, and in 2018 an IPCC report spelled out the serious harm inevitable at 1.5°C, IPCC (2018). See Jaeger and Jaeger (2011); Schellnhuber et al.(2006); Carbon Brief, "Two Degrees: The History of Climate Change's Speed Limit" (Dec. 8, 2014), online at http://www.carbonbrief.org/two-degrees-the-history-of-climate-changes-speed-limit.

rise of greenhouse gases. The developing countries that had been omitted from obligations, notably China, continued to build coal-fired plants at a breakneck pace—partly to produce goods that were exported to Europe and other developed regions. Far from decreasing, world CO_2 emissions had accelerated and were now climbing more than 2% a year (and methane even faster); the total carbon emitted since the Kyoto meeting was comparable to the total emitted in all the centuries preceding it. Perhaps the most useful result of the exercise was to demonstrate how easily market mechanisms failed under pressure from industrial lobbies.

Toward a Policy Consensus (2010-)

For its next report the IPCC revised its procedures, stung by criticism from people who denied any prospect of dangerous climate change. Critics had fastened on a single remark buried in the three thousand pages of the 2007 reports. The IPCC's cumbersome review process, overwhelmed by thousands of comments, had failed to notice an implausible claim that Himalayan glaciers were likely to disappear by 2035 (the text was eventually traced to a misreading of a speculation that the glaciers could disappear by 2350). The critics howled as if this one inconsequential error invalidated everything the IPCC had done.

Worse had come in 2009 with the "climategate" publication of naively frank private emails among a few prominent climate scientists. Impugning the scientists' integrity, critics demanded that all discussions and all data be opened to public scrutiny. The panel resolved to be more careful and more transparent. It made a major overhaul of procedures that imposed formal accountability in matters such as peer review, and improved public access to research data. Almost anyone who claimed any expertise in the field could now register as a reviewer.[1]

The IPCC's fifth Assessment Report (known as AR5), issued in 2013, took only small steps beyond the 2007 report. "Evidence for human influence has grown," the panel noted. "It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century." Estimates for future sea-level rise were increased, but otherwise the predictions remained about as before. None of this made much of an impact on anyone not already concerned.[2]

Often overlooked in the 2013 IPCC report was a statement about the world's permissible "carbon budget." Two landmark articles published in 2009 had taken a new approach to global warming. Avoiding the complexities of calculating one or another "pathway" of greenhouse emissions over the decades, the authors simply asked how much warming would arise from a given total amount of fossil fuel carbon emitted into the atmosphere. It turned out that regardless of what pathway our

[1] Glaciers and climategate: Kutney (2014), pp. 29-31, 67-112. Procedures: Beck (2012), Edwards (2022). For historical summaries of science-government-international relationships from the 1960s forward see Howe (2014) and Hecht (2014). Social-science studies of the IPCC in this period are reviewed by Hulme and Mahony (2010), Beck and Mahony (2018), and Berg and Lidskog (2018); more recently, see De Pryck and Hulme (2022).

[2] IPCC (2014b). Quote: IPCC (2014a), p. 17.

emissions took as they rose and fell, once we got the emissions down to zero the global warming would level off at a temperature set by just one thing: the total number of tons we had emitted since factories began to burn coal.

The budget was tight. The world was liable to pass beyond the 2°C limit for "dangerous" climate change if more than another trillion tons of fossil fuels were burned after the year 2000. But more than a quarter of that had already been burned between 2000 and 2013. To level off at 2°C, "less than half the proven economically recoverable oil, gas and coal reserves can still be emitted up to 2050."[1] Diplomats shied away from the politically unthinkable problem of dividing up the remaining emissions (notably how to treat developed countries, which had already emitted far more than their fair share).

Everyone agreed that a Kyoto-style comprehensive treaty, but stronger, was out of reach. The future would have to rely on nations spurring and shaming each other into local pledges. Some observers advised that it was time to give up the chaotic and time-consuming FCCC process altogether, and settle for whatever could be negotiated among smaller groups of parties. The European Union took the lead. In October 2014, after complex negotiations, the EU's national leaders issued a joint pledge that by 2030 they would cut their combined greenhouse emissions by at least 40% from 1990 levels, and would get at least 27% of their energy from renewable sources.

