Chapter 31. Testifying to Congress: 1982 & 1986

Testimony to Congress is the pinnacle for communication with the public and lawmakers on important matters and on actions that may be required to address those matters.

Washington in the 1980s was more than the nation's capital. It was the world's capital. Its architecture includes spacklings of ancient Egypt, Greece, Rome and medieval Europe. However, the power of the almighty dollar is what made Washington the one capital city that could set the world on a different energy course, if Washington had the will to do so.

Congressional hearings have trappings that create an essential aura. Lawmakers, like Supreme Court Justices, sit on a raised dais behind an impressive oaken podium. Trapped between this platform, usually curved outward, and the gallery behind, expert witnesses sit at a bare table, nervously. With a full gallery, television cameras, and congressional aides scurrying behind the Congress people, this is a setting that can catch public attention.

My first congressional testimony was to a joint hearing of two subcommittees of the Committee on Science and Technology of the U.S. House of Representatives. James Scheurer of New York and Albert Gore, Jr. of Tennessee chaired these subcommittees.

Their initial hearing, in 1981, featured Roger Revelle. As a professor at Harvard in the 1960s, Revelle had introduced undergraduate student Al Gore to the CO_2 greenhouse problem. His professorial presentation had spurred Gore's interest, but such an academic presentation would not ignite the public. The evening television news and the newspapers ignored the hearing.

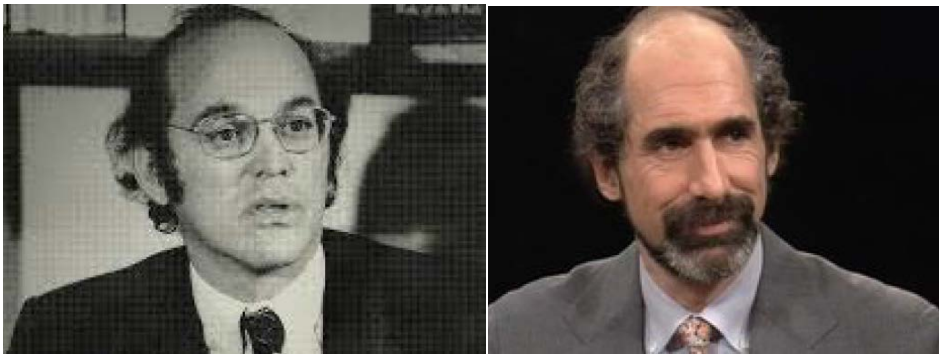
The second hearing, on a cold March day in 1982, fared little better. It featured Melvin Calvin, Nobel Prize winner in chemistry for work on photosynthesis. Much of the hearing was wasted on Calvin's notion that biofuels could replace fossil fuels. The implausibility of that idea – in fact, fossil fuels had saved the world from total deforestation, and energy demand had grown enormously since wood was last the main energy source – seemed to escape the lawmakers.

As the second witness, I showed relevant scientific results: our 1981 *Science* paper, still reasonably fresh, and two newer papers. The first of these, by Andy Lacis and co-authors, showed that the increase of non-CO_2 trace gases in 1970-80 added almost as much greenhouse effect as CO_2. This was observational proof of what Yuk Ling Yung had argued in 1975.

The second paper, by Vivian Gornitz and co-authors, used data from tide-gauge stations around global coastlines to show that sea level had risen about 10 centimeters (4 inches) already in the 20^{th} century, a much faster rate than in recent millennia.

The hearing's objective was to consider the research needed to understand the effect of CO_2 on climate, so I concluded my presentation with recommendations for the highest priority research tasks: 1) monitor solar irradiance, to see if its variations were a significant factor in climate change, 2) monitor non-CO_2 trace gases, which, unlike CO_2, were poorly measured, 3) extract a global cloud climatology from satellite images, as cloud changes were likely a major climate feedback, 4) measure ocean heat storage and transport, and 5) monitor ice sheet changes.

In other words, I tried to make my testimony strictly scientific, of the nature I would expect from scientists such as Don Hunten or James Van Allen. My belief, naïve as it may have been, was that such an approach actually provided the best chance of ultimately receiving financial support.



Rafe Pomerance and Michael Oppenheimer

Al Gore's objective for the hearing was to prevent DoE from decimating its CO_2 research funding. Thus Fred Koomanoff was a principal witness.

Koomanoff listed what was known about the CO_2 climate matter: that CO_2 was increasing rapidly and this was due mainly to human activities. And what was unknown: the timing, magnitude and regionality of climate change, the future use of fossil fuels, the level of CO_2 that is acceptable, possible mitigation strategies, the costs and benefits of higher CO_2 concentrations.

In other words, Koomanoff was a witness against himself. He admitted that CO_2 climate effects might be important, but he claimed that we lacked good understanding of those effects. So why was DoE slashing the research budget? In the end, Gore was able to claim credit for preventing DoE from phasing down their research budget. However, the lawmakers had no way to assure that DoE spent the money effectively.

I hoped there would be a question about our budget. There was not. Before leaving the building, I spoke with one of the congressional staffers who had arranged the hearing, telling him that DoE had zeroed out our funding. He suggested that we send our proposal to the Committee, which would forward it to DoE, allowing the Committee to assure that it was treated fairly.

I did not respond on the spot. I knew Koomanoff was determined not to fund us. He could easily find reviewers who would say that our model resolution was too coarse. I decided that we had a better chance of getting funding from EPA.

Rafe Pomerance came to my office to discuss our 1981 *Science* paper. The date of that meeting is uncertain. It does not appear on my personal calendar, which I began to keep in January 1982, a few months after becoming GISS Director.

Pomerance was a gangly six foot four, stooping as if to apologize for his height, loud-speaking but in a friendly way, it was easy to like him. It surprised me when, in discussing coaching youth, he implied that he was a good athlete – hard to imagine him playing soccer (football) – but he was earnest, so you had to believe what he said. An environmentalist, he was trying to educate himself on climate change. He was clearly not a scientist. I assumed that he was a lawyer, but he actually majored in history, which may be good for dealing with politicians.

That first meeting is described colorfully, with a bit of exaggeration, by Nathaniel Rich in *Losing Earth, The decade we almost stopped climate change. A tragedy in two acts*, which formed the entire issue of *New York Times Magazine* on 5 August 2018. It is true that my office contained 40-50 piles of papers, each with a piece of cardboard on top identifying the topic (methane,

volcanic aerosols, etc.), but most piles were only several inches tall. On the other hand, some piles including computer output did grow to at least a few feet!

I vehemently disagree with the thesis of *Losing Earth*. The political reaction to information on human-made climate change was remarkably swift following the congressional testimonies in 1986-1989. Almost all nations in the world united in Rio de Janiero to define the 1992 Framework Convention on Climate Change, an agreement that they would cooperate to avoid "dangerous human-made interference" with climate.

Dramatic missteps began after Rio. The villains were not we, the public at large, as *Losing Earth* asserts. The villains were a small number of identifiable people and groups. One of those responsible groups, I am sorry to say, was we scientists, who failed to provide the public with good, clear, technical information, but others were equally or more culpable.

Contrary to that article's title, moreover, Earth is not lost! It ***will*** be lost if we persist with present policies, but such persistence is neither necessary nor economically sensible. Delayed response of the climate system, the very characteristic that creates a slow-moving emergency, also allows time for an effective response that avoids most potential consequences.

To be sure, some climate change impacts are now unavoidable. Some have already occurred. However, these effects pale in comparison with consequences awaiting today's young people, if we allow today's powers-that-be to maintain their grip on the throat of our future world.

It is still possible to preserve most of the species that tread the ground of our marvelous planet. We can avoid making the subtropics and tropics so unpleasant that unstoppable migratory pressures make Earth ungovernable. We can even retain our shorelines and the history harbored in the world's great coastal cities.

It will not be easy. Crucially, we must begin to phase down fossil fuel emission, by moving steadily toward honest pricing of all energies including their costs to society, and by urgently supporting research, development and demonstration of advanced energy technologies.

In addition, we will need to draw down some excess CO_2 from the air via improved agricultural and forestry practices that store more carbon in the soil and biosphere. There are multiple ways to do this, including soil restoration that promotes more rapid weathering.

Keeping historic shorelines also may require action that falls under the category of 'geoengineering,' but that is not yet certain, and the action is one that most people would find to be acceptable. We will discuss all of these matters in due course. My point is that there is a basis for optimism, but that optimism is contingent on appropriate policy changes.

A gap of four plus years occurred between the March 1982 Gore/Scheuer hearing and a series of hearings in the United States Senate in 1986, 1987, 1988 and 1989 that I testified at. These four hearings had an ebb and flow, culminating in a crescendo, sweeping the world with remarkable speed to the 1992 Framework Convention, a potentially powerful covenant.

Before describing the turmoil of those four hearings, I must relate my perspective on the years leading up to them. Those years were divided in two distinct phases, the division occurring just weeks after the Gore/Scheuer hearing. That was when our friends, the Kims, persuaded us on the merits of moving from the city to Ridgewood, New Jersey.

In the decade prior to moving, we lived in a coop apartment just blocks from my office. Rich captures the nature of that decade in his description of a single event. I would give my left arm for Rich's writing ability, but, absent that barter, I provide my own prosaic description.

Cracks covered our apartment's ceiling. One area sagged ominously, water damaged by a leak in the apartment above. Although Anniek did all the other work on fixing up the apartment, the ceiling was my job. It required standing on a tall ladder – sanding the cracks, plastering, sanding again, painting – aiming for a perfectly smooth ceiling.

We forbade Erik to go near the sagging part. A good thing. It came thundering down one night, destroying the love seat beneath it. We used the insurance money to help pay Erik's tuition at the Cathedral School. Andy Lacis helped me put up sheet rock to cover the hole.

My point is the long time that I took, from spring until fall, to do the ceiling. I would work a couple of hours, then rush to the office. Only after Anniek burst into tears, finally showing anger about the dust that I kept leaving, did I finish the job, using Thanksgiving vacation for it.

Life was different in Ridgewood. I left for work by 6 AM to beat the traffic, but usually came home in time to play ball with Erik. I put up a basketball hoop in the driveway and would play against Erik and his friend Danny Burns. Somehow, in the end, they always won. I coached biddy basketball, little league baseball, and girl's softball after Kiki was old enough to play.

There was a housing development in the creek area behind our house. The trees they felled were magnificent oak and maple, extremely tall as they had reached for sun above surrounding trees. Wood was free for the taking; our neighbor stocked up for their woodstove. I bought a chain saw. Our neighbor avoided the trunks, three to four feet in diameter. But the trees were regal. they could not be left lying in the dirt. So I cut the trunks in 18 inch cylinders, rolled them to our car, a Dasher diesel hatchback, and hauled them to our garage, until it was full, enough wood to supply our fireplace for several years. I enjoyed chopping wood on winter evenings.

There was time to think in Ridgewood. Earth science was different than space science. Space science felt more like science, and friendlier, but maybe that was just because planetary science was a small field, you knew everybody. I did not regret the change to Earth science. Climate change was more important, but it was not as much fun. I looked forward more to coming home early, even before rush hour, while there were still hours of daylight.

What could our small research group do? It seemed that we were in competition with large modeling groups funded by NSF and NOAA. Goddard Space Flight Center was intent on building its own large group, and if we insisted on remaining in New York, we would be competing with that group too.

We should do something the public and lawmakers could understand, something they could relate to. Instead of doubled CO_2 experiments, why not run climate simulations in which CO_2 and other gases changed year-by-year as observed? Andy Lacis had developed accurate radiation calculations that allowed each gas amount to change as observed. If the climate model were realistic, it should produce global temperature change similar to observations.

The problem was the ocean. The ocean model must have a realistic heat capacity, or the time development of the greenhouse warming will be wrong. However, the ocean does more than

provide heat capacity: it transports energy, mainly from low to high latitudes. Without that dynamical transport of energy, the geographical distribution of climate will be unrealistic.

We did not have a dynamic ocean model yet. We were way behind Suki Manabe and Kirk Bryan, who had started at least 10 years before us. It would take years to build an ocean model. We did not have an oceanographer in our small group. We had to do something quickly.

Gary Russell made the suggestion. Then everyone said it was obvious. The basic idea was to assume that the horizontal transport of energy by the ocean would not change much during the next few decades. In other words, we would assume that dramatic changes such as a complete shutdown of North Atlantic Deep Water were not likely to occur in the 20th century.

