Spencer Weart

Government: The View from Washington, DC

The money that paid for research on climate change came mostly from governments. Governments were also central to any practical actions that might address global warming. Following the Second World War, the United States Federal government funded many kinds of research, much of it connected to Cold War concerns, and some of this happened to relate to climate change. During the 1960s, the government created major agencies for space, atmospheric, and ocean science, and in the 1970s, as public concern for the environment mounted, the agencies increasingly supported research targeted directly at climate change. But climate scientists were too few and disorganized to push through a unified national research program. Their budgets, divided among different agencies, would rise for a few years and then stagnate. During the 1980s, the funding and the science itself came under attack. The technical question of whether climate change might be a threat got caught up in political battles between pro-regulation environmentalists and anti-government conservatives. Demands for policies to mitigate global warming found little support among American politicians, who thought the ideas were politically unfeasible if not downright pernicious. (This essay covers only the United States government — the most important by far, in terms of influence and domestic greenhouse gas production. The views from London, Tokyo, Moscow, etc. taken together were equally important, and I apologize that I haven't written an essay on this. For international developments, see the essay on International Cooperation).

- LINKS -

During the first half of the 20th century, it would have been hard to find any institution that gave a penny specifically to support research on climate change. The work was donated by individuals, mostly university professors who were paid more for their teaching than for research, let alone for any particular subject of research.

The most important greenhouse effect work in the entire half-century was done by a complete amateur, the engineer G.S. Callendar, in his spare time. National meteorological services like the United States Weather Bureau, driven especially by the needs of military and civilian aviation, did spend large and increasing sums to observe the atmosphere.(1) But this treasury of data was compiled for daily forecasts and was seldom used for basic research. The few climatologists that national agencies supported were hired only to compile dull statistics of average weather conditions.

<=CO2 greenhouse
<=Climatologists

Around midcentury some meteorologists began to call for a more vigorous research effort. In 1953, a government advisory committee reported that the entire Weather Bureau needed new, young blood. Modest research that a few outstanding individuals had undertaken before the war had suffered a "slow, almost lingering death." The committee warned that climatology, starved for funds, was scientifically moribund.(2) Their report led to the appointment of a new climatology chief, Helmut Landsberg, who brought an improved "esprit de corps" and an important expansion. His group's main job, however, was still routine processing of data on past climates. Another report presented in 1957 complained that climate research remained a stepchild at the Bureau, inadequate in scope, with climatologists mostly "relegated to a mere housekeeping function."(3) While climate studies languished at the Weather Bureau, however, a flood of new Federal money began to push the field forward in other institutions, even though their missions were remote from weather research.

<=>Climatologists

Cold War Organizations and Climate Research (1950s-1960s) TOP OF PAGE

From the late 1940s into the 1960s, many of the papers cited in these essays carried a thought-provoking footnote: "This work was supported by the Office of Naval Research." The ONR's work is a well-known chapter in the history of American science. In 1945, as the war effort wound down and scientists worried about where they

would find support, the United States Navy decided to fund basic research. The other military services soon followed. Their support reflected a recognition among some officers that they would need scientists for many purposes. The war had been shortened, if not decided, by radar, the atomic bomb, and dozens of other scientific devices barely imagined a decade earlier. Who could guess what basic research might turn up next?

= Milestone

Besides, scientists who made famous discoveries would bring prestige to the nation in its global competition with Communism — in the Cold War, winning opinion came before winning territory. Scientists' glory would also reflect on the officers who were on good terms with them. More important, ready access to a stockpile of skilled brains might be vital in some future emergency. So there was reason to support good scientists regardless of what questions they chose to pursue.(4) Still, some fields of science were more equal than others in the long-term advantages they might provide to the United States. Nuclear physics in particular (think of bombs and submarine reactors), and solid-state physics (think of electronics and metallurgy) could count on especially generous support.

ONR: princely patron

Physical geoscience was one of the privileged fields. As historian Ron Doel has pointed out, military officers recognized that they needed to understand almost everything about the environments in which they operated, from the ocean depths to the top of the atmosphere. In some fields such as oceanography, another historian noted, "operational data and basic research results were often the same thing." Considering the complex interconnectedness of all things geophysical, the military services were ready to sponsor every kind of study. For good practical reasons, then, the U.S. government supported geophysical work in the broadest fashion. If purely scientific discoveries happened along the way, that would be a welcome bonus.(5)

=>The oceans
=>Revelle's result

Meteorology was especially favored. Weather has been crucial in warfare since antiquity. During the Second World, the armed forces had seen meteorologists provide life-or-death information for everything from bombing missions to the Normandy Invasion. After

the war, military agencies joined civilian ones in fostering research that might eventually improve weather prediction. The work ranged from better data-collecting networks to laboratory studies of radiation to attempts to model weather on digital computers.

=>Models (GCMs)
=>CO2 greenhouse

Beyond the daily forecast, some experts had visions of deliberately altering the weather. New schemes to help farmers by "seeding" clouds with silver iodide smoke, in hope of making rain, caught the public's attention. Government officials and politicians also took heed.(6) From the late 1950s forward, the U.S. government was pressed to fund meteorological studies in hopes that the nation might improve its agriculture with timely rains. A nation that understood weather might also obliterate an enemy with droughts or endless snows. By the mid 1950s a few scientists, particularly the brilliant mathematician and nuclear bomb expert John von Neumann, were warning that "climatological warfare" could become more potent than nuclear war itself.(7)

=>Climatologists
<=Rain-making

Von Neumann spoke from inside knowledge. He was hard at work applying electronic computers to meteorology. His group was initially located at the U.S. Army's Aberdeen Proving Grounds, and the Air Force too supported computer weather research. Von Neumann told yet another sponsor, the ubiquitous ONR, that his efforts had a dual goal: not only to predict daily weather changes, but to calculate the general circulation of the entire atmosphere, which might someday show how to deliberately change a region's climate.

Questions about long-term climate change over the planet as a whole were *not* a favored field of inquiry. To be sure, evidence that the Arctic was getting warmer caught the eye of officers in the Pentagon. Among other strategic considerations, the thickness of the ice mattered for the missile-bearing nuclear submarines that lurked beneath. The officers saw this as a question of monitoring natural changes. Why pay for research about, say, the global effects of increased carbon dioxide gas (CO_2), when that was expected to bring a shift of climate only with the passing of centuries, or more likely never? So it was only by chance that certain research projects

funded by government agencies turned out to be useful for the study of greenhouse effect warming.(8)

An example was the development of radiocarbon dating, which later became a key to working out the history of past climates. The pioneers in the delicate study of radioactive materials were a group of Manhattan Project veterans at the University of Chicago. They drew on parallel work underway at Chicago on the detection of fallout from atomic bomb tests. In this as in almost all American non-military research, something like half the support was indirectly related to Cold War military demands. Of course that left half the support to come from other sources. A good part of the funding for radiocarbon dating was simply the basic salaries and lab space that universities gave their professors. Other support came from philanthropic foundations interested in archeology, and from corporations that worked to improve radiation instruments as a commercial enterprise.

<=Revelle's result

=>Carbon dates

In many other areas of apparently pure science, without Cold War funding the research would have advanced far more sluggishly or not at all. For example, military agencies supported theoretical and experimental studies of the way infrared rays passed through the atmosphere, because the problem was important for heat-seeking missiles and other weaponry. One physicist doing such work was Gilbert N. Plass, who did theoretical calculations in association with an experimental group at Johns Hopkins University, funded by the ONR, that was gathering data on how pressure and temperature affected spectral lines. According to his later recollection, Plass learned about climate change only because he read broadly about topics in pure science, and happened upon the discredited theory that changes in the amount of CO_2 in the atmosphere could explain the ice ages. He took to studying the infrared absorption of CO_2 as a sideline, not far from his regular work.

Leaving Hopkins, Plass continued his research using a computer at the University of Michigan, also on ONR funds. Before he could finish his analysis, he moved on to join a group of scientists at the Lockheed Aircraft Corporation in southern California. In his new

job he was calculating the transmission of radiation through the atmosphere to answer questions directly related to weapons. Meanwhile he wrote up his results on greenhouse warming — "in the evening," as he later recalled, entirely separate from the military research for which he was now employed. The results turned out to be crucial for reviving the moribund greenhouse effect theory.(9)

=>Keeling's funds
=>Radiation math
=>CO2 greenhouse

There were many other examples. Studies of deep ocean circulation interested the ONR, because naval officers worried about disposing radioactive bomb debris and nuclear reactor wastes in the ocean depths. The information also happened to be crucial for understanding how much CO_2 the oceans could absorb, and thus the prospects for greenhouse effect warming. The Navy and other services lent logistical support for stations in Antarctica, mainly to gain experience in case they ever had to fight there. The logistics happened to be invaluable for studies that required a pristine environment, such as monitoring CO_2 levels in the atmosphere. The Air Force Cambridge Research Center in Massachusetts had an entire Geophysics Research Directorate which funded, among many other projects, laboratory and field studies of weather patterns that surprised everyone with crucial hints about how rapidly climate could change. In short, the military scattered so much money about that there was enough for studies that nobody connected with any practical issue. When scientists put together some of the results, they began to suspect that there was a genuine risk that burning fossil fuels could bring on global greenhouse warming. The U.S. military had bought an answer to a question it had never thought to ask.

<=>Revelle's result
<=>The oceans
=>Keeling's funds
=>Simple models
=>Rapid change
<=CO2 greenhouse

A more complete story of Cold War support for one key development is told in a supplementary essay on Roger Revelle's Discovery.