Further hopes were raised in November by a diplomatic breakthrough between the United States and China, nations that together were producing nearly half the world's greenhouse gases. Groundwork had been laid the previous year by a pact to restrict their production of hydrofluorocarbons (HFCs), a potent greenhouse gas. Now the American President, Barack Obama, promised that his nation would reduce carbon emissions at least 26% below 2005 levels by 2025; the Chinese President, Xi Jinping (who like Obama embraced environmentalism), promised that China's CO_2 emissions would peak by 2030. Both goals were achievable if the nations' current policies were continued and pursued aggressively. However, it was far from clear whether the U.S. political and legal system would allow Obama to follow through on his promise.

In December 2014, national representatives debated fiercely for two weeks in Lima, Peru, laying plans for a major Conference of the Parties scheduled for the following year in Paris. The Lima meeting seemed doomed to fail amid acrimony until the Chinese and U.S. delegations presented a text they had secretly negotiated. The key was a "shared winning" mindset derived from Obama's agreement with Xi—a radical rethinking of how nation-states could manage the global atmosphere even with no international institution that could compel compliance. Every nation

[1] IPCC (2014e), p. 10 (issued 2013). Meinshausen et al. (2009); "less than half:" Allen et al. (2009), see also Matthews and Caldeira (2008), Zickfeld et al. (2012). More recently, see McGlade and Ekins (2015); Rogelj et al. (2016) calculated an even smaller carbon budget by considering not only CO_2 but also other emissions such as methane. However, improved historical data gave a larger budget, a total of 580 Gigatonnes for a 50% chance of halting warming at 1.5°; at the then-current emissions rate the budget would be used up by 2032. IPCC (2018a), paragraph 2.2.2, IPCC (2018b), paragraph C.1.3. {from CO2 n. 64 & simple n. 118a}

would present a voluntary plan to cut emissions, in its own self-interest and for the sake of global cooperation. The delegates in Lima adopted the plan. It was the first time that all nations, notably including the developing ones, had agreed to make any sort of cuts.[1]

At the long-awaited Paris meeting in December 2015 (COP25) the negotiations went smoothly for once, lubricated with excellent French diplomacy and cuisine. 195 nations concurred in an agreement, if only because not much was demanded of anyone. Typical of the process was an argument over a statement that nations "shall" set their own goals for cutting emissions. The word implied a legally binding treaty, which the Republican-controlled U.S. Senate would have rejected. A last-minute demand by the U.S. changed the offending word to "should." Thus the agreement allowed each nation to limit emissions as it chose, and left them to monitor their own compliance.

The idea of "climate justice" was prominent in Paris. Mentions of the phrase in the media had risen along with street protests at the 2009 Copenhagen Conference. In Paris the developing countries, largely blameless for the rise of greenhouse gases, demanded and secured pledges from the industrialized countries for a transfer of $100 billion over five years. The money was to help the developing countries mitigate climate change (that is, reduce their emissions), and also adapt to it, making their societies more resilient to the harmful impacts that were now inevitable.

The *Paris Agreement* included a solemn declaration that the world would strive to limit the global rise to 1.5°. But global temperature in 2015 was already 1.0°above the pre-industrial level, and another half degree was locked in by the inertia of the economic and climate systems. Everybody knew that even if all nations somehow met their pledged targets, the targets were so modest that global temperature would probably mount 3°and perhaps more. Only a gargantuan program to suck carbon out of the atmosphere could prevent that, and few believed such a program was feasible without vast expense plus extraordinary technological breakthroughs.

Yet if most of the nations kept their promises and met their targets (a very big "if"), it would buy some time for acting to avoid the utterly catastrophic warming that would soon be inescapable in the absence of any restriction of emissions. And the nations agreed to reconvene every five years with new plans, presumably ratcheting to tougher goals in each round. When the final gavel fell, "a great roar issued from the crowd," a witness recalled. "People leaped to their feet, strangers embraced, tears welled up in eyes bloodshot from lack of sleep." Euphoric delegates called it a historic occasion.[2]

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[1] Figueres and Rivett-Carnac (2020), pp. 60-62. For how unilateral actions circumvented the free-rider problem of collective action in the global commons, extending back to the Clinton administration, see Aklin and Mildenberger (2020).