We ran the climate model with observed sea surface temperatures to calculate the flux of energy into or out of the ocean surface at each gridbox and each month of the year. We used the observed depth and temperature of the wind-driven ocean mixed layer, which averages about 100 meters. I will not go into details or equations, but you can imagine that we could then compute the ocean heat transported into or out of each ocean gridbox during each month.

That gave us a model, including the specified ocean heat transports, that produced a realistic global distribution of temperature. So now we had a model in which we could change the climate forcings and see how the climate changed. This was exciting, but we had a problem.

Our slow computer was the problem. Computers in that era could run only one job at a time. It took the computer a while to 'set up' the global climate model (GCM) for a run, because the computer program was several tens of thousands of lines of code. So it made sense to let the GCM only take over the computer for large chunks of time overnight and on the weekend.

We needed a control run of the model with 1958 atmospheric condition, so that we could start the experiments when Keeling's measurements began. And we would need to run two or three experiments with different scenarios for greenhouse gas growth rates, to examine the impact of alternative energy scenarios on future climate change.

These calculations were going to take time – three years, as it turned out. In the meantime, there was a practical question that I wanted to examine.

Warming of a few degrees did not seem like much to the public. Even doubled CO_2 warming, not expected until well into the 21st century, is 'only' about 3°C global warming. Converted to Fahrenheit, it seems a little more impressive: 5.4°F. And as we already showed, warming over land is more than over ocean. So 3°C global warming yields 8-9°F warming over land. That begins to sound like something to the 'person-in-the-street.'

Still, critics argue, people move from Minneapolis to St. Louis, or even further, say to Dallas. Such a move is a climate change of 8-9°F or more. What is the big deal about such warming?

People do not notice average temperature, but they notice extremes. So I defined a problem for our Summer Institute on Planets and Climate: How would doubled CO_2 affect the number of summer days with temperature above 90°F? Above 100°F?

Our climate model, with Texas-sized gridboxes, just ten boxes for the U.S., could not calculate the temperature for a city, and besides the error for any gridbox was typically a few degrees.

Despite such systematic errors in climate models, we expected the calculated temperature *change* to be accurate, because we calculated the radiative forcing by gases very accurately.

So the task for the student was to take the daily temperature record for the past 30 years and count the number of days that the temperature exceeded, say, 100 degrees. Then add the calculated warming for each month for the gridbox in which the city was located, and again count the number of days in which the temperature limit is exceeded.

Washington, DC, and Omaha were the two cities that I specified, one being where lawmakers sometimes reside the other being near my hometown. We found that the number of days per year above 100°F in Omaha increased from three per year in 1951-1980 to 20 per year with doubled CO_2. In Washington the increase was from 0.7 per year (7 days in 10 years) to 12 days per year with temperature exceeding 100°F.

Anniek, having grown up in cool Holland, considers 90°F (32.2°C) to be a terrible heat wave. For both Washington and Omaha we found the number of days exceeding 90°F to increase from about 35 per year to 85 per year.

We found that the number of nights in which the temperature did not fall below 80°F (26.7°C) increased in Washington DC from four in 10 years to 19 nights per year. In Omaha the increase was from two nights in 10 years to nine nights per year.

These were numbers that might get a lawmaker's attention.

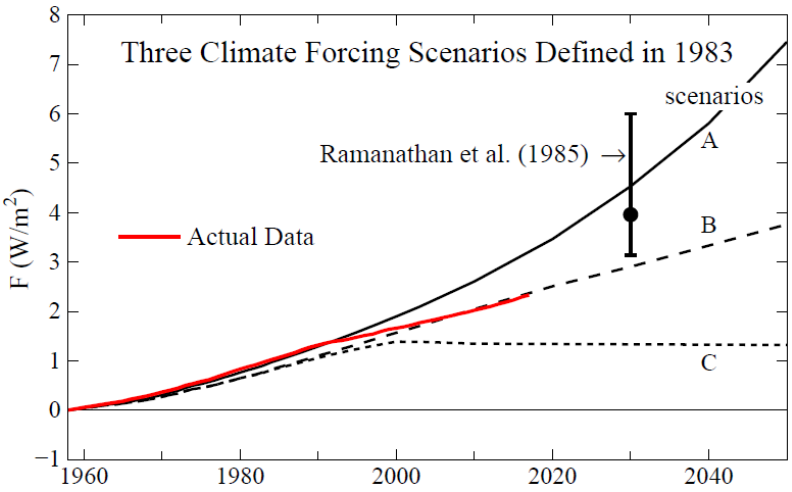
I drafted a short paper on these results after the 1983 Summer Institute. This was the period I was shepherding and editing papers for the Ewing volume, writing our paper for that book, and dealing with the two friendly elephants who supported us. The paper lay for two years in a pale green folder under the roller deck on my file cabinet by the window looking out on Broadway.

Rafe Pomerance and Michael Oppenheimer came to my office in July 1985. Pomerance had not been involved in the Gore/Scheuer hearing in 1982, which occurred at about the time of his prior visit to my office. But by 1985 Pomerance was fully engaged in climate change.

He and Oppenheimer made a powerful team, Pomerance well-connected in Washington and Oppenheimer a first-rate scientist. Oppenheimer, who was then chief scientist for Environmental Defense Fund, had played a lead role in finding a solution to the acid rain problem. Specifically, he advocated the cap-and-trade approach, which allowed utilities to collaborate in achieving least-cost reduction of national sulfur emissions.

They were working with Congress people and staffers, making plans for hearings and legislation. Based on a follow-up letter that Pomerance sent on 26 July and my 4 August response to him, I infer that we talked about 'unrealized warming' described in our paper on climate response time that was about to appear in *Science* and the GCM simulations underway. Also, I gave them a copy of the draft paper 'Effect of Doubled CO_2 on Severity of Summers in the United States.'

In my letter I warned them that I would not submit the 'Severe Summers' paper for publication for at least another year. My rationale was that the 1982 El Chichon volcanic eruption and the 1982 El Nino would both tend to make the middle 1980s relatively cool. So there would be a better chance of a hot summer in a year or two, and thus more impact of a paper about hot summers. That rationale would prove to be prescient.



Greenhouse gas climate forcing for three scenarios and for observed gas changes.

I was also hoping that they would not move too fast. I wanted to have results from our 'transient' climate simulations, the ones in which the greenhouse gases change year by year.

We had started simulations for Scenario A, which was the high forcing scenario, with continued exponentially increasing amounts of CO_2 and all trace gases including CFCs. Scenario A reached a forcing of 4 W/m^2, equivalent to doubled CO_2, by 2025.

We did not want to present results only for the most extreme high emissions scenario. We defined a greenhouse gas scenario B with approximately a linear growth of the forcing. This could be achieved, e.g., by phasing out CFCs and reducing the rate of growth of fossil fuel use to about half of the rapid growth that occurred in the first three decades after World War II. Scenario B reaches 4 W/m^2 forcing early in the second half of the 21st century.

Scenario C was extreme on the low side, with growth of the climate forcing stopping after year 2000. That would require CO_2 emissions to be reduced by about 50 percent in 2001, with emissions continuing to decline slowly after that.

By the summer of 1986 our climate model run with scenario A had reached 2020 and scenario B had reached 1985. It was a sufficient start to provide fodder for testimony to Congress.

Ozone Depletion, The Greenhouse Effect and Climate Change was the title of the hearing held in the United States Senate on 10-11 June 1986. Mixing the ozone and climate topics was the idea of Curtis Moore, a Republican staffer, who persuaded Pomerance that lumping the two problems had the best chance of stirring political interest in climate.

It was a deft move, even though it confused the two issues for the public. The ozone hole, springtime loss of ozone over Antarctica, had been discovered in 1985. If ozone loss spread to populated regions, it would deprive the public of protection from harmful ultraviolet radiation. The immediacy of the ozone threat offset the slow, futuristic pace of the global warming issue.

Also there was a legitimate connection of the ozone and climate problems: some gases, mainly the CFCs, were guilty of both destroying ozone and causing greenhouse warming. Recognition of this relation, and some adept policy maneuvers, eventually proved to be beneficial.

The hearing started with ozone, the witnesses being Robert Watson of NASA Headquarters, and Sherry Rowland, both effective presenters. Watson had been a laboratory chemist at the Jet Propulsion Laboratory before a sojourn to NASA Headquarters to run the upper atmospheric research program. With his stage presence and British accent, he commanded attention, in sharp contrast to most NASA scientists. Watson had found his calling. Headquarters would keep Watson as a rising science manager, a good career move for both Watson and the planet – in ensuing years Watson would ably lead global assessments of the ozone and climate problems.

The hearing was educational for me. As the third witness, the first on climate, I had stuff to show, global maps of warming for scenarios A and B. I said that by the 1990s the warming would be out of the noise level, exceeding natural variability. Doubled CO_2 would cause a big increase in extreme hot days. However, these were all model results.

Senator Chafee, the Chairman, asked a simple question "Do any of you believe that we need more scientific data before we could reach the conclusion that what is taking place now, if continued, will increase the temperature on the globe?"

The obvious answer was "no," but my answer and Sherry Rowland's were too long-winded. Bob Watson said "No. I believe global warming is inevitable. It is only a question of the magnitude and the timing."

The hearing was a big success, garnering the public attention that Pomerance and Oppenheimer were seeking. "Global warming is inevitable. It is only a question of the magnitude and the timing" was in all of the papers. I grumbled, "that statement does not say anything, if the magnitude is negligible, there is no effect," but I learned something.

The science is inherently complex, but the communication has to be simple. However, Einstein said that a theory or explanation should be as simple as possible, but not simpler. So, it is hard. How can we explain what is known in a way that the public and policymakers appreciate?

Communication was not my cup of tea. I was not good at it and did not enjoy it. Bob Watson was good at it and loved it, bantering with the Senators. His background was in chemistry, but it was clear that he wanted to get into the climate topic. He used the last portion of his testimony to describe his views on global warming.

When it was time for my testimony, I asked Bob if he would turn my charts, put them on the viewgraph machine for projection onto a screen. He snorted, seemingly peeved by the request. I did not think fast enough. I should have asked Sherry Rowland, who I am sure would have been happy to do it, and even interested.

Bob was not a good chart-turner, as he did not pay attention to my talk and whispered to other people. I interpreted this as intentional, a way of showing that what I was saying was not very significant, but I now suppose that it was an honest lack of interest in what I was saying.

This incident forced me to think about potential future testimony. Did I prefer to just do science and let NASA Headquarters take care of the testimony? I had no desire to testify. Watson's summary statements about climate were o.k. However, they did not actually say much.

My main consideration, however, was that I did not want somebody else to be speaking for me. Shenanigans the next year, when I submitted planned testimony for approval, were to prove my judgment, in this specific case, to be fitting and justified, at least in my opinion.

William Graham, Deputy Administrator of NASA, testified on the second day, June 11. Graham had been nominated by President Reagan to be his Science Adviser and Director of the White House Office of Science and Technology Policy. He would soon assume those roles.

I had returned to New York and only later read Graham's statement about planned NASA observations, including measurements from NASA's "proposed space station polar platform, the Earth observing system." Yikes! That sounded nuts!

I was unaware that NASA Earth Sciences was fighting, successfully, to extract itself from Space Sciences. Our honeymoon, reporting to Angel #2 was about to end. Soon my supervisor would accuse me of "fighting NASA" and I would be placed in a box as punishment.

Before I describe that intra-NASA turmoil, I must finish the testimonies of the 1980s. But as a balm, as a temporary respite from the battlefields, please allow me the pleasure of my final summer of content, on the field of dreams, the dusty ballfield in Ridgewood, New Jersey.

Fathers coach little league teams in Ridgewood. There was one great coach, Lew Dickinson. He knew baseball, having pitched in college. He loved kids, his job working with them at the Y. His wife was a school teacher. He always said the right thing to encourage kids. He did not favor his son on his team. In other words, he was impossible to emulate successfully.