By the end of the 1950s, the U.S. government — or rather, the few and scattered people in Congress and the bureaucracy who took any interest in weather science — had become vaguely aware that there was a risk of unwanted climate change. This awareness was largely the doing of a highly respected oceanographer, Roger Revelle. As

<=CO2 greenhouse

soon as his studies of CO_2 convinced Revelle that the oceans probably would not absorb all the gas that human industry was producing, even before publishing the results he took the matter to both government officials and journalists. When a committee of the National Academy of Sciences produced a "First general report on climatology to the Chief of the Weather Bureau" in 1957, it picked up a metaphor that Revelle had begun to use: "In consuming our fossil fuels at a prodigious rate, our civilization is conducting a grandiose scientific experiment."(10) Meanwhile Revelle came before a Congressional committee to testify that the rise of CO_2 might bring severe climate shocks within the next century.

<=Public opinion

Revelle had come to Washington to promote a general boost in funds for all of geophysical science. It was his part in a world-wide campaign that geophysicists had mounted to win a really big pot of money for their research, a campaign that reached fruition in the International Geophysical Year of 1957-1958. The U.S. National Committee responsible for IGY plans had called groups of experts together in early 1956. As one minor part of their work, the experts devised a modest program of climate research. Among other things, the committee set aside some IGY money to temporarily support a program of measurements of the concentration of CO_2 in the air. (11) Other climate studies got similar important benefits.

=>Keeling's funds

=>International

Although the IGY officially ended in 1958, its success gave research a lasting impetus. Above all (literally above all) were the Soviet *Sputnik* and other satellites. Nominally built for geophysical research and launched under IGY auspices, in reality the satellites were meant chiefly to gather military intelligence. To the American public, *Sputnik* was a frightening demonstration of vulnerability to nuclear-armed missiles, and seemed to show a Russian lead in science and technology. The "crisis," as some called it, drove the government to boost funding for all areas of science.

The *Sputnik* anxieties brought a particularly big raise to the National Science Foundation, which Congress had established back in 1950 with a modest budget to support fundamental scientific research. By 1959, the NSF's funding had jumped more than tenfold. Meanwhile

military officers' interest in supporting basic science waned, and during the 1960s, Congress decided that the armed forces should stick closer to their immediate needs. The NSF with its fattened wallet took over much of the support of basic climate research from the military agencies.

Still, military funding remained important for many activities. For example, the bases that the U.S. Navy had set up in Antarctica during the IGY remained indispensable during later decades for research on the potentially fateful interactions between ice sheets and global warming. Other nations funded similar if smaller programs. For example, the Soviet Union likewise established a half-military, half-scientific presence in Antarctica. Without this logistical base, the Russians and their French partners could never have drilled through the ice cap to get crucial data on past glacial periods.

=>Sea rise & ice

=>Climate cycles

During the 1960s, scientific technology proved its importance not only in Cold War activities but in all areas of economic life. Coupled with rising prosperity, the promise of benefits prompted nearly all nations to expand their funding of science. Atmospheric science got its share of the new budgets. Meanwhile university departments of meteorology proliferated, driven by a demand for trained staff. The rapidly spreading air transport industry needed meteorologists, and so did the still more rapidly spreading television weather shows, not to mention the military weather services. Private meteorological services also began to burgeon, as the cash value of forecasting increased in step with its precision. Still, the rise of meteorology was no faster than other areas of university science, driven by their own mushrooming practical demands.(12) Equally rapid expansion benefitted other fields of geophysics where research relevant to global warming might be found.

In the early 1960s, Federal officials decided to target the atmospheric and ocean sciences for a special boost. Scientists and bureaucrats who were dedicated to ocean research, and who had never gotten much National Science Foundation money, had already begun a lobbying effort in the late 1950s. Their warnings that the

nation was lagging behind its rivals evoked all the *Sputnik* worries, and Congress at last gave NSF substantial funds for oceanography research.(13) Meanwhile others sought to brush away the Weather Bureau cobwebs. The key idea came from the physics community. To build and run their gigantic particle accelerators, physicists had put each instrument in the hands of a consortium of research universities. Imitating this model, in 1960 Congress established a National Center for Atmospheric Research with 14 universities as initial NCAR members (dozens more joined over the following decades). The funding came through the National Science Foundation. The NSF got a good boost in its meteorology research budget not only to support NCAR but also to build up university groups.

NCAR labs

In 1965, the government enacted a still grander reorganization, bringing the Weather Bureau together with several other science agencies in a new agency named the Environmental Science Services Administration (ESSA). Federal funding for meteorological research jumped sixfold (in constant dollars) in the decade 1958-1967. Then it leveled off, and for the next two decades support barely kept ahead of inflation. But the gain was permanent for people like the computer modelers who had helped to set up NCAR. Their work was a line item in NCAR's budget from the beginning, so the costly computer studies of climate went forward as a matter of course.(14)

=>Models (GCMs)

Ocean scientists had an initiative of their own. Support for their field was even more divided than support for the atmospheric sciences, scattered among small and disorganized programs that dealt with everything from offshore oil to fisheries. A group of leaders lobbied for a "wet NASA." A presidential commission was organized in 1968 to address the issue, and it surprised everyone by recommending that ocean programs be integrated with atmospheric ones. The commission was in tune with recent thinking, seeing the seas and air in a unified way. They were concerned about "modification of weather and ocean conditions by interference with natural environmental processes," and called for monitoring of the

entire "global air-sea envelope."(15) Prodded by marine interests in Congress, President Richard Nixon's administration supported the idea. In 1970, the various marine research, technology, and administrative programs were folded together with ESSA into a new organization, the National Oceanic and Atmospheric Administration (NOAA). The hopes for a top-ranked independent agency like NASA were not entirely fulfilled, however, for NOAA was created as only one of the many agencies within the Department of Commerce.(16)

=>The oceans
= Milestone

From the beginning, NOAA was one of the world's chief sources of funding for basic climate studies. For example, one of its units constructed what were arguably the most important of all computer models of climate. But the agency was created by rearranging programs without adding new money. Insofar as NOAA had any central focus, it followed the original impetus to develop economically important marine resources such as fisheries. The atmospheric sciences were left mired in ambiguity. As one observer reported, through the next decades there were "serious programmatic gaps... stemming from the agency's complex history and resulting confusion as to its central mission." An example was the important Landsat satellite program, NOAA's best bet for monitoring overall global change. This program was designed to study land surfaces rather than clouds, and it was "treated as an orphan" through its first three decades. As for observational systems aimed directly at meteorology, they were designed mainly to aid daily weather prediction rather than to gather and retain the data needed for monitoring long-term climate change.(17)

=>Models (GCMs)

=>Climatologists

The Nixon administration created another significant agency related to atmospheric science in 1970, the Environmental Protection Agency (EPA). This was the year of the first Earth Day, marking the point when the public in the United States (and soon after, many other nations) began urgently pressing their governments to pay attention to environmental harms. Congress funded NOAA and EPA largely in obedience to this growing public concern, which was directed less at possible future global troubles than at visible

<=Public opinion

nearby evils like filthy rivers and choking city air. The EPA was created to deal with human health risks such as smog, not climate issues, and had only minor funds to give to global warming research.(18) Practical near-term thinking also motivated pollution-control laws such as the Clean Air Act (passed in 1970 and strengthened in 1977). This viewpoint made sense to scientists, who mostly put "environmental" questions in the category of immediate practical problems, separate from abstract speculations about climate change.(19)

It was no wonder if nobody was devoting much effort to mobilizing funds for climate change studies — who would feel responsible for the task? The planet's climate is not organized along the lines of government agencies. Nor does it fit with the standard academic scientific disciplines ("Nature is ignorant of the ways our universities are organized," as one scientist remarked). Key problems in the field, such as the study of how carbon moves among the atmosphere, the oceans, and the biosphere, fell between stools. No institution had a budget line devoted to these problems. (20) There was no institutionalized field of "climate change science." There was only a variety of individual scientists in a medley of fields, studying everything from computer models of weather to glaciers to sunspots — specialists who may never have heard of one another. So there was no community to lobby for funds, organization or policies.

<=Climatologists

Scientists who wanted funds for global warming research had adopted a strategy so traditional that they probably did not think of it as a strategy at all. They had worked hard to build up individual scientific institutions, academic and international as well as Federal, in their respective fields. In each institution, elite scientists would be in charge, directing research funds as they thought best. The result was that climate change studies, fragmented among many organizations, received a fairly reliable but modest fraction of various research budgets. Nobody made a special effort to create a unified climate studies program, the kind of strong and independent institution that could fight for a big lump of funds.(21) After all,

scientists in the 1950s and 1960s saw global warming as only one of a thousand interesting questions, something that would not be a problem for many decades if ever, nothing at all to do with current government policies.

A few people did notice implications for their present concerns. When Edward Teller told an assembly of scientists in 1957 that rising CO_2 levels might eventually melt back the polar ice caps and inundate the world's lowlands, he had a personal stake as a nuclear expert. These were years when many people in government and industry, including Teller, were enthusiastically promoting the building of nuclear reactors. Some of them noticed that the risks of greenhouse warming could give minor reinforcement to their arguments for weaning humanity from dependence on coal and oil. Recognizing an attack on fossil fuels, a scientist working for Shell International Chemical Company publicly denied that "our furnaces and motor car engines will have any large effect on the CO_2 balance."(22) From time to time on through the 1960s, nuclear power advocates would mention greenhouse warming in passing as a future drawback of fossil fuels. That may have helped maintain awareness of the greenhouse issue in policy circles.(23)

Foreseeing weightier issues was not impossible. Two reporters who spoke with scientists in 1957 sketched out some striking implications of the greenhouse effect. If it ever became certain that CO_2 was warming the planet, they wrote, we would see "a type of control regulation, law, interstate compact, and international agreement which could scarcely help clashing with some of our cherished notions of free enterprise. Industry, which might blossom in some directions...would be hamstrung in others.... Further, in view of the global nature of the problem, ordinary international agreements might prove inadequate for effective regulation." But an international regime that imposed actual penalties would be "sure to foster great heat and controversy."(24) The reporters were far ahead of their time. For decades, hardly anyone else would raise these grave questions.