[2] Andrew Restuccia, "The One Word That Almost Sunk the Climate Talks," Politico, Dec. 13, 2015, at http://www.politico.eu/article/one-word-almost-sunk-climate-talks-legally-binding-cop21-deal-global-warming/; Suzanne Goldenberg, "How US Negotiators Ensured Landmark Paris Climate Deal Was Republican-proof," *The Guardian*, Dec. 13, 2015, online at

Another important international agreement, almost invisible to the public, came in 2016 with the "Kigali amendment" to the Montreal Protocol. The Protocol had been a great success in protecting the ozone layer by halting emissions of CFCs. It happened that CFCs were potent greenhouse gases, and it turned out that without the agreement, a continued accumulation of CFCs in the atmosphere would have accelerated global warming at a disastrous pace. The Montreal Protocol came to be recognized as not just an agreement to protect the ozone layer, but a mechanism to retard global warming. Indeed it had done more to protect the climate than the Kyoto Protocol and all other agreements preceding the Paris Conference.[1] However, the industrial role of CFCs was being taken up by hydrofluorocarbons (HFCs), which were themselves greenhouse gases. Complex negotiations now concluded with an international ban on these as well.

The IPCC's next move hit the world like a bucket of ice water. In a special report issued in 2018, scientists explored what the Earth would be like at 1.5° and 2° of warming. They bluntly reported that the impacts would be so severe at 2° that this would already qualify as a seriously dangerous level. A decade earlier few had thought it was realistic to imagine halting warming below 3 °C. Now phenomenal progress in wind and solar energy and other technologies (thanks to generous government subsidies), and rapidly evolving public concern, put a lower limit within reach. However, we could get there only through swift and radical transformations in our economy and society. In particular, to stop at 2° would require that "global net anthropogenic CO_2 emissions... decline by about 25% by 2030..." Journalists translated the dry phrases into a terrifying message: we had twelve years to save civilization.[2] (*Note that warming would be much greater than the 2°C global average at northern latitudes, and greater over land than over the oceans.*)

The 2015 Paris Agreement had called for a meeting in five years to declare stricter commitments. The Covid-19 pandemic delayed the conference, COP26 in Glasgow, to 2021. The delay gave the IPCC time to finish its next big science report (AR6). The pandemic drove some 300 delegates into an unprecedented 11-day virtual meeting, plagued by shaky internet connections and clashing time zones. To everyone's surprise, the delegates reached final agreement barely an hour past the scheduled closing time. The grim text reinforced the findings of the 1.5° report: severe harm could be avoided only if global emissions fell to "net zero" by mid century. The report also highlighted the rise in damage from "weather and climate extremes" that could now be firmly attributed to human influence. The authors broke IPCC precedent by emphasizing that beyond their projections of the most likely consequences, science could not rule out a possibility of much worse catastrophes: "Abrupt responses and tipping points... cannot be ruled out."

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http://www.theguardian.com/us-news/2015/dec/13/climate-change-paris-deal-cop21-obama-administration-congress-republicans-environment. "Great roar:" James Dyke, Robert Watson and Wolfgang Knorr, "Climate Scientists: Concept of Net Zero Is a Dangerous Trap," TheConversation.com, April 22, 2021, online at https://theconversation.com/climate-scientists-concept-of-net-zero-is-a-dangerous-trap-157368.

[1] Velders et al. (2007).

[2] IPCC (2018), quote: IPCC (2018b). For "twelve years" see note {158} in the essay on "The Public and Climate Change."

In Glasgow the gray November streets filled with some 100,000 demonstrators, mostly young. "For the first time," a veteran observer wrote, "it felt to me that the adult delegates inside the conference halls were more afraid of the kids outside than they were of one another or the press." The talks got a boost from independent announcements by a variety of groups. A pledge to reduce methane emissions 30% by 2030 was signed eventually by more than 150 countries (but not by China, Russia, India and some other major emitters). Nations that contained nearly 90% of the world's forests signed a pledge to end deforestation by 2030. And most of the world's major investors, lenders and regulators made a commitment to include reduction of carbon emissions in their investment decisions. The pacts showed what climate diplomacy had become—an elite quasi-community of thousands of practiced negotiators, whose countless subtle interactions shifted policies incrementally using promises, pressure, shaming, and even scientific facts.[1]

The main point of the meeting, however, was the pledges each nation brought to Glasgow for their emissions, and these were mostly disappointing. If every nation met its goal, global heating was still likely to reach a truly dangerous level. Once again the delegates spent much of their time and emotion on demands for massive transfers of money from rich nations to poor ones, concluding with dubious promises.