When Erik was 11, I inherited the Renato's Pizza team from a retiring father. We got second place to Lew's team. Being ultra-competitive, I scouted the 10-year old league. One kid, bigger than the rest, struck out 15 in a five-inning game. I picked next to last in the draft the next spring, but nobody else had scouted and Gene Ret was still available. With Gene, Erik and Dave Huffman we had an outstanding pitching staff. We did not lose a single game in 1986, an unheard-of record. As champions of East Ridgewood, we played in the traditional game at the end of the school year, easily defeating the West Ridgewood champion.

Our players enjoyed their swagger as the 'green machine,' named for their green Renato shirts. Yes, I know, it might have been better to have a competitive league, but I am telling you the way it was, not the way it should have been. I warned you that Lew was the only good coach.

Ridgewood was just over the population limit to be allowed to field a single team for the little league world series. I was asked to coach the East Ridgewood team. Kids do not play baseball the way they used to – too many other activities. They really needed practice. I put up a batting cage in our backyard. I bought a six-foot-by-six-foot piece of chain-link fence, put weights on it, and dragged it behind my Dasher to smooth out the lumpy field at Hawes School.

It was difficult to get the kids together to practice as a team. I hit infield/outfield practice from home plate with Kiki's softball glove on my left hand and a bat in the right. After hitting the ball toward a fielder I caught the return throw in the glove, flipped the ball in the air, and hit it to another fielder. I could easily hit the ball over the fence with one hand. The other fathers somehow got the idea that I had been a semipro player. Ha, ha. I did not tell them that the last time I played, at age 15, I could not get the ball out of the infield.

We got a bye in the first round, so we drove to the town where West Ridgewood was playing. We would play the winner of that game. Both teams made several errors. West Ridgewood blew the game in the end, but we were confident that we could beat either team.

Danged Robert Burns again: schemes gang aft agley. Erik did not feel well on the way home. Next morning 105 degree fever. Anniek stayed with him. Other team had saved their ace, assuming they could beat West Ridgewood. Gene pitched well, but we lost. As losers, we had to play again the next day. Erik dragged himself out of bed, too weak to pitch, but played second base. Dave pitched well and Gene hit a home run, but we lost. Season over.

These years of leisure came to an end.

I wanted to prepare better testimony. Washington had impressed me, in a positive way. Senators, Republican and Democratic alike, were intelligent and interested, even if they had trouble with science. The two political parties seemed to work together in those days.

If we did a good job as scientists, we might help them move the world in the right direction. So it seemed that it was worth working really hard. I thought that I could prepare testimony that made the climate story clearer to decision-makers.

Another thing happening in the same town, Washington, was the beginning of NASA's Mission to Planet Earth. Mission definition was pretty much top down. That is not the way that I think it should have been, but the way it was. I speak from the perspective of a space scientist, a scientist whose views were shaped by space science leaders such as Don Hunten and James Van Allen. Others may see things differently.

These two stories played at the same time, with rapid action in both during 1987-1992. I will judge one as making great strides, the other not so much, but you can judge for yourself.

Chapter 32. 1987: What to Tell Decision-Makers?

The letter from Senator J. Bennett Johnston requesting testimony to the full Committee on Energy and Natural Resources specifically requested my "views on the likely pace and regional implications of the Greenhouse Effect and Global Climate Change, with specific reference to temperature changes in the nation's cities." That specificity made it obvious that the staffers for the Committee were being coached by Rafe Pomerance.

I did not want to just present my views. I wanted to provide information on the basis for those views. So I prepared written testimony consisting of 10 pages of text and 14 figures, which I would need to summarize in a brief oral testimony.

Understanding of climate change is based on (1) knowledge gleaned from paleoclimate, Earth's long-term climate history, (2) modern observations of climate change and climate processes, (3) climate models, numerical simulations of climate based on fundamental physics.

Paleoclimate and modern observations are the real world. So they are the primary sources of our knowledge. But models are an essential tool to help us understand and interpret climate change.

Senator Johnston's focus on the pace of climate change in the U.S. required use of our climate model. It was an opportunity for us to present the first time-varying climate simulations based on observed greenhouse gas changes. This was research carried out with colleagues Fung, Lacis, Lebedeff, Rind, Ruedy, Russell and Stone that we would document in a later publication.

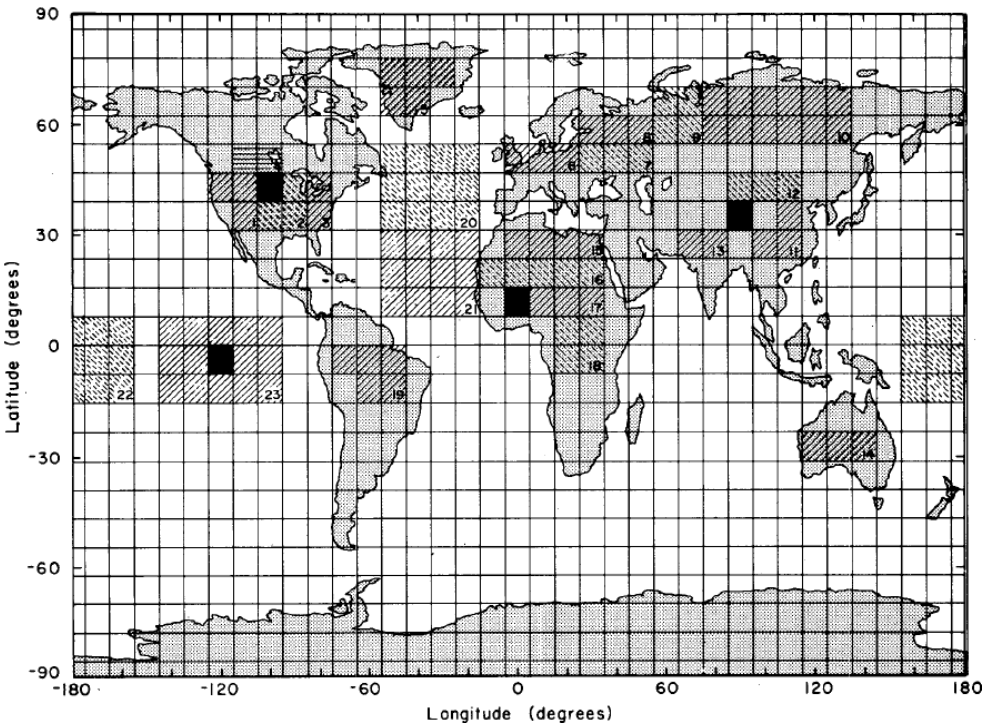
I summarized the essence of a climate model on a single page. The upper half was a global map, shown here, with our coarse grid. The lower half listed and described the fundamental equations of the climate system and sketched a 'cartoon' of key physical processes.

Our modeling philosophy and model differ a bit from most large modeling groups, so it is appropriate to note a few idiosyncrasies. The 8°×10° (latitude ×longitude) resolution allowed us to make long simulations, even with an old computer. The detailed map beneath the grid is not actually resolved. The map is used only to determine the fraction of land within each gridbox.

The rectangular world that we prefer for our maps makes Antarctica and Greenland appear larger than they really are, but we view that as a merit, not a problem. It is the optimum projection for locating a specific latitude and longitude. Also, instead of wasting white space on the page, as other projections do, our rectangular map provides higher resolution for the polar regions. I keep a world globe on a stand next to my desk. I believe that a globe plus quantitative rectangular maps make the best combination for research and thinking about global problems.

The shaded regions on the map are a particular choice of places where data is saved at a high frequency for study of physical processes, for example, for comparison with field studies.

My written testimony, available in the Congressional Record, drew conclusions based on paleoclimate data for peak warming in the current and prior interglacial periods, paleoclimate evidence for climate sensitivity, the warming (about 0.6°C) that had already occurred in the 20th century, and simulated warming with our climate model.



Grid spacing in 8°×10° climate model.

It was clear that major climate change will occur even under conservative projections for greenhouse gases that yield the equivalent of doubled CO_2 in the second half of the 21st century. Given warming 'in the pipeline' and the inertia in greenhouse gas growth rates, I concluded that *global* warming should emerge from the noise of natural variability within several years.

Global maps of *decadal mean* surface temperature revealed ubiquitous decade-by-decade warming for the realistic scenario B greenhouse gas growth rate. However, weather variability affects regional *monthly mean* temperature so much that a substantial fraction of the global area continues to have monthly mean temperature colder than the 1951-1980 average well into the 21st century. The location of colder than average conditions fluctuates from month to month.

Observations of global surface temperature change were displayed in several maps, based on a paper[1] in press that was attached to the testimony.

The 1980s (1980-1986) were shown to be warmer than the 1951-1980 climatology, with the largest warming in Asia and the Arctic. The year 1987 through October was shown to be on track to be the warmest year in the period of record, that is, since 1880.

I concluded, regarding observations, that the world was undergoing a strong warming trend. Also, global temperature in the 1980s was at the highest level in the history of (instrumental) recorded measurements. Temperature was well above the relative maximum at circa 1940.

Memphis, Dallas, Los Angeles, Denver, Chicago and New York were the cities I chose to illustrate the effect of doubled CO_2 warming on the number of summer days with extreme heat.

[1] Hansen, J. and S. Lebedeff, Global trends of measured surface air temperature, *J. Geophys. Res.*, **92**, 13345-13372, 1987.

The number of days per year with temperature exceeding 100°F (38°C) in Memphis increases from 4/year in 1951-1980 to 42/year with doubled CO_2, for example. The number of days that the temperature exceeds 90°F (32°C) increases from 65 to 145 per year and the number of nights in which the temperature does not fall below 80°F (27°C) increases from 2 to 51 per year.

I concluded that doubled CO_2 warming would dramatically alter climate perceived by the public.

As antidote to the shock accompanying these numbers for doubled CO_2, I showed results for a few cities for scenario C. For each city the increase in the number of extreme days was less than the interannual variability in observational data for that city. Thus the climate change associated with scenario C, implausible as the scenario may be, would hardly be noticeable to the public.

The delayed response of the climate system is a crucial characteristic for decision-makers to understand. The delayed response is a result of the ocean's great thermal inertia, the long time required for the massive ocean to come to equilibrium with a changed atmosphere.

This delayed response implies that there is additional warming 'in the pipeline' due to gases already in the air. I concluded that unrealized warming calls into question a policy of 'wait and see' regarding the issue of how to deal with increasing atmospheric CO_2 and other trace gases.

Finally, I mentioned the need for better more complete observations of the climate system and the forces that drive climate change. I pointed out the comprehensive discussion of needed observations [*Earth System Science: A Closer View*] prepared by the Earth Systems Sciences Committee, chaired by Francis Bretherton.

Friday, 6 November 1987, I received a call from Lynne Murphy of NASA Headquarters. My testimony scheduled for Monday three days hence was not approved. The White House Office of Management and Budget (OMB) wanted changes to many statements in the testimony, changes that diluted and distorted my conclusions.

I suggested some clarifications that I was willing to make. Interactions with whoever at OMB was requesting went via Lynne. OMB must have been busy, no response. I decided to go home.

That evening I got a call from Lynne Murphy. OMB insisted on essentially all of their changes. Stubbornness is one characteristic that I seemed to have inherited from my mother. I would be damned if I would make any of their changes. We had an impasse.

Out of the blue, Lynne, in effect, said 'of course you have the right to testify as a private citizen, if you cannot come to an agreement.' I doubt that employees in NASA's Office of Congressional Affairs are encouraged to make that suggestion. When I asked about Lynne the next year, I was told "she is not here any longer. I believe she went to work for an environmental organization."

Lynne got "approval" of OMB for me to testify as a private citizen, and the 50 copies of my testimony were shipped to my office. I went to my office on Sunday and replaced the front page on all 50 copies of the testimony.

I changed my address from NASA to 33 North Pleasant, Ridgewood, New Jersey. [We had just moved. Thanks to the work Anniek did improving the South Irving house, we could move to a larger house with more than an acre of land including a big red barn.]

As introduction I added "I am appearing today as an expert on global climate and global change, based on my experience of more than 10 years in terrestrial climate studies and more than 10 years in the exploration and study of other planetary atmospheres. Although I direct the NASA Goddard Institute for Space Studies, I am appearing on the basis of my scientific credentials; the views that I present are not meant to represent in any way agency or administration policy."