Through the 1960s, a modest level of official interest was sustained

by new scientific findings. Most telling was C.D. Keeling's measurements of the level of CO_2 in the atmosphere, a curve that dramatically rose year after year. The idea that the government should actually do something about this — if only to sponsor climate research more systematically — first arose in 1963, when Keeling and a few other experts met in a conference sponsored by the private Conservation Foundation. Their report warned that the doubling of CO_2 projected for the next century could raise the world's temperature some 4°C (more than 6°F), bringing serious coastal flooding and other damage. The government should give the subject more consistent attention, they believed, and more money. Decrying the lack of continuity in greenhouse gas research, the group recommended that Keeling's program for monitoring CO_2 levels (whose funding was threatened) be continued. Above all, they called on the National Academy of Sciences to create a committee to look into the whole question of atmospheric change.(25)

<=CO2 greenhouse

<=>Keeling's funds

A more complete story of the vicissitudes of support for one key development is told in a supplementary essay on Funding Keeling and CO_2 Monitoring.

Gradually the government reacted. In 1965, when the President's Science Advisory Committee formed a panel to address environmental issues, it included a subpanel of leading climate experts. They reported that greenhouse warming was a matter of real concern. There could be "marked changes in climate," they reported, "not controllable through local or even national efforts." That put the issue on the official agenda at the highest level of government — although only as one item on a long list of environmental concerns, many of which seemed more pressing.(26)

=>Public opinion

The following year, 1966, the Academy answered a government request to report on how human activity could influence climate. The experts sedately said they saw no cause for dire warnings, but they did believe the CO_2 buildup should be watched closely. "We are just now beginning to realize that the atmosphere is not a dump of unlimited capacity," the report said, "but we do not yet know what the atmosphere's capacity is." The panel's primary conclusion

=>Models (GCMs)

was typical of such reports — a maxim that came from the heart of scientists' belief in their calling — More Money Should Be Spent on Research.(27)

These efforts were only minor byways in the government's atmospheric science work. Short-term weather prediction came first. For longer-term problems, the titles of the panels show what was on people's minds. The President's advisory group was named the "Environmental Pollution Panel," and the Academy's was the "Panel on Weather and Climate Modification." Asked about human influence on the atmosphere, the public would think first about smog. Next they would think about deliberate attempts to make rain (by the early 1970s, the NSF was spending almost as much on "weather modification" as on all the rest of the atmospheric sciences combined).(28) That included climatological warfare — indeed the U.S. armed forces had already begun secret attempts to bog down the North Vietnamese army with artificial rainmaking.

<=Rain-making

Research on climate change was not the particular responsibility of any government official. As the 1965 panel remarked, "no agency or program is concerned with the average condition of our environment."(29) The 1966 Academy panel added that for climate as for most environmental fields, support was "diffused among many agencies." Thus "there exists no single natural advocate in the Federal structure, nor is there a clear mechanism for making budgetary decisions." In the mid-1960s, a variety of government agencies together spent roughly $50 million a year for all aspects of meteorological research. That was not much, and climate change caught only a few percent of that.(30) Studies of the topic had to fit in as minor components of programs that had been set up to work on more immediate problems.

Perhaps the best hope of climate scientists was that a bit of the money devoted to climate modification (which mainly meant rainmaking) could be diverted toward research on... well, call it "inadvertent climate modification." The phrase was often used during this period by people concerned about greenhouse warming. (31) But defining the greenhouse effect as "inadvertent climate

<=Rain-making

modification" made it sound like just one of the countless byproducts of economic progress, a sort of smog that could be handled easily by more technology. Leading experts suggested that if global warming ever became annoying, there were technical schemes, not excessively costly, that could counteract it. In short, climate change was of far less interest to the government (and the public) than chemical pollution, dying lakes, and countless other environmental problems.

=>Keeling's funds

A Federal Program for Climate Change Research? (1970s)

TOP OF PAGE

When a group of citizens (in this case, scientists) decides that their government should do more to address some particular concern, they face a hard task. The citizens have only a limited amount of effort to spare, and officials are set in their bureaucratic ways. To accomplish anything — to bring about a new government program, in particular — people must mount a concerted push. For a few years concerned citizens must hammer at the issue, informing the public and finding allies among like-minded officials. These inside allies must form committees, draft reports, and shepherd legislation through the administration and Congress. Interests that feel threatened by change will put up roadblocks, and the whole process is liable to fail from exhaustion. Typically such an effort succeeds only when it can seize a special opportunity, usually news events that distress the public and therefore catch the eye of politicians.

In the early 1970s, a few climate scientists sought such an opportunity to mount such a concerted push. A month-long workshop at the Massachusetts Institute of Technology in 1970, and an international conference in Stockholm in 1971, put global climate change on the table as a significant policy concern. The scientists were spurred to the task by new data and calculations, which convinced them that the world's climate might change far sooner and more drastically than had seemed possible only a decade earlier. There was now evidence from ancient ice sheets and the seabed of abrupt climate changes in the past. A fresh look at mechanisms driving the climate system found such changes entirely

<=International

<=Rapid change

plausible. The next ice age might start within their own lifetimes! When scientists in a 1972 workshop found themselves in agreement that such things could happen, several of them wrote a letter to President Nixon to recommend that the government support intensified studies.(32) A high-level panel convened by the administration reported in 1974 that a sudden freeze was indeed possible within the next century (although the panelists did not find it very likely).(33)

This effort fitted with a broader movement, in which scientifically trained people were making contact with more traditional policy elites to address the planet's environmental future. As historian Paul Edwards described it, a "hybrid science/policy community" was taking shape. Policy makers as much as scientists were taking advantage of new tools — the aggressive gathering of all sorts of global information and the computer modeling to analyze it.(34) <=Public opinion

That was the traditional "insider" approach to policy. Other scientists thought government action would follow only if they could reshape public attitudes. A reshaping had in fact begun, in the mass environmental movement that burst into full flower in the early 1970s. Some climate scientists adopted the mood and rhetoric of the movement, describing climate change in dramatic terms as a threat to the well-being of the living planet. <=Public opinion

One focus of environmentalists was atmospheric pollution, meaning the toxic smog that people felt in their eyes and lungs. Since factories and automobiles emitted not only smog but greenhouse gases, environmentalists might mention global climate change as one more argument against polluting industries. Thus when some groups fought to prevent the government from building a fleet of supersonic transport airplanes in the early 1970s, their warnings included an occasional mention of the long-term harm that airplane exhaust might do to global climate. The worries were strong enough to push Congress to fund a "Climatic Impact Assessment Program" (CIAP). It was one of the biggest of all scientific research projects undertaken to that time, involving numerous agencies of the U.S. and foreign governments and more than a thousand

scientists. In three years of studies, ranging from data-collecting with balloons to mathematical modeling of stratospheric chemistry, they tried to define the threat from aircraft emissions.

The result was inconclusive, which meant the scientists could provide no reassurances that a fleet of supersonic airplanes would not change the weather. Meanwhile an even greater scientific concern had come up. Among the studies were some that pointed out a more definite and immediate risk: emissions from the airplanes could damage the high ozone layer that blocked solar rays. This might well bring a rise in skin cancers and other harm to people and biological systems. The main thing that offended the public, however, was a likelihood of noise pollution and the waste of their tax money. Congress closed the issue in 1971 by refusing to subsidize the airplanes.(35) For climate scientists, the CIAP program produced a trove of useful data. But it had been only a short-lived effort on a narrow topic, far short of the sustained coordination and funding they desired.

<=Other gases

<=>Public opinion

=>Aerosols

Their opportunity came in the early 1970s, as news media reported an extraordinary series of weather disasters. Around the world droughts were bringing horrific famines and (what more deeply affected the U.S. government) distress to American farmers. For the first time ever, climate change mounted high in public awareness, catching the attention of some politicians and government officials. In 1974, Alvin Weinberg, a leading energy expert from the nuclear establishment, put the issue succinctly. The danger of climate change, he explained, placed some kind of limit on the world's energy systems. The nation needed proper organization for climate research "so that, say 20 years from now, we can base our energy policy on a much sounder understanding of this limit... The problem of global effects of energy production... is everyone's problem, and therefore no one's problem. I propose, therefore, that an institute (or even institutes) of climatology be set up with a long-term commitment..."(36)

<=Public opinion

Weinberg was only one of many scientists who were now urging the government to organize climate research. Another example was a

<=Public opinion

group at the University of Wisconsin. In 1973 they presented a plan for a climate program to the National Security Council, and the plan was duly reviewed by the NOAA and NSF bureaucracies. Meanwhile the National Academy of Sciences established a Committee on Climatic Variation, which in 1974 presented its own recommendations for a national climate research plan. Alongside the recent weather troubles, policy-makers from Senators to Air Force generals continued to worry about deliberate climate modification. That meant everything from the recently revealed American rain-making in Vietnam to problematic Russian schemes for altering the Arctic. Such schemes now looked more likely to bring environmental damage and ignominy than useful results. Meanwhile, improved computer models were suggesting that greenhouse gas emissions really would cause a global warming within the foreseeable future. The entire human interaction with climate was looking increasingly problematic.