In the final agreement, again negotiated in weary hours long past the scheduled deadline, the representatives simply promised to try harder to bring emissions down quickly. Nations would issue new, presumably better, pledges the very next year. (The 2022 conference would actually bring only a few additional pledges, and was preoccupied with how rich nations might compensate poor ones for their "loss and damage" from climate change.) Less noticed at Glasgow was a concrete outcome, the culmination of decades of inscrutably complex negotiations: an agreement on strict rules for trading carbon credits between governments. Offsets traded by corporations remained unregulated and often illusory.

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[1] IPCC (2021b), A.3, C.3.2 & passim. "First time:" Thomas L. Friedman, "The Climate Summit Has Me Very Energized, and Very Afraid," *New York Times*, Nov. 10, 2021, p. A21, online 9 Nov. 2021 at https://www.nytimes.com/2021/11/09/opinion/climate-change-summit-glasgow.html. On efforts, mostly invisible to the public, to get banks and other financial institutions to redirect financing away from carbon emitters, see Jacquie McNish and Liz Hoffman, "Who Pays for Climate Change?" W*all Street Journal*, Oct. 30, 2021, p. B1, online at https://www.wsj.com/articles/mark-carney-ex-banker-wants-banks-to-pay-for-climate-change-11635519625. For extensive reports and analysis see Earth Negotiations Bulletin, "Summary Report, 26 July–6 August 2021 [on AR6]," online at https://enb.iisd.org/climate/IPCC/IPCC-54-WGI-14/summary#brief-analysis-ipcc-54, and for COP Earth Negotiations Bulletin, "Summary report, 31 October–12 November 2021 [on COP26]," online at https://enb.iisd.org/glasgow-climate-change-conference-cop26/summary-report#brief-analysis-cop-26.

Outside analysts of COP26 called it a modest step forward. If the specific pledges announced were implemented in full, the temperature rise above the pre-industrial era could be held well below 3°—an encouraging improvement over the dismal prospects a decade earlier. If everybody also pursued their airy long-term promises to the extent realistically possible, the rise could conceivably be held below 2°. That is, provided the effect of greenhouse gases on global temperature turned out to be what the IPCC considered most likely. News reports scarcely mentioned that if the gases turned out to have a stronger influence, which the IPCC thought rather unlikely but certainly possible, the heating could be far worse.[1]

The Conferences of the Parties were now grandiose enterprises attended by tens of thousands of people, with corporate representatives as numerous as activists. Thousands of journalists worked the corridors; each conference brought a spike in media coverage of climate issues. Whether the public was impressed is another question. For example, in COP28 (Dubai, 2023), where passionate debate concluded in an agreement to "transition away from fossil fuels," reporters called the statement a historic landmark—but foresaw no practical consequences. And few noticed how negotiators, for the first time, took up the vast emissions from agriculture, animal husbandry, and food supply in general, or how the attempt to forge a consensus statement collapsed.

As multilateral negotiations inched ahead, many pinned their hopes instead on unilateral actions that would be plainly beneficial in themselves. For example, a nation could cut its share of the hundreds of billions of dollars of subsidies that supported the use of fossil fuels (which would save trillions more in health costs as the pollution from the fuels decreased.) It was even easier to encourage the development and deployment of more benign energy sources. Western European nations and China were already subsidizing solar and wind energy (plus nuclear energy in China) on a massive scale, and in 2022 the United States joined with a trillion-dollar program. Below the level of national policy, local governmental and corporate entities were beginning on their own to seek efficient ways to limit their emissions. Citizens increasingly looked for ways to contribute in their local communities and personal lives. An international study in 2018 found that in more than half the nations surveyed, citizens ranked climate change as the worst global threat. Two years later, nearly two-thirds of people surveyed in 50 nations agreed that "climate change is a global emergency."[2]

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[1] Meinshausen et al. (2022); Zeke Hausfather and Piers Forster, CarbonBrief.org, Nov. 10, 2022, "Analysis: Do COP26 promises keep global warming below 2C?" online at https://www.carbonbrief.org/analysis-do-cop26-promises-keep-global-warming-below-2c. Far worse heating: see note on 5% possibility in the essay on Impacts.