Before leaving my office I wrote a note to my supervisor, Jim Trainor: "Jim, This is the testimony I'm giving to the Senate Energy Committee Monday. OMB decided Friday evening that they would not approve it. They wanted changes in every section which diluted and distorted what I was saying, so I could not make the changes. Lynne Murphy got them to agree to let me testify as a private citizen and returned the copies to me over the weekend, but I was obviously unable to get the Committee advance copies as they requested. I don't understand the basis by which OMB can sensor scientific opinion." I copied the Goddard Director's office.

My anger about the attempted censorship was not matched by Senators on the Committee. Chairman Johnston must not have been present, because I scratched "Mr. Chairman" as the first words of my oral testimony and instead read: "Senator Wirth, Senator Murkowski, thank you for the opportunity to testify. Before I begin I would like to state that, although I direct the NASA Goddard Institute for Space Studies, I am appearing here on the basis of my scientific credentials; the views that I present are not meant to represent in any way agency or administration policy."

Tim Wirth of Colorado was a Democrat and Frank Murkowski of Alaska a Republican. I thought that the strange beginning to my testimony at least would elicit dialog, if not consternation. But not a peep.

Two issues cried out for discussion. First, why did the White House try to reduce, so thoroughly, the degree of confidence in human-made climate change and its importance to the public?

Second, on what basis is OMB allowed to alter the expressed opinion of scientists? I asked that question of NASA Congressional Affairs and was told that it was to assure that any testimony of government employees is "consistent with the Administration's budget request to Congress."

Say what?! So the science needs to be altered to fit the budget?! It made no sense, but nobody seemed interested in talking about it. Later I found that these shenanigans are practiced by both Democratic and Republican administrations.

We went into a separate smaller room after the hearing – it was Rafe, the congressional staffer he worked with to organize the hearing, and me. Rafe wanted to talk about next steps, another hearing, but I was grumpy. Hearings are a lot of work, there was so little interest, only two Senators attended, and media coverage was much less than for the ozone and climate hearing a year earlier.

One reason for lack of interest, I argued, was the cool season. I did not want to testify again unless it was in the warm season, when the public and lawmakers might pay more attention.

Senator Ted Wirth had the same thought. He scheduled the next hearing for 23 June 1988.

Chapter 33. 1988: Mother Earth Speaks

Gaea, the Goddess Mother Earth, conspired with us. That is how it seemed. Nature, science and politics all aligned at the summer solstice in 1988. It was a great opportunity to draw attention to the danger faced by our home planet, and the threat to all those who depend upon Mother Earth for sustenance.

Politicians focused on the Presidential election, the spectacle of early favorite Michael Dukakis crashing and burning from his own missteps in the face of negative campaign ads and President Reagan's eviscerating depiction of him as an invalid. Attention was diverted. Political censors fell happily asleep at the switch. My testimony passed through NASA and OMB untouched.

Our climate simulations were complete at last, using observed greenhouse gas amounts for the past and three scenarios for the future. Our paper describing the results, including examples of how extreme temperatures would increase in American cities, was submitted, refereed, and accepted for publication in the *Journal of Geophysical Research*.

Mother Earth was the star of the show, albeit as villain. Global temperature had risen to a record level. Mid-America seared in the heat, and the nation's discomfort was amplified by a drought of biblical proportions. The mighty Mississippi River dried up. Paddlewheels on giant riverboats ground to a halt. An enormous bubble of hot Midwestern air expanded to encompass the nation's capital, where the temperature surpassed 100°F.

I called Rafe Pomerance the day before the Senate hearing. "I hope we have good media coverage tomorrow. I'm going to make a pretty strong statement."

I put down the phone and started writing my 'oral' testimony, a brief summary that I would read to the Senate committee. 'Just in time' preparation allows more to get done. I thought it would be easy, because the three main conclusions of my testimony were simple and clear.

I wrote on a tablet of white lined paper, printing initially in large, dark square letters that were easy to read. The first conclusion was that Earth was warmer in 1988 than at any time in the history of instrumental data. I noted, referring to my first graph, that the four warmest years in the past century all occurred in the 1980s. Also the rate of warming in the last 25 years was the fastest in the record, and 1988 to date was so warm that it would probably break the prior record.

It was hard to work on the plane. When I got to my hotel in Washington, the evening before my testimony, I had finished one page. I commenced work on my second conclusion, namely that we could ascribe the global warming to the greenhouse effect with a high degree of confidence.

I should not have tried to get the Yankee game on the radio, while lying on the bed and writing. It was hard to catch announcer words among the static from the distant New York station. The Yankees had lost two in a row to the Detroit Tigers, both in the Tigers' last at bat. Now, having fallen out of first place, the Yankees needed this last game in the series to reverse their slide.

Global temperature is 'noisy,' fluctuating a lot from year to year. The atmosphere and ocean are dynamical fluids that, in effect, slosh about rather chaotically. The standard deviation, the typical amount that the temperature fluctuates annually about its 30-year climatology, is 0.13°C.

When we wrote our 1981 *Science* paper, with observational data up to 1980, global warming in the prior century was 0.4°C. In the 1980s global temperature increased another 0.2°C. The warming rate was accelerating.

Our new study, in press at the *Journal of Geophysical Research*, focused on the period since 1958 when accurate greenhouse gas data became available. Fossil fuel use in this period accelerated. Climate forcing by growing greenhouse gases was large. Expected warming for the observed increase of greenhouse gases, if climate sensitivity was 3°C for doubled atmospheric CO_2 as indicated by the Charney study and paleoclimate data, was almost 0.2°C per decade based on simple models. Our global three-dimensional model concurred.

Natural climate forcings were small. Solar irradiance measurements, initiated in the late 1970s, showed that solar climate forcing was small. The large Mt. Agung volcanic eruption in 1963 had a cooling effect for a few years, but after that climate forcing by volcanic aerosols was small.

By 1988 the observed warming in the prior two decades reached 0.4°C, three times larger than the standard deviation. Such warming could have been a chance statistical fluke, with a probability of about one percent. Thus I could say with 99 percent confidence that it was a real warming trend, not 'noise', i.e., not a chance statistical fluctuation.

Furthermore, I had 'insider' information: global warming at the observed rate was expected because of increasing greenhouse gases. Therefore, I could say, with a high degree of confidence, that there was a cause and effect relationship between increasing greenhouse gases and observed global warming, which was attributable to the greenhouse effect.

Other characteristics of the observed temperature change also carried a signature of the CO_2 greenhouse effect. For example the stratosphere, the atmosphere above a height of about 10 miles, was cooling, while the lower atmosphere and the surface were warming.

"In all of these cases," I wrote, "the signal is at best just beginning to emerge, and we need more data." And further: "There are certainly other climate change factors involved in addition to the greenhouse effect."

"Altogether the evidence that the earth is warming by an amount which is too large to be a chance fluctuation, and the similarity of the warming to that expected from the greenhouse effect represents a very strong case, in my opinion, that the greenhouse effect has been detected, and it is changing our climate now."

I was on the third page already, my writing was getting scrunched and light, and I was mixing long-hand with printing. The testimony was too long, maybe 10 minutes for a nominal 5-minute summary. The Senators probably will not cut me off, I thought, it is too important. But I still had to write the third conclusion. So I scratched some explanations on the second page.

The Yankees lost in extra innings. Again. Steinbrenner surely would go berserk. Why did I hang on these games? Was it not clear that both the Yankees and Don Mattingly were sinking fast?[2]

[2] Mattingly's career peaked at age 24 in 1985, when he had 35 home runs, 145 RBIs and the Yankees won 97 games; Mantle's career also peaked at age 24 in 1956 with 52 home runs and 130 RBIs. (Mantle's second peak in 1961 was from weakened pitching with league expansion). The Yankees finished 1988 in fifth place.

My eyes drooped and I could not think well. I decided to sleep. Better to get up early. I would not need breakfast. I had a raisin bagel with me – I always take raisin bagels on my trips – and I could get coffee at NASA Headquarters, where I had to attend a meeting in the morning.

The next morning I started a clean 4th page, for a fresh beginning on my 3rd conclusion: global warming was already large enough to affect the probability of extreme events such as an unusually hot summer. This should have been an easy explanation. If only I had stuck to what I had written in the *Journal of Geophysical Research* paper.

I started with that. The idea is simple. Take the 30-year period 1951-1980 to define the normal climate that people expected. At each location around the world we define the 10 coldest summers as 'cold summers.' The 10 hottest ones are in the category 'hot summers,' and the middle 10 are the 'average' or 'normal' climate. So during that 30-year period there was about a 33 percent chance that a given year would fall within the temperature range defined as 'hot.'

The point I wanted to make was that greenhouse warming caused by CO_2 and other trace gases was changing the odds. I wrote: "In the late 1980's the probability of a hot summer is somewhere in the range 40-60%," but I put this in parentheses. The testimony was getting very long, already four pages, so if the Chairman asked me to speed up, I would skip statements in parentheses.

I should have stopped there, but, foolishly, I started a fifth page. I would need to finish it at NASA Headquarters. I arrived a few minutes late, but the scientists, about 30 of them, were still milling about, finding seats at a long table or in chairs along the wall.

Ichtiaque Rasool, Chief Scientist in NASA Earth Sciences, announced that he had approval for a $2,000,000 per year research program for early detection of global climate change. I wanted to appear involved in the meeting before I tuned out to work on my testimony, so I piped up "Are you sure you are not missing a zero?" Two million dollars was chicken feed to NASA. Twenty million could cover observations and high-speed computers, as well as research and analysis. Likely the question was not appreciated, as it implied that he had not negotiated well.

Rasool continued with the meeting, and I resumed writing a description of global maps of temperature change computed by our climate model. But when Rasool emphatically stated that "no respectable scientist" would say that the human-made global warming signal had already been detected, my head jerked up from the tablet and I said "I don't know if he's respectable or not, but I know a scientist who is about to make that assertion." Several scientists turned to look at me, but Rasool did not take the bait.

At the coffee break I pulled David Rind aside to ask about atmospheric dynamics in our model. Was there a dynamical reason for the Midwest and Southeast U.S. often having extreme summer heat in our model runs? He noted that the ocean off the East Coast tended to warm less than the land, which could cause high pressure along the east coast and thus circulation of warm air north into the Midwest or southeast, but he included appropriate caveats about model shortcomings.

David's suggestion was fine, but I misused it. A comment on atmospheric dynamics was unnecessary, made my testimony longer, and exposed me to criticism from fellow scientists. I included caveats, but I should not have commented on dynamics. Our model did not yet include

ocean dynamics. Atmospheric dynamics in our eight-by-ten degree model was adequate for poleward heat transport, but not for reliable analysis of a specific regional climate feature.

The Senators did not seem to notice or understand my brief comment on dynamics, but it was to be a cause of irritation and outrage for certain fellow scientists.

At lunch break, I rushed out of the NASA building and hailed a cab. The ride to the Dirksen Senate Office Building was short – no time to rehearse the testimony. I already planned to just read it. But, because of squiggly inserts and scratch-outs, I would not be able to look up much.

However, I thought of a summary statement, which I tried to memorize. A one-liner might stick. Even the Preface, with three numbered conclusions, was too long for most media. On a separate page I wrote 'it is time to stop waffling so much and say that the evidence is pretty strong that the greenhouse effect is here and is affecting our climate now.'

I put this page behind the five numbered pages in my folder. The idea was to use it during the give-and-take discussion that I anticipated after all the witnesses gave their oral testimonies.

I found the hearing room with time to spare. A staffer pulled me aside to speak with Senator Wirth – who said that he had read my statement and wanted to make me the first witness. Of course, I agreed. People would be paying more attention at the beginning.

Hearings begin with each attending Congress-person given the opportunity to make an opening statement. At least half a dozen Senators were present, good attendance for an environmental hearing. They were aware that media would be present, which provided the chance for a sound bite that would get on television or in the newspapers.

J. Bennett Johnston, Louisiana, Chairman of the Committee on Energy and Natural Resources, went first and uttered a one-liner that got in the news: "We have only one planet. If we screw it up, we have no place else to go." He followed with some insightful commentary, presumably prepared by his staffers: "The greenhouse effect has ripened beyond theory now. We know it is fact. What we don't know is how quickly it will come upon us as an emergency fact, how quickly it will ripen from just simply a matter of deep concern to a matter of severe emergency."