<=Rain-making

<=Models (GCMs)

The President's Domestic Council worked to pull all the strands together in a proposal for a National Climate Program. Staff members drafted a National Climate Program Act, centered on an increase of funding for research and monitoring. With the recent droughts much in mind, in May 1976 a Congressional committee began hearings, the first ever to address climate change as their main subject. Leading climate scientists and publicizers of climate change explained at length their call for expanded work.(37)

The talk dragged on with little public attention and little result. Without the backing of some unified community or organization, the movement for reorganization was impeded by the very fragmentation it sought to remedy. The proposals were various, but all of them threatened to usurp the activities of existing research bureaucracies. And the effort had come in cramped economic times, as Congress sought ways to cut the budget. But the worst weakness was what one participant called "a failure to demonstrate to funders of such research the practical benefits that can result within a time frame of relevance to their mandate." Lawmakers cared far more about the few years until the next election than about the following

century. In the end, the sole useful consequence was that the Nixon administration set up an interagency group to coordinate climate research. Only in a limited sense could that be called an official U.S. climate program, and for practical purposes it counted for little.(38)

The efforts continued. Ominous warnings in National Academy of Sciences reports and sensational journalism repeatedly brought climate change to the attention of the public and politicians. Scientists and officials tried again from time to time to create some kind of centrally organized national program or institution. For example, in 1978 a proposal was floated to establish a national CO_2 directorate at the MITRE Corporation, a Cold War think tank. The idea went nowhere. Meanwhile, prompted by scientists and bureaucrats, legislators in the U.S. Congress were proposing a small flurry of bills related to climate, starting in 1975 and reaching six introductions in 1977 and another six in 1978.(39) Scientists testified before Congress that the rise of CO_2 could bring world disaster. Agency officials wrote and rewrote plans and negotiated tenaciously over who should get control of what research budget.

<=Public opinion

Adding to this agitation was a public controversy that erupted in the mid 1970s when scientists discovered that certain chemicals, widely used as propellants in spray cans, could damage the protective ozone layer in the stratosphere. Counter-arguments publicized by the chemical industry failed to quell the protests. Congress responded in 1977 by restricting the spray can chemicals. The issue had no visible connection with climate. But it showed that technical scientific findings about a future atmospheric risk could arouse the public enough to sway legislation and strike at major industries.

<=Public opinion

Scientists who hoped to stimulate action on climate, stymied in Washington, found better opportunities in working through the international science community. Efforts by a group of nations — not just their combined money but the consensus of their prestigious scientists — might help convince American politicians to act. Besides, internationalization might offer some of the organization that was lacking in the U.S. Since 1963 the World Meteorological

<=International

Organization (WMO), an association of national weather services under the auspices of the United Nations, had administered a World Weather Watch that usefully coordinated the gathering of data around the world. In 1968 the WMO combined forces with the International Council of Scientific Unions, a non-governmental congress of scientific organizations, to create a "Global Atmospheric Research Program" (GARP). This provided essential coordination for research projects everywhere.

To manage American participation in GARP, the National Academy of Sciences set up a "U.S. Committee for the Global Atmospheric Research Program" which included many top scientists. They kept up the pressure for organizational action. In 1975, the committee published an influential report, referring to the recent deadly droughts and declaring that "We simply cannot afford to be unprepared for either a natural or man-made climatic catastrophe." The scientists insisted that a rapid deterioration of climate was possible, although they could not agree on how likely that was to happen anytime soon. Emphasizing the lack of knowledge, the panel called on the government to build up a National Climate Research Program as the nation's share of an international effort. They said the Federal climate research budget should be doubled (from expenditures of less than $20 million in 1974), and doubled again by 1980.(40)This report was followed up in 1977 by a still more widely publicized Academy report on "Energy and Climate." The panel of experts, chaired by Revelle, announced that average temperatures might climb a dangerous 6°C by the middle of the next century, possibly with a catastrophic rise of sea level. They recommended "a lively sense of urgency" for studying the problem. There had never been so much reason to insist on the old principle, More Money Should Be Spent on Research.(41)

=>Rapid change

=>Public opinion

The Academy's experts were by no means prepared to stretch so far as to recommend actual changes in the nation's energy policies. They did suggest (not very prominently) that it might turn out that the world would need to reduce its use of fossil fuels. But they knew climate predictions were too unreliable to support such a

move in the visible future. If the panel avoided concrete advice, they did drive home a general truth — the threat of climate change was intimately connected with energy production. As a page one headline in the *New York Times* (July 15, 1977) summed it up, "Scientists Fear Heavy Use of Coal May Bring Adverse Shift in Climate." Officials were starting to grasp the fact that CO_2 emissions had economic implications, and therefore, political ones. The oil, coal, and electrical power industries began to pay close attention. After all, as a leading government energy official put it, "If CO_2 proves to be the problem people think it is, we'll have to restructure our entire fossil fuel program."(42)

The nation's fossil fuel policies were already under intense scrutiny. In the 1973 "energy crisis," inconvenience and anxiety beset millions of people as Persian Gulf states withheld their oil. When President Jimmy Carter's administration proposed to shift the nation from oil to coal, politics began to overlap with climate studies like the Academy's. It became particularly noticeable that some of the people most concerned about CO_2, Alvin Weinberg in particular, were advocates of nuclear power — an industry vigorously promoted as an alternative to foreign oil, but coming under vehement attack as a danger to the environment. One environmental argument often made in favor of nuclear reactors was that they emitted scarcely any greenhouse gases. The greenhouse effect also came up when some proposed the government should subsidize synthetic fuels as a substitute for oil: opponents pointed out that synthetics produced more CO_2 than comparable fossil fuels.(43) Meanwhile, the energy crisis was empowering advocates of renewable energy sources, ranging from Federal solar-energy bureaucrats to anti-government environmentalists, and they too found the greenhouse effect useful in arguing for their cause — the more of our power we generated from windmills, the lower our CO_2 emissions. Policy discussions grew increasingly sophisticated, exploring such issues as strategies to mitigate the effects of global warming, international legal mechanisms for restricting emissions, and ethical considerations in assigning costs and risks.(44) In all these debates, however, climate change was only one more weight

= Milestone

<=>Public opinion

thrown into the balance, and far from the heaviest one in most people's minds.

Nobody of consequence proposed to regulate CO_2 emissions or make any other significant policy changes to deal directly with greenhouse gases. Academy reports and other scientific pronouncements advised that any such action would be premature. They pointed out that predictions of future warming were based mainly on computer models, which were grossly oversimplified and relied on poorly measured numbers. Some scientists expected cooling rather than warming. If the world was currently warming (which they doubted), that might be just part of a natural cycle. Or the climate system might fluctuate in a purely random way, regardless of what humanity did.

<=Models (GCMs)

<=Chaos theory

Policy debate about the nation's energy systems revolved around more obvious economic, environmental, and national security problems. It was to address these issues that the Carter administration created a cabinet-level Department of Energy (DOE). With a mandate to lead in energy policy, a few DOE administrators proposed in 1977 to take responsibility for research on greenhouse gases. Their expansive plans ranged from monitoring the level of CO_2 in the atmosphere to predicting the economic and social consequences of future greenhouse warming. One administrator said that they needed data in less than a decade so the government could decide whether to promote coal as an alternative to oil.(45) To pay for the research, they requested a big budget expansion, from the $1.5 million that DOE was spending in 1977 to as much as $30 million a year.

Other agencies disliked the DOE plan, however, and their complaints went beyond the normal bureaucratic defense of turf. Prestigious scientists on a Climate Research Board, newly created by the Academy, criticized the plan as poorly designed and over ambitious. Meanwhile an Interdepartmental Committee on Atmospheric Science, as well as NASA, NOAA, and the Department of Defense, were each developing their own research plans.(46) The meteorological community and its friends in the

bureaucracy were determined to push for a better-designed consolidation of climate research.

The Academy's Climate Research Board took the lead under its full-time chair, Robert M. White. A widely admired scientist-administrator, "Bob" White had already served as head of the Weather Bureau and then of NOAA, as official representative in international meetings — one on whaling, for example, another on desertification — and in countless other capacities. In particular, he had recently chaired the President's Committee on Climate Change and a committee on weather modification. Bob White deserves notice as the most outstanding example of many people whose names are not mentioned here. It was their long years of negotiating and hard thinking, mostly out of public view, that gave climate research its funding and organization.(47)

Bob White

<=>International

Congress at last passed a National Climate Act in late 1978. This established a National Climate Program Office with NOAA, not DOE, named as the lead Federal agency. It was a step forward, but the new Office had only a feeble mandate and a budget of only a few million dollars. It was the hard-driving DOE officials who won large budget increases for CO_2 work. However, some of the expansion in the formal budget was not new money, but only a transfer of funds that had already been available through other programs. It was a pattern that administrations would often follow when they wanted to boast of their support for environmental causes.(48)

= Milestone

=>Keeling's funds

With the passage of the National Climate Act, the minor flurry of legislative attention ended. No climate-related bills were introduced in the U.S. Congress in 1979, and not more than one a year thereafter until the late 1980s.(49) The program to study climate change was underfunded from the start, and the large increases of the 1970s came to a dead halt in 1980 as Congress tried to balance the budget. Such money as was available seemed to go as much into paperwork and meetings as into actual research.

<=Keeling's funds

In 1980, the prominent geophysicist Wallace Broecker, who had

spoken out repeatedly about the dangers of climate change, vented his frustration in a letter to a Senator. Declaring that "the CO_2 problem is the single most important and the single most complex environmental issue facing the world," and that "the clock is ticking away," Broecker insisted that a better research program was needed. "Otherwise, another decade will slip by, and we will find that we can do little better than repeat the rather wishy washy image we now have as to what our planet will be like..."(50)

While research funding and organization remained well below the level climate scientists felt they needed to paint a correct picture of the future, the 1970s had not slipped by entirely without progress. Military agencies had continued to fund some research, such as secret computer-modeling studies of proposals to deliberately alter a region's climate. Meanwhile the NSF, DOE, and NOAA had supported a broad array of studies. Still more money had come from the National Aeronautics and Space Administration.

<=Rain-making

Founded in 1958, NASA was responsible for developing the satellites that were the primary source of accurate world-wide data on the atmosphere. There would have been no science satellites at all, of course, but for the billions of dollars lavished upon the exploration of space, thanks partly to popular enthusiasm and partly to the many military applications of rocketry. Military agencies had proposed the use of satellites for weather "reconnaissance" in a secret report as early as 1950. The first public "weather satellite," TIROS-1, launched in 1960, had been built under a Department of Defense contract, although it was transferred in 1959 to NASA as a civilian program. Through the following decades, the military secretly put up meteorological satellites that used the exquisite and highly classified technologies developed for spy satellites.