[2] Jacob Poushter and Christine Huang, "Climate Change Still Seen as the Top Global Threat, but Cyberattacks a Rising Concern," Pew Research Center (Feb. 10, 2019), online at http://www.pewglobal.org/2019/02/10/climate-change-still-seen-as-the-top-global-threat-but-cyberattacks-a-rising-concern/. United Nations Development Programme, "Peoples' Climate Vote," Jan 26, 2021, online at https://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/The-Peoples-Climate-Vote-Results.html. See also Leiserowitz et al. (2022) and James Bell et al., "In

In the early 2020s more than a third of the world's greenhouse gas emissions were covered by some kind of tax or permits regime. In particular, the European Union had worked out the problems in its trading scheme and was aggressively reducing emissions. Mindful that the reduction was partly due to driving manufacturing to countries with less restrictions, in 2023 the EU began to levy tariffs on certain imports calculated according to their "carbon content." A useful step in a different direction was the collapse of the market for "nature-based carbon offsets" (such as planting trees), a market exposed as largely fraudulent if not actually harmful. Various entities took up the challenge to establish trustworthy standards.

And the scientists? Their research continued to be coordinated by the World Climate Research Programme, which celebrated its 40th anniversary in 2019. Some of the early WCRP programs such as ISCCP and CLIVAR were still underway, joined by newer mega-projects devoted to ice sheets, atmospheric processes, computer modeling, and more. Decade by decade the scale and scope of the work had expanded, calling up a patchwork of new organizational components. In 2018 a review panel found that the "structure of WCRP has become increasingly unwieldy. It has evolved largely by accumulation of new working and advisory groups." The reviewers warned that the WCRP lacked "an up-to-date overarching strategy; as a consequence, it is struggling to set priorities and to bring to an end less important activities." Following the panel's advice, in 2021 the numerous organizations were reassembled in a new structure. Meanwhile each of the international programs continued to raise funds from national agencies and carry on with countless studies, working groups, conferences and publications. Cooperation was fostered by the IPCC, whose deliberations and periodic reports, forcing a search for consensus on what was known, pointed out where more research was needed.

With these solid international institutions and the inescapably global nature of its problem, climate research was now conducted more internationally than any other great human project. Supercomputers in national centers digested terabytes of data beamed down from satellites or gathered by legions of scientists, students, and technicians seeking "ground truth" in ocean, ice, tundra , and jungle, plus hundreds of laboratory facilities. For example, to study how tropical forests absorbed carbon, hundreds of researchers measured more than half a million trees in 213 forests in 24 nations; the list of their 178 institutions took up four columns of tiny print.[1]

Response to Climate Change, Citizens in Advanced Economies Are Willing To Alter How They Live and Work," Pew Research Center (Sept. 14, 2021), online at https://www.pewresearch.org/global/2021/09/14/in-response-to-climate-change-citizens-in-advanced-economies-are-willing-to-alter-how-they-live-and-work/.

[1] ISC, WMO and IOC of UNESCO (2018), *Review of the World Climate Research Programme (WCRP)*, Julia Slingo (chair), 72 pp. Paris: International Science Council [doi:10.24948/2018.03], available online at https://council.science/publications/review-of-the-world-climate-research-programme-wcrp/, quotes pp. 7-8. See the WCRP site https://www.wcrp-climate.org/. Tropical forests: Sullivan et al. (2020). Another random example: a simple review of data with authors from 59 institutions in 17 nations, Friedlingstein et al. (2019).

Looking back over this long history, we can see a clear trajectory towards greater cooperation and frank, rationally-based advice and negotiation. In scope and potential consequence, nothing remotely like the IPCC had ever existed before, nor anything like the huge and ambitious Kyoto and Glasgow conferences. In the teeth of opposition from the fossil-fuels industry—the strongest concentration of economic power the world had ever seen—and its ideological allies, based on nothing but statements by a few thousand scientists, the world's governments and many other bodies had made significant promises to alter fundamental practices. They had not acted early enough to avoid dangerous climate change. But the policies they put in place greatly reduced the risk of unbearable future catastrophe. The founders of the International Meteorological Organization, farsighted though they were, could scarcely have imagined it. If the trajectory were extended a few decades ahead as the harm of global warming became urgently obvious to everyone, it was likely that further safeguards would be negotiated belatedly into action.

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

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

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