Johnston then turned the chairmanship of the hearing over to Senator Timothy E. Wirth of Colorado, who stated: "The Energy Committee must move aggressively to examine how energy policy has contributed to the greenhouse effect and the kinds of changes in energy policy that may be needed to reverse the trend of increased emissions of carbon dioxide…"

Senator Dale Bumpers of Arkansas made an emphatic statement that proved prescient, indeed, it sounded like an instruction to all the media in attendance: "Dr. Hansen is going to testify today to what…ought to be cause for headlines in every newspaper in America tomorrow morning."

Hansen testifying on 23 June 1988

Doubtless I was tense, given this introduction and my last-minute preparations, but I was confident, both because I could read the testimony and because I knew that I could answer their questions. I wanted to be sure that my three conclusions were unambiguous, so I began:

> Mr. Chairman and committee member, thank you for the opportunity to present the results of my research on the greenhouse effect, which has been carried out with my colleagues at the NASA Goddard Institute for Space Studies.
>
> My principal conclusions are: (1) the earth is warmer now than at any time in the history of instrumental measurements, (2) the global warming is now sufficiently large that we can ascribe with a high degree of confidence a cause and effect relationship to the greenhouse effect, and (3) in our computer climate simulations the greenhouse effect is already large enough to begin to effect the probability of occurrence of extreme events such as summer heat waves.

Microphones were fixed on the table, making it impractical for me to place my charts on the projector and speak in the mic. So I asked Suki Manabe if he would put my charts on the projector. Suki was a decade my senior and a more accomplished scientist, but he readily agreed.

My oral testimony was probably 12-15 minutes. Senator Wirth then had the other scientists give their testimony before opening up for discussion. The other panel members were Michael Oppenheimer, George Woodwell, Suki Manabe, Dan Dudek and Bill Moomaw.

Discussion following the presentations raised several points. There was agreement that a specific drought or other meteorological event cannot be blamed on the greenhouse effect. However, the probability and severity of such events increases in a hotter world.

My assertion that we could say with 99 percent confidence that the world had entered a period of long term warming, and that we could associate that warming with an increasing greenhouse effect with a high degree of confidence, astonished some Senators. Senator Wirth said that he agreed with my 99 percent assertion, based on his reading of studies and meeting many people in this research field. However, he seemed to anticipate scientific backlash to my testimony, as he pointed out that programs such as energy conservation, alternative energy sources and reforestation should take place regardless of the degree of confidence in the climate assessment.

The Senators needed to rush to a vote on the Senate floor, but Senator Domenici took over as the presiding Senator, because he wanted to continue discussion about policy, chiding the other Senators, to laughter of the audience, that he could still "run there and get there."

Senator Domenici in the waning moments raised the issue of incrementalism, the question of whether an appropriate policy was incremental diminution of the problem via steps such as improved energy efficiency, at least in early policy stages. He seemed to get agreement on the incremental approach from those scientists who focused on policy.

Senator Domenici foreshadowed the great policy failure. Incrementalism, accompanied by strategic long-term vision and action, made sense. But incrementalism as an excuse to avoid bald-faced policy implications of the science, sentenced future generations to certain climate disasters. Yet once the reality of the climate threat was recognized globally the policy choice recommended by the United States, and accepted by the global community, was incrementalism.

The hearing adjourned at 4:15 p.m. As I was picking up my papers, I saw my note about waffling. Darn, forgot to use it in the discussion! But as we turned to leave the hearing room, several reporters were waiting for us. Phil Shabecoff of the New York Times asked me what global temperature rise was needed to confirm the human-made greenhouse effect as cause. This was my opportunity. I said that there was no "magic number" for that, but "it is time to stop waffling so much and say that the evidence is pretty strong that the greenhouse effect is here."

The next day, Friday morning, this quote -- along with our graph of global temperature from 1880 to 1988 -- was prominent in Shabecoff's lead-off, left-side front-page article, which the Times headlined 'Global Warming Has Begun, Expert Tells Senate'.

But the lead article on the front page of our New Jersey newspaper, The Record, was 'George Fires Billy – Again!' The Wednesday night extra-inning loss to The Tigers caused Steinbrenner to fire Billy Martin for the fifth and final time. Over on the right side ran an article titled "Pollution raised risk of drought," with subhead "NASA expert blames 'greenhouse effect'."

The Shabecoff article in the New York Times was an accurate portrayal of what I had said and of the message that I tried to deliver. In that, it was an exception. Most stories – including almost all of the brief television newscasts – reported that I had ascribed the drought to the greenhouse effect. Widespread misimpressions about my testimony were apparent by the day after my testimony. These were probably unavoidable, given the preoccupation of the nation with the massive ongoing heatwave and drought. I did very few interviews after the hearing, but when I was invited to go on a popular Sunday morning news program I jumped at the chance to clarify the message that I was trying to convey.

I already had made a set of large dice for that purpose. One die was for the climate of 1951-1980, the most recent three complete decades, which NOAA took to represent the climate that people expected to see. This 'normal' climate die had two white sides for near average temperatures, two blue sides for cool summers, and two red sides for summers notably hotter than average.

The other die, for end-of-century climate, had four red sides, one white side and one blue side. Climate change, global warming, is loading the climate dice enough that people should notice the change by the end of the century from the increased frequency of extreme hot events.

Hansen and Oppenheimer on This Week news program, Sunday 26 June 1988

That night, Sunday night, when we were in bed, Anniek told me that she thought she had breast cancer, and that she was waiting for laboratory confirmation. The doctor had given her that initial opinion two weeks before, but she did not tell me, so as to avoid upsetting me before the Senate testimony.

Climate stayed in the news and there was a continuing scientific fracas related to my testimony, but I withdrew from it. From a friend we learned of a doctor at Columbia Presbyterian Hospital, who was supposedly the best, or among the nation's best, in treating breast cancer, at least among those who specialized in surgery. We were fortunate to get an early appointment.

He provided the latest data on breast cancer survival rates and assured us that Anniek's odds were good because her cancer had been discovered early. My maternal grandmother had died from breast cancer when my mother was 13. Anniek's sister-in-law got breast cancer when her children were young, but she did not succumb to the disease until they were adults. We did not think Erik and Kiki would be subjected to such trauma, yet the first thought that enters your mind is how to reduce the chances of that to the absolute minimum. We believed, and Anniek decided on, and scheduled, a double mastectomy. The surgeon provided affirmation, saying that he and his wife had decided on that course, if his wife should ever develop breast cancer.

After we got home, we read articles about breast cancer and its treatments. George Schuyler, my sister Lois' brother-in-law, ran annual meetings of the Radiological Society of North America. George put us in contact with a New York University professor who was a leading expert in radiation treatment of breast cancer. He assured us that, in a case such as Anniek's, there was no discernable difference in survival rates in comparisons of mastectomies with minimal surgery to remove the cancerous lump followed by treatment with radiation and possibly chemotherapy.

We decided there was no need for Anniek to sacrifice her beauty. She had the small lump removed along with some lymph nodes that proved to be cancer-free. Anniek then underwent radiation and chemotherapy treatments; she has been cancer-free ever since.

Michael Oppenheimer and Steve Schneider told me that they were happy to do interviews, if I preferred to divert requests to them. I was glad to do that. I found it difficult to string together

sensible sentences, especially during television interviews. It did not make sense to mess with time-consuming interviews, when much better communicators were ready and willing.

However, I became concerned about perceptions of my testimony. The supposedly 'correct' answer to a question on Jeopardy, a television quiz program, was that I had testified that the drought was caused by the greenhouse effect. That was not the message I intended to deliver.

I began to write a book. Climate change was too complex for oral communication anyhow, even if I were a good speaker. In a book I could describe the many information sources, the delayed response of the climate system, the actions needed to change our energy systems.

Meanwhile, Wally Broecker called. He was at a meeting of the National Academy of Sciences. Jerry Namias, Wally said, was "on the warpath." He was extremely upset about my testimony, in particular the implication that the greenhouse effect had a role in the drought. When someone tried to defend my testimony, Namias shook his fist and said "I saw him say it on television!"

Jerry was referring to my comments about possible effects of modeled ocean temperature change on atmospheric dynamics. Namias was the nation's most respected weather forecaster, with a long resume of scientific accomplishments. I knew he was partly right: it was foolish of me to include comments about atmospheric dynamics in my testimony. I had no expertise in that area, and such speculations detracted from my main conclusions, which I was certain were rock solid.

Broecker was delivering a message that I needed to write down a clarification of what I was trying to say in my testimony. A hard admission of fault was necessary to satisfy Namias.

I refused. First, my position would not likely satisfy Namias, who insisted that the drought "has no connection whatever with the greenhouse effect."[3] I did not agree with that. Second, admission of any flaw was likely to get in the news, cast public doubt on my testimony in general, and likely destroy any good produced by the testimony.

The real problem with my testimony, I concluded, was that I did not give equal emphasis to both extremes of the hydrologic cycle: stronger heat waves, droughts and a longer fire season, on the one end, and heavier rain, more extreme floods, and stronger storms, on the other. Global warming pumps up both extremes.

At the times and places where it is dry, higher temperatures from an increased greenhouse effect make the heat and drought more extreme. However, a warmer atmosphere holds more water vapor. One consequence is that rain, when it comes, tends to come in more extreme events. As a result, so-called '100-year floods' will occur more often than once a century in a warmer world, and the largest floods will be more extreme. Also, storms driven by the latent energy in water vapor and/or a warm sea surface – including thunderstorms, tornadoes and tropical storms – have the potential to become stronger as the planet becomes warmer.

I wrestled with the book. Writing is hard. I did not even have a good vocabulary. Book writing would have to wait for decades. Fortuitously, I received a phone call from Rick Adcock, Senator Al Gore's assistant. Could I testify at a new hearing on global warming? This time, I thought, I will communicate better. This time I will be ready. Things will go smoothly. So I thought.

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[3] Namias, J., Cold waters and hot summers, *Nature*, **338**, 15-16, 1989.

Chapter 34. 1989: Bipartisan Cooperation, Of Sorts

Life was comfortable, out of the fray. Ridgewood is a wonderful town for families. Good schools. An outdoor swimming pool, where you can sit or lie on the grass under a tree. A pleasant duck pond a few blocks from our house, with a popular ice cream parlor across the street, and a broad path along the creek for walking, running or bicycles.

We had acquired a dog, a collie. I suppose that I was trying to recreate Pal, our loyal farm dog who loved to bring in the cows and protected the children with a determination and allegiance that few humans could match. We thought Kiki would prefer a smaller dog. So when we went to talk with a collie breeder we first made an oath that we were not getting a dog that day.

As we drove home, Kiki was in the back, the puppy's head in her lap the entire trip.

America's two-party political system still functioned in the 1980s, to a degree. Old-timers, once transfixed by the bipartisan Watergate hearings, expected as much. Youngsters today, acquainted only with echo-chamber monotony of political extremes, may be surprised. In the old days the 'other' party often produced the hero of the day.

So it was following the explosion of 'global warming' into the world of politics. It would turn out be, alas, the last time that our two-party system functioned well on climate change.

A letter from Ernest Hollings, Chairman of the Committee on Commerce, Science and Transportation tempted me to abandon temporarily my plan to escape the public fray. It was an invitation to testify to the Senate in April 1989 at a hearing conducted by Senator Al Gore, Chairman of the Subcommittee on Science, Technology and Space.

The hearing was postponed when Al Gore's six-year-old son, Al Gore III, was injured when hit by a car as he ran onto a busy street outside Memorial Stadium after a Baltimore Orioles baseball game. Al Gore spent a month in the hospital with his son as he recovered from near-fatal injuries. The hearing was rescheduled for Monday 8 May.

The invitation from Hollings requested me to testify on my "research on global climate models." Specifically, I was asked to "to discuss what processes are included in the models and what are not, and to summarize the conclusions that can be drawn from the models."

This was an open license. I saw it as an opportunity to correct a misimpression created by my 1988 testimony. The media coverage, during an extreme heat wave and drought, made people think that I was predicting more of such conditions.

For sure, increased global warming will worsen summer heat waves and droughts, but the other extreme of the hydrologic cycle may be more damaging. As the atmosphere becomes warmer, it is certain that the air will hold more water. This has important effects.