These technologies gradually made their way into the open civilian program of weather satellites. NASA built and launched the devices, but once they were in orbit they were operated by the Weather Bureau — which got its budget doubled for the purpose. The responsibility was taken over along with the Weather Bureau

by ESSA, followed by NOAA. The arrangement worked well for a few years. But in the late 1970s, public interest in space exploration flagged, and NASA's budget was cut. NASA stopped developing and testing new spacecraft for NOAA, and the weather satellite program deteriorated.(51)

TIROS and its successors were designed to help with daily weather forecasts, but some of the NASA satellites also did fine work for climate studies. Computer modelers had reached a point where their progress would come to a halt unless they got much better data on the actual atmosphere. The answer was Nimbus-3, launched from Vandenberg Air Force Base in 1969. The satellite's infrared spectrometers measured the temperature of the atmosphere comprehensively — at various levels, night and day, over oceans, deserts and tundra. It was a wealth of systematic data inconceivable a generation earlier, and invaluable for climate research. In particular, Nimbus-3 measurements gave an important check for a key computer model of 1975.(52) This was followed in the mid 1980s by a series of Earth Radiation Budget Experiment (ERBE) satellites which likewise provided data essential for accurate computer modeling.(53) At the same time NASA funded a variety of laboratory and theoretical studies and workshops related to atmospheric studies, and vigorously advocated research on every kind of global change.(54)

<=Models (GCMs)

=>Models (GCMs)
=>Solar variation
= Milestone

=>Models (GCMs)

NOAA, between operating the satellites and its other programs, was the world's most generous contributor to the international Global Atmospheric Research Program. Meanwhile, on the world's oceans NOAA almost fulfilled its ambition to be a "wet NASA." Its extensive oceanographic programs, mostly based in universities, produced many findings on ocean circulation and the like which were crucial for understanding climate change. No less important were NSF-funded projects. A survey of several oceans (GEOSECS, 1972-1978) took advantage of the one-time historical opportunity to track the fallout from the atomic bomb tests of the late 1950s, using the radioactive isotopes as markers of ocean circulation. Even more useful was NSF's Deep Sea Drilling Project, an ongoing series of

=>The oceans
=>Climatologists

cruises that extracted countless cores from the seabed (DSDP, 1968-1983, followed by an Ocean Drilling Program). Among much else, cores pulled from many locations helped map out the world's climate in the depths of the last ice age, posing an important test for computer climate models.(55)

Global Warming as a Political Issue (1980s) TOP OF PAGE

By 1980, many climate scientists thought it likely that harmful global warming was on the way, but Federal budgets for their research were not rising. In 1981, Ronald Reagan took the presidency with an administration that openly scorned their concerns. He brought with him a backlash that had been building against the environmental movement. Many conservatives denied nearly every environmental worry, global warming included. They lumped all such concerns together as the rants of business-hating liberals, a Trojan Horse for government regulation. The National Climate Program Office found itself serving, as an observer put it, as "an outpost in enemy territory."(56) The new administration laid plans to cut funding for CO_2 studies in particular, deeming such research unnecessary. Everything connected with the subject became politically sensitive. Thus when NASA scientist James Hansen published a study showing that the world had been getting warmer, and the *New York Times* made it a front-page story, the DOE reneged on funding they had promised Hansen. He had to lay off five people from his institute.(57) Such cutbacks were not enough for the DOE program's enemies. "The question of concern," one staff scientist remarked, "will be whether we have jobs rather than how we spend money."(58)

= Milestone

<=Modern temp's

A total gutting of greenhouse effect research was narrowly averted when scientists rallied behind Representative Albert Gore, Jr. As a student at Harvard a quarter-century back, Gore had been impressed by lectures Revelle gave there. Revelle had displayed Keeling's curve of relentlessly rising CO_2. "We were looking at only eight years of information," Gore recalled, "but if this trend continued, human civilization would be forcing a profound and disruptive

change in the global climate." It came as a shock to him, exploding his childhood assumption that "the Earth is so vast and nature so powerful that nothing we do can have any major or lasting effect on the normal functioning of its natural systems."(59) Over the years Gore had kept abreast of the technical issues as they developed, and he shared the concern about global warming as it grew among scientists. No doubt he also saw a political opening. As a champion of environmental issues he could display leadership in one of the few areas where the Reagan administration's policies disturbed a large majority of voters.

Gore joined a few other Congressmen to embarrass the administration with hearings on the proposed cuts. The hearings won a smattering of attention in the press, including an editorial in the *Washington Post* saying that global warming had moved outside the "sandals and granola crowd" to mainstream science. The hearings themselves counted less than the echo in the press. As an aide close to the process put it, "the popular media is the most potent way of convincing a member of Congress that he should pay attention to scientific issues." Politicians did not read scientific journals, nor much care what they said. Rather, they relied on the press as the "prime detector of the public's fears."(60) Sporadic press attention to greenhouse warming through the rest of the year embarrassed the administration enough to avert the worst of the threatened budget cuts.

<=>Keeling's funds

The small band of climate scientists who were not only alarmed about global warming, but determined to do something about it, worked harder than ever to attract attention, even at risk of sounding alarmist. They had some success at getting stories into newspapers and magazines. The politicians who supported them were still more oriented toward getting press coverage. For example, for a 1984 hearing Gore called in Carl Sagan, a respectable atmospheric scientist but far more famous as an astronomy popularizer. Sagan would attract television cameras to the hearings better than the specialists who devoted all their time to research.

<=Public opinion
<=>International

The biggest concern of Sagan and some other atmospheric scientists

pointed in another direction. In 1983, they announced calculations that a nuclear war could bring on a "nuclear winter," a profound cooling that might last for years. While this warning had little connection with the greenhouse effect, it did thrust forward the troublesome idea that human technology could bring on a climate disaster. The "nuclear winter" discussion grew into a harsh political controversy, for it was a deliberate attack on the Reagan administration's refusal to reduce the nation's nuclear arsenal. This reinforced the tendency for debate about possible climate changes to polarize along traditional political lines.

<=World winter

As the public forum became a stage for strident combat, the only progress came from the scientists who worked quietly behind the scenes. One of the best tools they created was an Earth System Sciences Committee, set up by NASA in 1983. The space agency was planning a "Global Habitability" program, which would eventually launch satellites to observe global change, and needed to fit this in with the plans of other agencies. The new advisory committee organized the government's first truly large-scale, interdisciplinary initiative to study global change with full interagency and international cooperation. On the committee, members struck bargains among agency officials and leaders of science disciplines, forging a common front. Eventually they issued a report that represented a consensus of the leading players.

This method for consensual lobbying drew on practices that physicists and astronomers had devised in the 1960s in their search for increased funding. Rather than competing piecemeal, leading scientists fought out their differences first among themselves. Once they agreed on a short list of top-priority programs, they put the weight of their joint prestige behind it. The administration's budget officials and Congress, pleased to see a coordinated effort endorsed by scientific authorities, opened their pockets, and there was more money for everyone.(61)

Quiet negotiation among scientists of a consensus program also worked well on the international level. A landmark World Climate Conference, held in Geneva in 1979, gave rise to a "World Climate

<=International

Research Programme" that organized a variety of large-scale cooperative projects. U.S. scientists played a major role in designing the projects, then went back to government agencies with a strong case for funding their share.

A more traditional tool for bringing scientific prestige to bear on policy was the National Academy of Sciences. In 1980, Congress passed an Energy Security Act which included a section directing the administration to hire the Academy to carry out a comprehensive study on the impacts of rising CO_2. The Academy's Climate Research Board had already sponsored a 1979 review of the most crucial issue, the validity of computer models. A panel of experts chaired by Jule Charney had endorsed the models, announcing they were now good enough to rely on. The experts were therefore quite confident that doubling of CO_2 would bring substantial warming (1.5-4.5°C) by the middle of the coming century. Heat was already building up in the atmosphere-ocean system, they concluded, so that "A wait-and-see policy may mean waiting until it is too late."(62*)

<=Models (GCMs)

Using this as a starting-point, in 1983 the Academy issued the comprehensive report that Congress had requested. It was the fruit of a sustained effort to work out a consensus in a panel of leading experts. The scientists agreed that they were "deeply concerned" about the environmental changes that they expected a temperature rise would bring. Worse, they pointed out that "we may get into trouble in ways that we have barely imagined" — for example, if global warming released methane (a potent greenhouse gas) from seabed sediments. These cautions, however, were only passing remarks, for overall the Academy panel was cautiously reassuring. As Hansen remarked, the panel's report "seemed to be aimed at damping concern."

<=Other gases

The report concluded that warming would probably not be very severe. Ignoring some problems pointed out by Charney's panel of experts, the Academy panel leaned toward the lower end of the range of increases that Charney's group had thought likely. Among other things that the Charney report had stressed, the Academy

<=The oceans

panel failed to consider that the appearance of warming might be delayed because the oceans were absorbing heat. The Academy report projected a mere degree or two of temperature change in the foreseeable future, and pointed out that this was a level of change that people in the past had managed to get through well enough. The panel advised against any immediate policy changes, such as trying to restrict use of fossil fuels. "Overall," their report concluded, "we find in the CO_2 issue reason for concern, but not panic." Their chief recommendation was that before doing anything else, the government should fund vigilant monitoring and other studies — truly, More Money Should Be Spent on Research.(63*)

Americans might have received this as just another dull Academy document, but three days later the Environmental Protection Agency released a report of its own about the greenhouse effect. The science was mostly the same, but the tone of the EPA's conclusions was more anxious. "Substantial increases in global warming may occur sooner than most of us would like to believe," the EPA authors warned. Since a ban on fossil fuels seemed out of the question on both economic and political grounds, they saw no practicable way to avoid a rise of temperature, perhaps a big rise. There could be "a change in habitability in many geographic regions" within a few decades, with potentially "catastrophic" consequences.(64) The *New York Times* took notice in a front-page story. This EPA report was the first time a Federal agency declared that global warming was, as the reporter put it, "not a theoretical problem but a threat whose effects will be felt within a few years." Emphasizing the worst, the *Times* warned of damage to food production and a rise of sea level within decades.(65)

The Reagan administration saw the EPA report as an attack. Officials responded by criticizing it as "alarmist" and pointing to the more reassuring Academy report. For as the *New York Times* science reporter put it, the Academy had said that "the greenhouse effect is for real but we can live with it." Here was a tale of battling perspectives, just what journalists needed to make a lively story. It spread through the newspapers and even got onto national

<=>Public opinion

television. "NOAA's phones have been ringing all over the country," one agency scientist recorded.(66) The controversy, piled on top of Congressional hearings and the efforts of outspoken scientists, alerted a sizable fraction of citizens and politicians to the prediction that stood at the center of both reports. It was official — global warming might be coming. Climate scientists found themselves in demand to give tutorials to journalists, government agency officials, and even groups of senators, who would sit obediently for hours of lecturing on greenhouse gases and computer models.