I based my new testimony on a paper that we were just finishing.[4] We concluded that dry places get drier and wet places wetter as global warming increases. Also, the warming is greater in the

[4] Hansen, J., D. Rind, A. Del Genio, A. Lacis, S. Lebedeff, M. Prather, R. Ruedy, and T. Karl, Regional greenhouse climate effects, in *Preparing for Climate Change*, Climate Institute, Washington, D.C. 1989.

dry places. Summers in the Southwest United States and the Mediterranean and Middle East regions, which are in the dry subtropics, will get much hotter and drier.

Most of the world is sometimes wet and sometimes dry. The timing and location of wet or dry conditions are variable and difficult for models to predict accurately. Therefore, for the sake of analyzing the physics of the climate changes, we sorted the climate model diagnostics at each location into the dry times and the wet times. The picture that emerged was intensification of both dry and wet conditions as global temperature increases.

Although these results were obtained with a specific model, the GISS climate model, we showed that results from other models, such as Manabe's at the Geophysical Fluid Dynamics Laboratory, were consistent with ours. Furthermore, the intensification of dry and wet extremes was a logical result of increased surface heating and evaporation in a warmer world.

Storms become stronger in a warmer world. Most storms were not resolved by any climate model in 1989, as the finest resolution was a few hundred kilometers, and surely not by our model with its grid spacing of about 1000 km. Nevertheless, we could extract diagnostic data to investigate how storm intensity would change with increased global temperature.

Specifically, we could calculate change of the 'fuel' for storms, something called moist static energy, which is the sum of sensible heat, latent heat and geopotential energy. We found a rational result: increased evaporation from Earth's surface with global warming leads to a large increase of moist static energy near the surface. In turn, this implies that a warmer climate is prone to more powerful vertical convection that reaches greater altitude. We showed that a similar conclusion follows for the completely different model of Manabe and Wetherald.

These changes lead to increases of deep moist convection, with associated heavy rainfall. In our model, doubled CO_2 caused the height of the convective cumulus storm cells to increase several hundred meters. Higher absolute humidity, thus greater latent heat, and deeper penetration of moist convection cause a larger portion of the rainfall to occur in intense thunderstorms, as opposed to the more gentle rainfall from large-scale stratiform clouds.

Increased storm strength with rising CO_2 is not limited to thunderstorms. Kerry Emanuel of MIT, a recognized world expert on tropical storms, used sea surface temperature changes from our doubled CO_2 experiment to estimate the effect of greenhouse warming on the maximum intensity of tropical cyclones. He found the minimum sustained surface pressure decreased from 880 millibars to 800 millibars. The corresponding maximum wind speed increased from 175 mph (miles per hour) to 220 mph.

The surface pressure and wind speed of individual hurricanes and typhoons depend on many factors, and seldom approach their maximum potential intensity. However, storm damage increases exponentially with wind speed, so it is the less frequent but most intense storms that cause the lion's share of storm damage.

The picture that emerged from the modeling was clear, but it was not pretty. Global warming increases the strength of storms, and it causes more extreme precipitation events and greater floods. Those effects alone would be important.

The picture becomes more alarming, however, when we consider the combination of rising sea level with stronger storms and more extreme precipitation. Most of the world's large cities are

on coastlines. The proportions of population and infrastructure in coastal regions continue to increase. Rising sea level and storm surges will combine with increased precipitation to cause enormous flood damage, even if buildings are designed to withstand high winds.

This qualitative picture is not dependent on model details and uncertainties. The expectation of increased precipitation extremes and stronger storms is a straightforward consequence of fundamental moist thermodynamics.

Similarly, the conclusion that global warming tends to cause most dry areas to get drier and hotter, while wet regions tend to get wetter, is a straightforward consequence of increased heating of the surface. All realistic models obtain these results.

On Friday 5 May 1989 I received a phone call from NASA Headquarters. OMB had requested changes to my prepared testimony, which I had submitted to Headquarters a few days earlier. The requested changes were being sent to me by fax.

Embers of anger began to smolder as I awaited delivery of the fax. I did not understand why OMB should even have the right to review my testimony. The first requested change was insertion of the following paragraph:

"Again, I must stress that the rate and magnitude of drought, storm and temperature change are very sensitive to many physical processes mentioned above, some of which are poorly represented in the GCMs. Thus, these changes should be viewed as estimates from evolving computer models and not as reliable predictions."

The embers began to burn hotter. In my opinion, I had already included appropriate caveats. As the first paragraph of my testimony I had written "This statement is based on studies carried out with my colleagues David Rind, Andy Lacis, Tony Del Genio, Reto Ruedy, Sergej Lebedeff, Michael Prather and Peter Stone at the NASA Goddard Institute for Space Studies. The opinions expressed represent our scientific conclusions, but they do not necessarily represent NASA policy or a consensus of the scientific community."

Further, I included additional caveats within the testimony. And most important, we had been careful to focus not on detailed model results but rather on basic physics of climate processes so we could say "…certain fundamental conclusions emerge which we believe are very unlikely to change as knowledge of the climate system becomes more precise."

OMB's second change was to add the sentence: "One point that remains scientifically unknown is the relative contribution of natural processes and human activities to these forcings."

The third and final OMB change was to replace my statement: "Although it will be more difficult to constrain CO_2 emissions than was the case for CFCs, there are many policy options which would reduce atmospheric CO_2 growth rates and make good economic and environmental sense, independent of concerns about an increasing greenhouse effect." The OMB replacement read: "Although it will be more difficult to constrain CO_2 emissions than was the case for CFCs, any policy options which should reduce atmospheric CO_2 growth rates should make good economic and environmental sense, independent of concerns about an increasing greenhouse effect."

Only this third change was directly relevant to the nation's budget. However, they seemed to be saying that the nation should not even consider actions to address the greenhouse effect, per se,

only actions that made sense independently of the greenhouse effect. They were trying to jam such a policy statement into my mouth.

There were at least two or three bureaucratic layers between the OMB censor and me. The person at NASA Headquarters delivering messages to me seemed to be low level, so I asked to speak to her supervisor. I explained that I could not accept the first insertion, because it vitiated my entire testimony, and I said that changes were needed in the other two insertions.

Late Friday afternoon OMB's decision arrived: the only change they were willing to make was to replace "these climate forcings" in their second insertion with "non-CFC climate forcings," because it could not be denied that CFCs were human-made.

I was furious, but I was already preparing for such eventuality. I told my secretary to say that I would make the one change that they had approved, and I asked her to obtain Senator Gore's fax number and make sure that his office was aware that I was sending him a message.

The message would not be on NASA letterhead or go through the chain of command, and there was no time to go through typing, proof reading, and corrections. It would not be finished until after business hours. I printed the message on a lined tablet, except the three OMB paragraphs, which I cut out of the testimony with scissors and taped into the message.

The three-page message included an outline of points I wanted to make in my oral summary. I was in the middle of a disagreement with NASA Earth Sciences, as I was pressing them to spend more money on developing brainpower and less on giant hardware in space. So the bottom line of the testimony was my recommendation for a more balanced allocation of resources.

In this note to Senator Gore I suggested that he query me during the hearing about the first OMB insertion. I wanted to make clear that the statement was OMB's opinion, not mine.

It was after 7 PM when I got home. Anniek greeted me, saying that Senator Gore had called.

"What did he say?"

"He wants you to call him. I only asked him about his son." Anniek said that his son was home in a full body cast. He had suffered multiple broken bones and a concussion. More than half of his spleen was removed, but he was expected to recover.

When I called, Gore expressed indignation about OMB's edits of my testimony. He wanted to make an issue of it, if I had no objection. Of course, I agreed – my aim, in addition to giving my own views on the science, was to draw attention to the practice of White House censorship.

Senator Gore asked if I was willing to do an interview with the New York Times over the weekend, warning me that I might get in trouble.

"It's o.k. I think I'm in trouble anyhow."

Gore responded "there's an old Chinese proverb that covers cases like this."

"Oh? What is that?"

"If they can't take a joke, f**k 'em."

I chuckled. He asked me to stop by his office Monday morning before the hearing.

After I hung up, Anniek asked why I had laughed. I told her what he said. She frowned. I guess she does not appreciate Chinese proverbs.

Senator Gore saw an opportunity for a brouhaha that might affect an ongoing battle in Washington. He was prescient. The battle was over the mind of President Bush, specifically his position on climate change. Was there a need for an international global climate agreement?

The guardian of Bush's mind was his chief of staff, John Sununu. Bush relied on Sununu's political acumen. It would be difficult to affect Bush's position without first persuading Sununu. Or, perhaps, boxing Sununu in.

Bush claimed to be an activist during the hot 1988 summer. "Those who think we are powerless to do anything about the greenhouse effect forget about the 'White House effect'; as President, I intend to do something about it," he said in Michigan in August. He promised to convene an international environmental conference. "We will talk about global warming, and we will act."

Not so fast. Bush was no scientist. Once elected, he needed technical advice. He found it at his right hand as soon as he chose John Sununu, ex-governor of New Hampshire, to be his chief -of-staff. Sununu had once been a scientist. He had a Ph.D. in mechanical engineering from MIT.

Sununu was also a politician, a very successful three-term Governor of New Hampshire. He was a pragmatic conservative, who turned a budget deficit into a surplus without raising taxes. His environmental record was strong. He increased spending on public-land preservation. He signed the nation's first acid-rain legislation, and he lobbied President Reagan for a national 50 percent reduction of sulfur emissions, consistent with the target advocated by the Audubon Society.

Sununu had both political and scientific perspectives on climate change. These are still relevant today, so let's examine them in simplified terms. First, the political perspective.

Core conservative values include minimal government and regulation. Conservatives believe that economic growth will help solve global environmental problems, including over-population. Their rationale is that family size will decline as living standards rise, even to the point that fertility rates fall to or below replenishment levels. Most conservatives agreed that other things are required to make this approach work, including (at least in those days) universal women's rights and a good amount of sensible regulations. Let's call this the 'growth' perspective.

The 'antigrowth' perspective is exemplified by *Limits to Growth*,[5] a study commissioned by the Club of Rome to explore consequences of finite world resources on human numbers and activities. *Limits to Growth* was widely panned because it gives short shrift to the potential for technology to solve problems of resource depletion, pollution and food production. Yet, it can be argued, much real-world data remains consistent with the business-as-usual scenarios in *Limits to Growth* that lead to economic and societal collapse in the latter part of the 21st century.

So the growth/antigrowth picture is still debated, with resolution uncertain -- at least to a degree.

Sununu's political perspective was clear. He saw an international global climate agreement as a threat to the conservative worldview. Such an agreement would be used by the antigrowth

[5] Meadows, D.H., D.L. Meadows, J. Randers and W.W. Behrens III, *The Limits to Growth*, Potomac Associates, 205 pp., 1972.

crowd to promote command and control, antigrowth policies, he feared. The U.S., with its very high per capita level of resource consumption, was certain to be a target.

Sununu's scientific perspective was skepticism, to put the best face on it. President Bush's science adviser, D. Allen Bromley, a nuclear physicist, was also a global warming skeptic. Skepticism is the soul of good science, if it induces the rigorous study of critical issues.

Sununu zeroed in on an important climate model shortcoming. His engineering background led him to doubt that models accounted well for heat transfer into the ocean. He wanted his own model. He would run it to show that the great heat capacity of the full ocean reduced global warming to a negligible level. Warren Washington, leader of the National Center for Atmospheric Research (NCAR) modeling group, rebuffed Sununu, telling him that a GCM would not fit on his Compaq 368 desktop computer (W. Washington, priv. comm., 2019).

Sununu would not be denied. He badgered Bromley to extract a model from NCAR. Eventually they provided Sununu a simple one-dimensional model. When he attached the full ocean heat capacity to the model, he could reduce warming at Earth's surface to a small amount, depending on how efficiently heat mixed into the deep ocean.

Ocean models used by climate scientists were primitive, but we knew something about ocean mixing. Ocean measurements revealed how deep CFCs and other human-made chemicals had penetrated into the ocean. In our GISS climate model we used mixing rates for heat anomalies inferred from these passive tracers. Heat is not a passive tracer, because ocean temperature change can alter mixing rates. However, warming the ocean surface reduces the density of the surface layer, which is likely to reduce ocean overturning and thus reduce penetration of heat anomalies into the ocean. So, if anything, our approach probably overstated ocean heat uptake.

Sununu was correct to point to ocean mixing as an issue, but this was no surprise to the climate research community. Indeed, a good ocean dynamics model was the Holy Grail. Years later, thanks to the ocean model developed by Gary Russell and others, we could explore the deepest mysteries of sudden climate changes during Earth's paleoclimate history, including effects on ocean circulation and global climate caused by increasing meltwater from Greenland and Antarctica. We could also use this global model to investigate options that humanity can consider with the objective of stabilizing global shorelines.

Sununu's main interest, however, was not science. He had become chiefly a politician. He aimed to thwart the antigrowth environmentalists. Science desecration was acceptable. He knew the answer that he wanted from his model and chose parameters accordingly. He used his knowledge of scientific terminology to sprinkle credibility on unscientific nonsense.

Sununu was aided and abetted by Bromley. To give Bromley his due, he was an effective Science Adviser. He pushed for increases in research funding to keep American manufacturing competitive and he supported expansion of the high-speed network that became the internet.

Bromley dutifully went along with Sununu's belief that global warming concerns were largely "poppycock," making no apparent attempt to alter Sununu's line. Bromley's responses to questions during congressional hearings illustrated his position well.

At one hearing Senator Gore asked, "Do you believe that the doubling of carbon dioxide in the atmosphere, which will occur in the next 40 years or so, is likely to result in global warming?"

Bromley replied, “It’s certainly possible, and probable to some degree, but that’s as far as I can say on the basis of the evidence.” Citing recent results[6] of British climate modeler John Mitchell, Bromley concluded “my answer is that I simply don’t know.”

Mitchell showed that the doubled CO_2 climate sensitivity of his model fell from 5.2°C to 1.9°C when he altered assumptions in his cloud calculations. Scientists like to publish results that stir things up, and such papers are useful if they point out critical, informative observations. Unfortunately, media often aggrandize such papers for the sake of ‘news.’ Albert Einstein was disgusted with such media reports that “give the lay public misleading ideas about the character of research. The reader gets the impression that every five minutes there is a revolution in science, somewhat like the *coup d’etat* in some of the smaller unstable republics.”[7]

Bromley’s job, as lead scientist for the nation, was to clarify such misimpressions. It was known that a climate model’s sensitivity can be altered almost arbitrarily by altering cloud calculations. Clouds largely determine Earth’s albedo. Uncertainties about cloud formation and other climate processes meant that models by themselves hardly constrain climate sensitivity. However, real world climate sensitivity is constrained, and shown to be high, by paleoclimate data.

Bromley should have tossed some water on the little fire started by the media. Instead, he threw gasoline on it. Bromley served Sununu well.

Sununu understood the big picture. The issue was whether the United States would spur and join an international framework convention on climate change. That would entail agreement that the world must avoid dangerous human-made climate change. Treaties must follow, but a framework convention was the umbrella, the essential first step toward effective climate policies.

Sununu was dead set against a framework convention. His main opponent in the Administration was EPA Administrator Bill Reilly. Secretary of State James Baker III also favored a framework convention. Ongoing international diplomatic meetings on climate were merely skirmishes, important mainly for their effect on the outcome of this larger war over a framework convention.

Sununu had the upper hand, as the trusted chief of staff for President Bush. Cartoons depicted Sununu as so huge as to blot out the Sun. In practice, Sununu controlled the U.S. position at the international meetings. He gave the orders. He discouraged the idea of following through on the Bush campaign promise to host an international environmental conference.

Reilly lobbied for the United States to get involved in climate treaty making, but Sununu was in charge. He ordered American delegates who would attend a climate meeting in Geneva in late May 1989 to make no commitment. That was the setting for Albert Gore’s Senate hearing.

I had to get up early in Ridgewood, New Jersey to catch the 6 AM Shuttle from LaGauardia on Monday morning. As I boarded the plane I failed to grab a free copy of the Times, because I was tired and still had to read and edit my oral testimony. So I was blissfully unaware of a headline on the front page: “Scientist Says Budget Office Altered His Testimony.”

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[6] Mitchell, J.F.B., C.A. Senior and W.J. Ingram, CO_2 and climate: a missing feedback? Nature 341, 132-134, 1989.
[160]Bernstein, J. *The New Yorker*, 5 November 1990, p. 154.

Hansen and Jerry Mahlman at 8 May 1989 Senate Hearing

Senator Gore showed me the article as I entered his office. I had expected it to appear the next day, after my testimony. Gore had an effective strategy though – there could be a second article the next day. Shabecoff's Monday article was substantial, laying out my assertions of censorship, some of the climate science, and the internal battle between Sununu, Bromley and Richard Darman, the head of OMB, on one hand, and Riley and Baker, on the other.

Gore wanted to start the hearing with the censorship issue, just as Wirth had rearranged the 1988 hearing. I preferred to do the hearing as scheduled, because I wanted to describe the science as I had prepared it. I did not trust my ability to extemporize. Gore consented, although it meant the heavy media presence, even greater than at the 1988 hearing, would have a long wait.

Senator Gore was considerate. He asked if I was all right. "You like this stuff, right?"

"No, but it's not a problem."

As we left his office, he said "Let's take separate stairs. If we go together they can get us both with one hand grenade." I assumed that he did not want the media to think we were conspiring.

The hearing itself was anti-climactic. The news was the censorship, not the science.

I did not succeed in focusing attention on the conclusion that increased global warming would lead to greater extremes at the wet end of the hydrologic cycle, more extreme rainfall events, extreme floods and more powerful storms, as well as more extreme heat waves and drought.

A photo that appeared in some newspapers had me holding up a tiny Christmas tree bulb, with Senator Gore squinting down as if to say 'what the devil are you trying to show?' This small bulb had a power output of 1.1 watts. I had brought one bulb in my suit pocket and one in my pants pocket, to be sure that I could find one when I wanted to show it.

My point was that the measured increase of greenhouse gases in the 30 years since Keeling began to measure CO_2 caused a climate forcing of 1.1 watts per square meter. This, to me, was a very large force. It is more than four times larger than the variation between solar minimum and solar maximum of the energy Earth absorbs from the Sun. Also, it is more than a quarter of the climate forcing that would occur with doubled atmospheric CO_2.

Later I was told that the demonstration probably has the opposite effect. The lay person thinks "the human effect amounts to a tiny light bulb? All the fuss is about that?"

Impromptu news conference outside Senate hearing room

A reporter crawled along the floor and handed me a note, while Jerry Mahlman, Director of the Geophysical Fluid Dynamics Laboratory at Princeton, gave his testimony. The note said that there would be a press conference with Senator Gore after the hearing – could I come?

"No, I need to catch a plane," I wrote on the note. Erik, a sophomore at Ridgewood High School, would be the starting pitcher in a JV game that afternoon. I had just enough time to get there. However, they set up the microphones just outside the hearing room door – it was unavoidable.

If I had been smart and media-savvy I would have prepared a couple of lines while Jerry was talking. I could have noted that global warming was pumping up both ends of the hydrologic cycle. I missed a chance for public education on the topic of my testimony.

The important point, however, was that the climate policy issue got elevated above Sununu. President Bush could not miss the story and its implications for him. Senator Gore made certain of that by ridiculing President Bush's prior claim to be the environmental President.

It was the lead story on the evening news. I did not see it, but I was told that I appeared in cameo and Gore castigated Bush. A spokesman for the Administration said that I was entitled to my opinion, and there would be no retaliation against me. Ha, ha. More on that topic later.

I escaped the news conference, making it home just in time for Erik's game. My car needed an oil change, so I took an oil filter, cans of oil, and a pan to catch the old oil from our barn and parked the car beside the ball field. I watched the game when Erik was pitching, and got under the car when Ridgewood was batting. Changing the oil was pleasurable. Everything was good. I was finished with politics. It was a beautiful day. Erik pitched really well, as a sign of things to come. The next two years he was the number one pitcher on the varsity team, with his trademark being that he pitched a complete game in almost every game that he started.

When I got home, Anniek gave me a message to call my supervisor, Jim Trainor, the successor to Frank Martin as director of the Goddard Space and Earth Sciences division. Trainor warned me that Gore was talking about having more hearings over the next week or two, bringing in the OMB censor, with me and other scientists to confront him.

Whoa, a terrible idea! Other scientists were unlikely to be supportive. Skepticism is the lifeblood of science, and skepticism of my testimony abounded. A workshop in Washington two

months after my 1988 testimony, in the opinion of one observer,[8] included a "get Jim Hansen" session. I was at that workshop and considered the discussion to be normal, healthy scientific skepticism. As I told Richard Kerr "When we're at this level of signal to noise, anyone can disagree with me. I don't argue with that."

The problem was how this scientific debate would be perceived by the public. I would make the case that paleoclimate data, plus climate modeling, plus modern data, plus basic physics together make a strong case for a human role in ongoing climate change. Others would disagree. It would seem to be an argument among experts. Therefore OMB and Sununu could claim that they were justified in turning my testimony into wishy-washy mush.

I could not provide this perspective immediately to Senator Gore. We barely had time to eat before Kiki's softball game. I was co-coach of her team. Coaching was easy. The games were more social activity than sport. I worked with Kiki on windmill pitching, but she was not very interested. She was well coordinated, though, and could throw the ball over the plate.

After the game I had to drive to Amherst, Massachusetts, where the ultimate, five-day 'get Hansen' meeting was already underway, focused squarely on my 1988 testimony. It was a 200-mile trip at night in the pre-GPS era, so it was after 2 AM when I sank into bed.

Probably intentionally, I was a few minutes late to the morning meeting. I always felt awkward in small talk over coffee. A copy of the Tuesday Science Times of the New York Times, with headline "White House Admits Censoring Testimony," lay glaring but silent on the table where I stirred my coffee. I could only wonder about the conversations that morning.

As usual, my talk was low key. I addressed the two substantive criticisms of my 1988 testimony that had emerged. First, a New York Times front-page story in January 1989 trumpeted "U.S. Data since 1895 Fail to Show Warming Trend" based on a paper[9] that found no discernable warming in the contiguous 48 United States. This result seemed to contradict my testimony. Had 'global' warming somehow failed to find its way to the United States?

The second issue was urban warming. Cities are warmed by our energy use and by human-made structures with large thermal inertia that do not cool off at night as much as the countryside. As a result, weather stations in urban areas record a spurious local warming not caused by the greenhouse effect. Was our global analysis spoiled by inclusion of some urban weather stations?

A persuasive way to deal with these issues, I decided, was to work with Tom Karl, NOAA's top expert on data records and data quality. Tom always began his presentations by describing the data problems, including urban warming, but also other effects such as station moves and change of the time of day at which the meteorological data are recorded. The care with which he addressed these issues gave him great credence with scientific colleagues.

Tom Karl and I compared several analyses of U.S. and global temperature change. Our study benefited from the fact that Karl had just completed the laborious construction of the Historical Climatology Network (HCN) data set for the United States. The HCN data were adjusted, station-by-station, as well as possible for all known biases.

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[8] Kerr, R.A., Hansen vs. the World on the Greenhouse Threat, *Science* **244**, 1041-1043, 1989.

[9] Hanson, K., G.A. Maul and T.R. Karl, Are atmospheric "greenhouse" effects apparent in the climatic record of the contiguous U.S. (1895-1987)? *Geophys. Res. Lett.*, **16**, 49-52, 1989.

In this joint study we concluded that there was in fact a warming trend in the U.S. for the period 1900-1987, but the rate of warming (0.26°C per century) was only half as large as the global warming rate. The contiguous 48 United States cover only 1.5 percent of the globe, so high temporal and regional variability could account for the smaller warming in the U.S. The warming rate for the 50 states, including Hawaii and Alaska, was 0.33°C per century.

These comparisons were the heart of my talk at Amherst. The paper describing this work was attached to my 1989 testimony and included in the Congressional Record.

Richard Kerr, the top writer for *Science Magazine*, attended the Amherst workshop. In an interview, I described the three conclusions in my 1988 testimony: the world is in a real warming trend (99 percent confidence), the warming is due to increasing greenhouse gases (high degree of confidence), and global warming will cause an increase of hydrologic extremes (more extreme heat waves, droughts, and fires as well as heavier rainfall and floods).