= Milestone

For the time being the issue was resolved: yes, global warming could be a threat, and the practical response for the moment was to study it. Weary of the issue and distracted by more urgent matters, the media and public turned their main attention elsewhere. But while the issue was no longer at a boil it continued to simmer. Through the 1980s, Gore and others in Congress repeatedly called upon Revelle and like-minded colleagues to testify about global warming. The hearings won modest coverage on inside pages of leading newspapers and occasionally a minute or two on television. As one government scientist remarked, many in Congress had "for the most part accepted the potential Doomsday scenarios..."(67) An example of the tone was Broecker's 1987 testimony to the U.S. Senate's Subcommittee on Environmental Protection, reporting that his studies revealed the possibility of "very sharp jumps" of climate within the near future. "I come here as sort of the prophet," he said. "There are going to be harsh changes." Like a good prophet, Broecker remonstrated with the Senators. Money had been wasted in the bureaucracy, he complained, rather than given to scientists for research. "We botched it — partly it is your fault — because you want answers to questions on a very short time scale."(68)

<=Public opinion

<=The oceans

The Reagan administration meanwhile backed off from its dogmatic stand, as it did on many issues after its first couple of years in office. The most opinionated anti-environmentalists had departed, and the DOE, EPA, and other agencies, responding to requests from Congress, began working to predict the likely social and economic

impacts of global warming.(69) A broadly multidisciplinary approach was taking shape, in which climate scientists began to interact with experts in many other fields. Most of their studies found that global warming could have severe consequences for agriculture, the economy, and so forth. They all became increasingly involved in discussing the issue with policy-makers.

<=Simple models

The concern did not translate into increased funding for scientific research. Repeated Congressional attempts to restrain Federal spending kept NSF's total budget, among other research budgets, no higher in 1985 than in 1965. Leaders of the Reagan administration particularly distrusted any activity, even research, that they connected with a threat of government restrictions on business. The Federal government spent less money for the environmental sciences during the 1980s than during the 1970s. As for global warming, by one discouraged estimate the U.S. government spent less than $50 million per year for research directly focused on the topic — a trivial sum compared with many other research programs.(70)

=>International

Organization of the work remained scattered. Up through the mid 1980s, the Academy had taken the lead in providing some general guidance on priorities, but with the increased prominence of the issue, both Congress and various executive departments insisted on playing a role. The National Climate Program Office, with little funds of its own to spend, held little sway. That left the job mainly in the hands of individual agencies, which, as an official complained, "pursued individual tracks, vying for primacy." In 1989, Rep. George Brown of California — long a mainstay of Congressional support for science in general and climate research in particular — called the climate change research program "a bureaucratic nightmare," a "failure" in addressing its vital goals.(71)

Yet the agencies had enough money and enough organization to push atmospheric research ahead, with results that aroused the public. The discovery of a "hole" in the atmosphere's protective ozone layer, although it was only indirectly connected with greenhouse warming, showed how industrial emissions could

<=Public opinion

swiftly damage the planet's atmosphere. The 1977 law banning "spray can" chemicals was plainly insufficient. By 1987, scientific and public concern had grown so strong that the U.S. and other governments signed an international treaty, the Montreal Protocol, further restricting the production of chemicals that destroyed the ozone. Some hoped that governments would follow the example in addressing greenhouse gases. In December 1987, Gore (now a Senator) introduced the ozone problem into presidential politics during a television debate with other Democratic candidates.(72) Sensitized to atmospheric risks, the public turned its attention back to global warming in the summer of 1988. It was a time of record heat waves, and drought so severe that barges could barely navigate the Mississippi River. The media reported testimony to Congress by NASA scientist James Hansen, and other warnings, far more widely than earlier statements. The public began to feel that climate change was a serious issue, something their government should no longer ignore.

<=International

<=Public opinion

The U.S. Congress, where few bills on the subject had been introduced since 1978, returned to the issue. Several bills related to climate were introduced in 1987, four of which specifically mentioned "global warming." By early 1988, even before the hot summer, practical steps were under serious study, such as a "carbon tax" levied on emissions of CO_2. President Reagan had signed a "Global Climate Protection Act" that required the administration to prepare a plan to stabilize the level of greenhouse gases.(73) New climate bills reached an unprecedented peak later in 1988, and they continued to be introduced fairly frequently for the next few years. Along with the bills a large number of hearings and other congressional actions addressed climate change, peaking in 1989. (74)

Most problems that a government addresses are thrust upon it by pressures of the day — foreign aggression, unemployment, and so forth. Global warming was harder to notice. It was only an issue because scientists predicted a future problem, and the scientists themselves shaded their predictions with qualifications and

uncertainties. To get advice on what should be done, through the 1970s and 1980s the federal government had drawn on panels of experts, mostly convened by the National Academy of Sciences. These had recommended no big policy changes, but only the usual call to spend More Money on Research, and even that advice had not always been followed.

Around 1988, however, many people both in the scientific community and among the public began to feel that governments ought to do something to retard the emission of greenhouse gases. By the nature of the atmosphere, such steps needed international scope. The scientific advice likewise should be international. Foreign scientists would not only engage their own nations in the process, but would offer the most prestigious and convincing consensus.

In the negotiations that crafted the Montreal Protocol to restrict ozone-destroying gases, the U.S. Department of State, working in alliance with the EPA, had become committed to international environmental cooperation. Officials hoped to repeat the success with greenhouse gases. Here as with ozone, the key would be to get an international consensus on the science. For global warming, however, that could take a long time. The administration's greenhouse skeptics, loathing the idea of another Montreal-style agreement with mandatory targets, welcomed any delay which would stave off demands for concrete action. Greenhouse worriers, on their side, expected that thorough studies and discussions would eventually result in scientific recommendations that would exert irresistible political pressure. Thus both sides agreed on a lengthy process.

What kind of process? The administration's skeptics entirely distrusted the independent, international committees of scientists that had been driving the issue. If the process continued in the same fashion, the skeptics warned, future prestigious groups might make radical environmentalist pronouncements. Greenhouse worriers were ready to agree to government supervision of the process, recognizing that nothing practical could be done unless officials and

bureaucrats were drawn into the work. The U.S. government therefore recommended to international agencies the creation of some kind of new "intergovernmental mechanism." Other governments fell in line, and an Intergovernmental Panel on Climate Change was established in 1988.(75)

=>International

After 1988

=>after88

The Intergovernmental Panel on Climate Change (IPCC) joined the National Academy as official climate adviser to the United States government. Representing virtually all the world's governments and their climate experts, the IPCC issued a series of reports that called with increasing conviction for action. Meanwhile other groups, ranging from government agencies to environmentalist organizations, devised lists of practical steps to retard global warming. In the first place, governments could set targets for reducing greenhouse gases. To meet the targets they could increase taxes on fossil fuels, impose efficiency standards, and so forth. There was no lack of advice on what should be done.

President George H.W. Bush was more receptive to environmental concerns than his predecessor. In a passing remark during the 1988 presidential campaign, he had pledged to take real action on the greenhouse effect.(76) Support came from the usual sources — the Department of State (under increasing pressure from European governments concerned about global warming), DOE, NOAA, and EPA. But many others in the administration, as in the Reagan administration, only wished the issue would somehow disappear. In particular, the powerful White House Chief of Staff, John H. Sununu, vigorously opposed any measure that environmentalists proposed. By the end of Bush's first year in office, when he spoke of global warming (or "global climate change" as he now called it), he concentrated on the scientific doubts and economic risks that argued against any action. A White House memorandum, inadvertently released, proposed that the best way to deal with concern about global warming would be "to raise the many uncertainties."(77)

Uncertainty was easy to raise, with an energetic minority of reputable scientists steadfastly denying all evidence and arguments for global warming. These scientists' skepticism was widely circulated in publications sponsored by conservative groups and by industrial interests that opposed regulation. In the forefront was the Global Climate Coalition, generously funded by dozens of major corporations. Advertising to the public and sending persuasive materials to journalists was the most visible part of the group's work, but perhaps not the most important part. With professionally crafted presentations, plus extensive face-to-face lobbying in Washington and at international meetings, the Coalition did much to persuade officials and members of Congress who were ignorant of science that there was no sound reason to worry about climate change.

<=Public opinion

In 1990, the IPCC, issuing its first report, based on an international scientific consensus, flatly contradicted the skeptical scientists' arguments. Nevertheless the minority viewpoint continued to find favor with top administration officials. Their stubborn rejection of the IPCC report became an embarrassment in 1992. World leaders were preparing their grandest meeting ever, an "Earth Summit" in Rio de Janeiro (officially, the United Nations Conference on Environment and Development). "Unless the Bush Administration quickly adopts a more reasonable course," the *New York Times* editorialized (Feb. 18, 1992), "it will cast the U.S. as an environmental pariah more concerned with its own comfort than with the well-being of the Earth." Sununu's departure from the administration permitted a less rigid position. The Rio meeting adopted targets which included rolling back U.S. emissions to the 1990 level by the year 2000. The Bush administration responded by adopting several inexpensive, "no regrets" policies to promote energy efficiency. These were far too modest to meet the targets, and in fact emissions continued to climb. The U.S. government remained more resistant to serious action against greenhouse warming than almost any other major industrial power.