Kerr wrote a long news article for *Science*: "Hansen vs. the World on the Greenhouse Threat." Andy Lacis, laughing, showed it to me: "they have you angrily shouting in a microphone." No doubt the editors, not Kerr, picked a photo from hundreds taken during my testimony. In reality, I had schooled myself to be relaxed in 1989, unlike 1988, when I felt tense.

Kerr reported unanimous criticism of my testimony, but he made it easy to read between the lines. He quoted one scientist "if there were a secret ballot at this meeting on the question, most people would say the greenhouse warming is probably there." Another "What bothers a lot of us is that we have a scientist telling Congress things that we are reluctant to say ourselves."

The phenomenon of scientific reticence was emerging. A primary reason for reticence is that the penalty for 'crying wolf' is clear and immediate, administered via peer review of papers and funding proposals. In contrast, there is no penalty for 'fiddling while Rome burns.' On the contrary, extensive caveats and calls for more research generate praise.

Kerr also exposed a worship of climate models: "What really bothers them is not that they believe Hansen is demonstrably wrong, but that he fails to hedge his conclusions with the appropriate qualifiers that reflect the imprecise science of climate modeling," Kerr wrote.

However, my conclusion that the world was warming was based on observations, not on models. Relation to the greenhouse effect was based on knowledge of the climate forcing by greenhouse gases and its dominance over natural forcings. Our conclusion about increasing climate extremes was based primarily on fundamental physics, not on climate models.

The political hullabaloo in Washington was over in two days. I left the Amherst workshop after Tuesday's sessions and drove back to Ridgewood, still concerned that Senator Gore might want more hearings to hammer on White House censorship. But the situation was already resolved, dramatically changed, as revealed by the Wednesday morning New York Times.

"White House Says Bush Will Call Meeting About Global Warming" read a headline. This was significant. President Bush had decided to honor his campaign pledge. There would be an international meeting as a step toward a Framework Convention on Climate Change.

And ndeed, the Framework Convention – in which all nations agreed to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic

interference with the climate system" – was signed by President Bush at the 1992 Earth Summit in Rio de Janeiro. Thus, three years after scientists could not even agree that Earth was warming, the crucial first step toward climate stabilization was taken. It was a remarkable achievement.

In "Losing Earth" Nathaniel Rich recently suggested that the decision to reverse course and work toward a framework convention was the product of a dialogue between Sununu and Reilly. That is preposterous. The decision was made by President George H.W. Bush, you can be sure.

John Sununu was recognized not only as being a successful Governor and an astute politician, but also as a model chief-of-staff. He was not shy about making his opinion clear, but he did not make critical decisions for the President – if he had, it would not have been for a Framework Convention! Sununu remained a global warming skeptic throughout the Bush Presidency.

Senator John Heinz, Republican of Pennsylvania, provided a glimpse into the politics of climate change. Two weeks after Gore's Senate hearing I received a phone call at home from Senator Heinz. First, he told me that he defended me and my testimony in discussion with Sununu and in a two-page letter to Sununu with a point-by-point criticism of OMB's changes to my testimony. He would send me a copy of that letter, dated 17 May 1989, which I still have.

Then, he asked me to reconsider his invitation to give a talk at what he described as his "town hall meeting with his constituents." The invitation letter described it as the "Heinz Senate Seminar on 'The Environment: Challenges and Priorities' at the Port of History Museum in Philadelphia." I had declined initially because it seemed to be a set-up for a fruitless debate with a climate change denier, Andrew Solow.

Senator Heinz assured me that was not his intent. I agreed to attend his "town hall." Senator Heinz made it clear that he supported the environment and the economy, and did not see a conflict between these. Senator Heinz said his aim was a bipartisan approach to climate and energy policy. He said that he had spoken with President Bush and that Bush wanted the United States to take a leadership role. It may have been a last gasp for bipartisanship, but the President did act and he did the right thing.

Senator Heinz was impressive. He understood the need and merit of a bipartisan approach to climate change. I do not know exactly what happened behind the scenes, but I would bet that Senator Heinz influenced President Bush. I am not a Republican, but I would have voted for Heinz in a heartbeat. However, I believe it was Senator Gore's public pressure that forced President Bush to make a decision about the Framework Convention.

Tragically, less than two years later, Senator Heinz was killed in an airplane accident.[10]

Senator Heinz had been viewed as a potential Republican candidate for the Presidency. We can only dream about how history may have been altered if he had been elected in 2000.

The incredible theme of Nathaniel Rich's "Losing Earth" is that solution of the climate problem was at hand in 1989 but was blown away by the Republican Administration's subsequent failure to set a target for reduction of fossil fuel emissions. Never mind that 30 years

[10] Heinz was in a small plane that collided with a helicopter attempting to observe the plane's landing gear. Two pilots on each aircraft also died. Falling debris killed two children in a school-yard and injured several more. The National Transportation Safety Board cited "appallingly poor judgment" by the pilots, noting that their visual inspection was pointless as it was impossible to see into the plane's wheel well to see if the nose gear was locked.

later the planet is still alive as are most of its species. Never mind that preservation of our planet is still possible. Never mind that the actions required make economic and public health sense, independent of climate. Never mind that the other political party, the Democrats, had control of both the Senate and House of Representatives when Clinton and Gore were elected in 1992, and also when Obama and Biden were elected in 2008 – yet their climate policy accomplishments did not amount to a hill of beans.

Our politics has become so polarized that we cannot see our own faults, only the faults on the other side. Echo chamber media and social networking reinforce our beliefs. Instead of using true scientific objectivity, we select data that supports our preferred policies.

For the first time I am scared. Maybe we will not come to our senses soon enough. Conceivably political polarization might continue long enough that young people inherit a global system out of their control. The ocean could warm enough that major ice sheet disintegration will be inevitable, locking in loss of coastal cities, where our populations and infrastructure have accumulated. Low latitudes might become so hot in the warm seasons that emigration pressures cannot be contained, and the planet becomes ungovernable.

Change of book-writing strategy: for the sake of finishing this book, I abandon any effort to describe all experience under a single chronological path. Instead, I pick several specific topics and summarize my venture over whatever period is relevant.

I start with the biggest frustration and failure in my NASA career. Damage to our Institute was dibilitating, our development was stunted. More important, we missed the opportunity to make a significant difference in the biggest scientific issue about human-caused climate change.

The snuffing of a dream still hurts, it is like the shudder of Obi-Wan Kenobi when he felt the life on a distant planet being exterminated. I could have done things differently. Perhaps there are lessons for others in our unsuccessful struggle.

Arnold will be forever peeved, because he was first to describe the globally connected ocean circulation, but Wally's showmanship was important and useful. Wally was not just describing what was known, he was asking questions and spurring the community to try to answer them.

Wally and others suggested that North Atlantic deep water formation shut down at the brink of the Holocene, causing a return to near ice age cold in the North Atlantic region. Such sudden cold reversals on Greenland and the North Atlantic region are now recognized to have occurred many times as Earth moved out of glacial periods into warm interglacials.

Optimum conditions for melting Northern Hemisphere ice sheets after the last ice age, i.e., maximum late spring insolation, peaked 13,200 years ago. However, Earth's orbital parameters changed slowly on millennial time scales, the forcing was weak, and the ice sheets were enormous, so the planetary warming and the ice sheet melting required several millennia.

The most recent cold reversal, called the Younger Dryas, began 12,900 years ago, when central Greenland suddenly (within 10 years) cooled 15°C (27°F), back to ice age cold. The tundra wildflower Dryas repopulated Europe and northward marching forests began marching south. That cold period, which lasted 1200 years, is called the Younger Dryas to distinguish it from two earlier cold reversals, each lasting a few centuries, during the deglaciation after the last ice age.

The Younger Dryas was prolonged because of the enormous volume of water discharged by the melting North American ice sheet. Part of that water was stored in Lake Agassiz, the meltwater lake abutting the ice sheet. As the ice sheet shrank, passageways of meltwater into the Arctic and North Atlantic opened. Freshwater draining off North America reduced the density of North Atlantic surface water, shutting down deepwater formation.

Interpretation of these cold reversals is now reasonably clear. When the surface water in the North Atlantic becomes so fresh that deepwater cannot form, the conveyor shuts down. Northward transport of heat by the ocean into the Greenland and Norwegian seas stops, sea ice expands southward, and Greenland and Europe are cooled. Shutdown causes cooling in northeast North America, but the Southeast United States can become warmer.

Can global warming and Greenland melt shut down North Atlantic deep water formation today, and, if so, what are the practical impacts? Climate models generally suggest a rather mild effect, mainly a reduction of human-made greenhouse warming in Europe.

I will conclude that these models are wrong, that the effects will be much greater, if we allow it to happen. Making that case requires that I first present evidence that the ocean models are filled with a 'sludge' that reduces their sensitivity to freshwater forcing. That story comes later.

Real world slowdown of the conveyor is already underway. The slowdown is why the waters off the United States East Coast are a few degrees warmer than normal. That warm water allowed Hurricane Sandy to retain hurricane force winds all the way up to New York City. Sandy ripped the balcony off our house, uprooted trees, and left us without power for a week. We suffered several thousand dollars damage. So I have a grudge. But let's not get ahead of that story.

Wally's seminal contributions in geochemistry, oceanography, and paleoclimate earned him the respect of his peers as the leading scientist in the world in the field of global climate. He deservedly achieved a nirvana that escaped even Galileo, as shown by his acknowledgements in

his paper *The Great Ocean Conveyor*:[11] "I thank Exxon Corporation and Livermore National Laboratory for their generous support of my research. Instead of requiring me to write long proposals and reports, they encouraged me instead to put this effort into articles such as this."

Two days after the Deep Water workshop the new Climate Center at Lamont, with Wally as Director, was announced at a Low Library press briefing. David Rind, Bill Rossow and I attended the briefing to describe interactions of GISS with the Climate Center.

Angel #2, Frank Marten, altered our NASA situation soon after his arrival. He allowed us to hire atmospheric chemist Michael Prather, our first civil service science position since David Rind, four and a half years earlier. It was clear that more positions would follow. We were no longer under siege – it was time to ask Anniek to make a large pot of hutspot[12] (carrot and onion stew). Soon thereafter we hired Tony Del Genio and Inez Fung, and within two years, planetary scientist Michael Allison and paleoclimatologist Dorothy Peteet. All of these scientists were capable of writing winning funding proposals. We were a much stronger group.

Angel #1, Ruth Levenson, was our champion with Columbia hierarchy. The fact that we needed her to exploit NASA's desire to expand activities into global change was indicative of my poor communication ability. I was happy to leave that outreach to Ruth. My compunction is that I never properly thanked her and gave her a big hug before she died of cancer in 1997 at age 68.

My merit was that I was good at hiring good people and letting them do their thing. That would be the best approach to develop an understanding of North Atlantic deepwater formation, its paleoclimate history, and the possibility of a future shutdown of the great ocean conveyor.

Interpretations of paleoclimate data by some scientists were elaborate. Evaluation of alternative suggestions required knowledge of ocean chemistry that we did not have. Some proposals were described as houses of cards, which often collapsed when new data came in. I am not criticizing that practice, however, because a house of cards can be useful, if it stimulates thinking.

I am just saying that our research employed simple fundamental physics, such as conservation of energy. We estimated climate sensitivity from paleoclimate data by looking at a planet's energy balance. Andy Lacis and I were on the same page, perhaps because of our similar backgrounds.

We did not yet have the tool needed to study the great conveyor: an ocean model that rigorously conserved energy and other basic quantities. However, with little encouragement from me, our mathematical and modeling wizard, Gary Russell, worked doggedly, developing his own ocean model from scratch, a model that could function with a coarse resolution. Years later Gary's model was the tool that we needed to analyze not only the status of the great ocean conveyor, but also the effect of the ocean on ice sheets and sea level, and actions that might stabilize sea level.

Meanwhile, we faced a daunting immediate challenge. How to get the attention of lawmakers on an issue of dramatic importance to their grandchildren but inconsequential on the time scale of their electoral concerns? Our computer was a dinosaur. Our model was called substandard. Focusing on the physics, we found, would not work. We needed to be more resourceful.

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[11] Broecker, W.S., The great ocean conveyor, *Oceanography*, **4**, 79-89, 1991.

[12] Leiden was under siege by the Spanish army in 1573-74 after Dutch rebels seized control of the city from the Spanish. Hutspot was a staple during the siege, but thousands of inhabitants died of starvation.