<=International

=>International

One thing that did move forward was studies, extending into

complex economic and engineering issues. A 1991 Academy report listed no less than 58 policies proposed for mitigating greenhouse warming. Some were "no-regrets" policies, so practical that they would be beneficial to the economy whether or not there was a global warming problem. Governments might, for example, promote improvements in the efficiency of commercial lighting, home heating, and trucks. Or they could reduce the costly subsidies that encouraged wasteful use of fossil fuels. Some policies would carry a modest cost that would be compensated by valuable social benefits. Why not devise ways to reduce car commuting time, for example, and reforest overgrazed wastelands? Some ideas were too expensive at present, but might become practical if technology was driven forward by the regulation or taxation of greenhouse gas emissions, or by plain desperation. It might someday make sense, for example, to extract CO_2 as a power plant burned fuel, and sequester the gas in the depths of the oceans or underground. And some proposals were visionary. Couldn't we replace fossil fuels by growing crops that stored energy from sunlight, or launch flotillas of mirrors into orbit to reflect sunlight away from the Earth?(78)

<=>Rain-making

After Bill Clinton took office as President in 1993, his new Vice President, Gore, and others persuaded him to endorse a U.S. "Climate Change Action Plan." This formally committed the nation to the Rio target for reducing greenhouse gases. More conservative forces still dominated Congress, however. Many powerful conservatives not only scoffed at any research that pointed to environmental problems, but held deep suspicions about the United Nations and all its cooperative international programs. Some turned away from science itself — preferring folk cures to research-based medicine, or denying the evidence for biological evolution. Faced with these ardent opponents, Clinton was unwilling to spend his limited political capital on an issue that would not become acute during his term in office. His greenhouse policy came down to only a few inexpensive steps such as improvements in energy efficiency, which would never meet the Rio target. Congress likewise gave little attention to climate, and during the mid-1990s almost no bills relating to climate were introduced.(79)

In international negotiations that culminated in 1997 with a huge conference in Kyoto, the United States remained the most powerful holdout against mandatory greenhouse gas reductions. The American public was interested in the issue but confused, and pressure on the government came mainly from industries that depended on fossil fuels. Corporate publicists pointed with horror at the specter of a carbon tax. They claimed it would impose a dreadful rise in gasoline prices, which was supposed to be intolerable to Americans (or anyway those in the United States—Canadians, like the citizens of almost every other advanced nation, accepted large gasoline taxes as beneficial). In the polarized debates, scarcely anyone remarked that more subtle approaches to averting greenhouse warming were possible, methods that might be scientifically, economically, and politically more effective. The opponents also appealed to nationalism by warning that other countries would seize an economic advantage over the United States unless all reduced their emissions together. Even before the Kyoto delegates assembled, the U.S. Senate declared by a vote of 95-0 that it would not accept a treaty that failed to set limits for developing countries.

<=Public opinion

<=>Other gases

The Kyoto conference nevertheless ended with an agreement that included exemptions: the Kyoto Protocol, a compromise brokered by Gore in an eleventh-hour intervention that saved the meeting from ignominious collapse. Back in the U.S., the Global Climate Coalition mounted a multi-million-dollar advertising campaign, insisting yet again that greenhouse gas restrictions were needless and would bring economic disaster. The administration never submitted the treaty to the Senate for ratification. With little debate, Congress declined to make any policy changes that might help move toward meeting the Kyoto targets.(80)

=>International

With the American public mostly confused or indifferent, politicians gave little time to the matter among the many demands for their attention. Global warming did not look like a winning issue for either party. During the election campaign of 2000, the candidates mentioned it only briefly in passing. When George W.

<=Public opinion

Bush became President, some hoped that as a proven conservative he could get restrictions on CO_2 through Congress more easily than his opponent, Gore, could have done. A few members of Bush's cabinet, and many foreign leaders, pressed the new President to take steps against climate change. But a furious lobbying campaign by Bush's friends in the energy industries and other conservatives drove the administration to renounce any restriction. The United States government repudiated the Kyoto Protocol. As for domestic initiatives that might reduce greenhouse gases, the administration considered them only so far as they might serve as public window-dressing for programs whose main aim was to strengthen corporations in the fossil fuel or other industries.(81*)

=>International

During these decades, heightened concern about climate change brought only one solid result: a stronger Federal research effort. That came partly as a simple share of a general increase in funding for all scientific research (in particular, the NSF's budget doubled between 1985 and 2000). Equally important was the public anxiety and media outcry that had broken out in 1988, forcing politicians to take some kind of visible action. Although politicians were loath to regulate fuels, they could promise more research. In 1989, the interagency Committee on Earth Sciences formulated a Global Change Research Plan for the United States, and the consensus among scientists helped encourage further budget increases. In 1990, the first Bush administration and Congress created a “United States Global Change Research Program” (USGCRP) with an annual budget that exceeded $1 billion in 1991 and climbed to $1.8 billion by 1995.

As often in environmental budgeting, a good part of this was not new money, but a reshuffling of existing appropriations under new labels. More than half of the Global Change program's funds were committed to NASA's 1992 "Mission to Planet Earth." This was an ambitious program of observation satellites that had many purposes besides studying global change. Still, climate studies did profit from the gathering of data on everything from atmospheric ozone to to tropical deforestation. Funding for climate research meanwhile

increased significantly in NSF and (at a somewhat lower level) the DOE. Meanwhile NOAA's support for research at universities took a big step up.(82)

Climate scientists were not satisfied, for the budgets were not rising as fast as their suspicion that global warming would wreak serious damage. Some program managers continued to complain they were starved for funding. "Why is this so?" one scientist asked. "I suspect the answer lies mainly in the unwillingness of top officials to make firm commitments to a problem that requires sustained focus for many decades.... 'What? No immediate payoff?'"(83) A panel reviewing U.S. climate studies reported in 1998 that the work suffered from concentrating on costly satellites at the expense of other approaches. There were also persistent problems with management, especially (no surprise) a failure to coordinate efforts across agency borders. "If you say everything is connected to everything else, then it's hard to make progress," the panel's leader observed.(84)

That was exactly the difficulty in climate science that had long hindered everyone, from scientists doing research to politicians making laws. With research dispersed among a variety of independent-minded scientific disciplines and agencies, the data and ideas that some understood very well remained obscure to others. Important new topics of study fell between funding stools. And policy-makers stumbled amid a clamor of different voices. In 2001 yet another Academy panel declared yet again that the federal government needed much better coordination of research.(85) Somehow a hundred threads, all the varieties of scientific and societal thinking, had to be woven into practical policies. If nobody did that, and so if nothing was done in the end — well, inaction would itself be a policy, if maybe not the wisest.

See general comments on postwar US science funding in the Keeling essay.

[*Update:* In 2002-2004, the Bush administration developed a "Climate Change Research Initiative" managed under a "Climate Change Science Program." Scientists initially criticized the plans, but after a series of revisions they agreed the program would

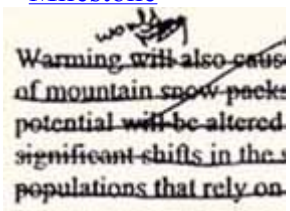
modestly improve coordination among the 13 semi-autonomous federal agencies involved in climate change research. The budgets for this research remained flat at best, in keeping with the administration's overall weakening of programs relating to the environment.(86)

[In August 2004, the administration sent Congress an analysis (developed at NCAR) explaining that greenhouse gases were the only likely explanation for the warming seen in recent decades. Unlike earlier reports, this came with endorsement letters signed by the Secretary of Energy, the Secretary of Commerce, and the President's science adviser. The administration thus at last officially agreed that humans were bringing on global warming. But it proposed no new practical actions to address the danger.

<=>Climatologists

[The Global Climate Coalition had already collapsed in 2000 as key corporations withdrew under pressure from public advocacy groups. Such a lobbying organization hardly seemed to be needed in any case, since the energy business felt its interests were well represented by the Bush Administration. Nevertheless a "Cooler Heads Coalition" (created in 1997) carried on, funded by corporations such as ExxonMobil and wealthy individuals. The new Coalition and other groups continued to lobby legislators, the press and the public.(87) For example, in February 2005 the Coalition held a "Congressional and media briefing on the Kyoto Protocol" with "light refreshments" in the Senate Dirksen Office Building. The aim was to decry the Protocol, which was about to go into effect after ratification by nearly every significant country in the world except the United States.

= Milestone



Official climate statement edited by industrial adviser.

[Climate change was scarcely mentioned by the presidential candidates during the 2004 election. During this period it stood in a political spotlight for only a few days in October 2003, when the Senate debated a bill sponsored by two sometime presidential hopefuls, maverick Republican John McCain and Democrat Joseph Lieberman. They hoped to create a weak carbon emissions trading system. The bid met opposition from the Bush administration, and was denounced by Senators who called global warming a hoax and

<=>Public opinion

exclaimed that restrictions would devastate the American economy. When the bill was defeated by a not overwhelming margin of 55-43, environmentalists were encouraged that opinion was moving in their favor, although slowly.

[Action proceeded more effectively at other levels of society. Eight states and New York City filed a lawsuit against five US power companies, citing damages for their contributions to climate change. The state of California proposed strong measures to restrict carbon emissions, and many other states and municipalities took various practical steps. Meanwhile the Conference Board, a nonprofit organization speaking for many major corporations, declared that efforts should be undertaken to mitigate and ultimately halt climate change; numerous corporations did in fact start programs. Efforts to restrict emissions were also taken up by nonprofit organizations, including federal agencies like the National Park Service, and many individuals.]

What can the United States government do about global warming, and what should it do? See my Personal Note and links.

RELATED:

Home
International Cooperation
The Public and Climate
General Circulation Models

Supplements:

Money for Keeling: Monitoring CO_2 Levels
Climate Modification Schemes

NOTES

1. For rise of weather services: Nebeker (1995), p. 87. BACK

2. United States (1953), pp. 4-7, 24, 36. BACK

3. National Academy of Sciences (1957), "housekeeping" p. 4, "inadequate" p. 14, "esprit" p. 15. BACK

4. Sapolsky (1990); Mukerji (1989), pp. 52 ff., see passim for government funding in general; Weir (2001). BACK

5. I thank Ron Doel for his draft, "Military constitution of the environmental sciences in America, 1945-1965," 1996. Also Doel (1997); Hamblin (2002), quote p. 26. BACK

6. Lambright and Changnon (1989). BACK

7. von Neumann (1955). BACK

8. On a secret Pentagon briefing by Ahlmann, see Doel (2002), p. 545. Probably there was classified climatological warfare work that has not come to light, and which contributed to the openly published developments. See Institute for Advanced Study, Proposal to establish Meteorology Project, May 8, 1946, published as Appendix A to Thompson (1983), p. 766; for further references, see Weart (1997). BACK

9. The Lockheed group split off soon after Plass joined it to found an independent Systems Research Corporation. Interview of Plass by Weart, 14 March 1996, AIP. BACK

10. National Academy of Sciences (1957), p. 8. BACK

11. Keeling (1960); see Weart (1997). BACK

12. Houghton (1996). BACK

13. van Keuren (2000). BACK

14. Hart and Victor (1993), p. 650; Fleagle (1992), p. 307; Fleagle (1994), p. 124. BACK

15. Commission on Marine Science (1969) (chaired by Julius Stratton), quotes pp. 197, 182. BACK

16. Wenk (1972), ch. 8. BACK

17. Fleagle (1994), pp. 114, 116 (data), 118. Landsat was reorganized in a 1992 Act of Congress. BACK

18. Fleagle (1994), pp. 128-131. BACK

19. Hart (1992), pp. 29-32. BACK

20. "Ignorant": Weyl (1968), p. 60; Hart and Victor (1993), p. 650. BACK

21. Hart (1992), pp. 17-22; Hart and Victor (1993). BACK

22. Teller was addressing the American Chemical Society in December 1957. Matthews (1959), p. 646; on promotion of nuclear reactors, see Weart (1988). BACK

23. The issue was brought up in hearings of the U.S. Congress's Joint Committee on Atomic Energy. See Clinton Anderson, interview by Ron Doel, August 1995, transcript, AIP. BACK

24. Phil Yeager and John Stark, "Mystery of the Warming World," *Washington Sunday Star*, 26 Jan. 1958, p. A26, copy seen in clippings file, Roger Revelle Papers, SIO. BACK

25. Other participants included Erik Eriksson and G.N. Plass. Conservation Foundation (1963); see also the Conservation Foundation's Annual Report for 1963 and Keeling (1998). BACK

26. The panel, chaired by statistics expert John W. Tukey, had a CO_2 sub-panel chaired by Revelle and including Broecker, Craig, Keeling, and Smagorinsky. President's Science Advisory Committee (1965), quote p. 9, see pp. 111-31. BACK

27. National Academy of Sciences (1966), "not a dump" vol. 1 p. 10. BACK

28. Budget: Kwa (2001), p. 140. BACK

29. President's Science Advisory Committee (1965), p. 26. BACK

30. National Academy of Sciences (1966), vol. 1, quote p. 20, budget p. 16. BACK

31. Hart (1992). BACK

32. Hecht and Tirpak (1995), p. 376. BACK

33. Federal Council for Science and Technology (1974); included as appendix in United States Congress (95:1) (1977). BACK

34. Edwards (2000), p. 245. BACK

35. Dotto and Schiff (1978), esp. pp. 67-89. BACK

36. Weinberg (1974). BACK

37. Domestic Council (1974); United States Congress (95:1) (1977), led by Rep. George Brown and featuring i.a. Bolin, Bryson and Schneider; United States Congress (94:2) (1976). BACK

38. I have not done enough research to sort out all the details of this complicated movement. Sources include Impact Team (1977), pp. 190-91; Hammond (1976); Domestic Council (1974); Hecht and Tirpak (1995), pp. 375-76, 378; quote: Laurmann (1976). BACK

39. Balco (1999). BACK

40. GARP (1975), quote p. 2, budget p. 99. BACK

41. National Academy of Sciences (1977). BACK

42. Philip White, head of ERDA's fossil fuel division, quoted Business Week (1977). BACK

43. Pomerance (1989), pp. 260-61. BACK

44. Kellogg and Schware (1981) is an example of policy discussions (1980 Aspen Institute workshops). BACK

45. Acting Asst. Secretary on the Environment James Liverman, cited by Science News (1977). BACK

46. Perry and O'Neill (1979), p. 1757 gives references. BACK

47. Fleagle (1994), p. 95. President's committee: the Domestic Council's Environmental Resources Committee, Subcommittee on Climate Change, 1975. BACK

48. Fleagle (1994), p. 126. BACK

49. Balco (1999). BACK

50. Broecker to Sen. Paul Tsongas, 7 April 1980, "CO_2 history" file, office files of Wallace Broecker, LDEO. BACK

51. Fleagle (1994), p. 120; Purdom and Menzel (1996), pp. 106-111; Johnson (1994). BACK

52. Vonder Haar et al. (1981); Raschke et al. (1973); Manabe and Wetherald (1975). I also used Jennifer Green (NASA History Office), "Nimbus Series," seen online at a site now gone. BACK

53. Satellite radiation budget measurement history is reviewed by House et al. (1986); for ERBE, see this NASA site. BACK

54. Fleagle (1994), p. 121. BACK

55. For this and other NSF programs: National Research Council (2000). BACK

56. Fleagle (1992), p. 72. BACK

57. Stevens (1999), p. 150. BACK

58. Elliott (1977-89), 6 Oct. 1981. BACK

59. "Eight years" would make this ca. 1966. Gore was a freshman at Harvard in 1965, where Revelle delivered freshman lectures starting that year. Gore (1992), pp. 4-6. BACK

60. Jensen (1990). BACK

61. NASA (1988). BACK

62. National Academy of Sciences (1979), quote p. viii (in the Foreword by Climate Research Board chair V.E. Suomi); in 1982 another Academy panel, chaired by Joseph Smagorinsky, reviewed computer studies and confirmed the first group's findings. National Research Council (1982). BACK

63. Hansen et al. (2000), p. 139; formally this Carbon Dioxide Assessment Committee, chaired by William Nierenberg, was under the Board of Atmospheric Sciences and Climate of the Commission on Physical Sciences, Mathematics, and Resources of the National Research Council. The study was commissioned by the President's Office of Science and Technology. National Academy of Sciences (1983), quotes pp. 3, 61. BACK

64. Seidel and Keyes (1983), quotes pp. ix, 7-7. BACK

65. Philip Shabecoff, "E.P.A. Report Says Earth Will Heat Up Beginning in 1990's," *New York Times*, Oct. 18, 1983, p. 1. BACK

66. "Alarmist:" presidential adviser Keyworth, quoted *New York Times*, Oct. 21, 1983, p. 1. Walter Sullivan, "How to Live in a Greenhouse" (editorial), ibid., 23 Oct. 1983, p. IV:18. Phones: Elliott (1977-89), 24 Oct. 1983 entry. BACK

67. E.g., *New York Times*, Dec. 11, 1985, p. 18. Quote: Elliott (1977-89), 13 June 1986 entry. BACK

68. U.S. Senate, Subcommittee on Environmental Protection, Hearings, Jan. 26-28 1987, pp. 21-23. BACK

69. Schneider (1989), pp. 130-32. BACK

70. D. Slade to E. Bierly and 8 others, 1/28/86, in "Trivelpiece" file, office files of Wallace Broecker, LDEO. BACK

71. Brown, address to EOGC conference, 18 Sept. 1989. Fleagle (1992), "vying" p. 69, see 70-74 for U.S. global change programs in general. BACK

72. Roan (1989), pp. 206, 208, 224. BACK

73. Pomerance (1989), pp. 264-65. BACK

74. Bills: Balco (1999); hearings: Jensen (1990). BACK

75. Agrawala (1998); Agrawala (1998); Hecht and Tirpak (1995), pp. 380-81. I thank John Perry for comments. BACK

76. Reported in an editorial in the *New York Times*, April 21, 1990, p. 22, but scarcely noted at the time, *New York Times*, Sept. 1, 1988, p. B9. BACK

77. *New York Times*, Feb. 3, 1990, p. 12, Feb. 5, p. 15, Feb. 6, p. 1, memorandum: April 19, p. B4. BACK

78. National Academy of Sciences (1991). BACK

79. On the Bush and Clinton policies, see Stevens (1999), pp. 290-95, 298; bills: Balco (1999). BACK

80. Christianson (1999), pp. 254-58, 263-68; for politics in the 1990s, see also Leggett (1999). BACK

81. Kyoto: *New York Times,* March 15, 2001, p. A23. An outstanding case of window-dressing was an administration initiative (Feb. 2003) to study hydrogen as a fuel. This could only reduce greenhouse gases in a distant future provided that nuclear or renewable sources were developed to generate the hydrogen. BACK

82. Fleagle (1994), pp. 119, 122, 125, 127. BACK

83. Mahlman (1998), p. 96. BACK

84. Berrien Moore, quoted Lawler (1998). BACK

85. National Academy of Sciences (2001). BACK

86. These developments can be followed in the *New York Times* and news articles in *Science* magazine. BACK

87. For the Bush administration and global warming see Gelbspan (2004), esp. ch. 3. BACK