

## Chapter 28. 1988: Mother Earth Speaks

**The planet seemed to conspire with us.** Nature, science and politics aligned on 23 June 1988. We had an opportunity to draw attention to the threat posed by climate change.

Mother Earth was the star. Mid-America was searing in heat, and the discomfort was amplified by a drought of biblical proportions. The Mississippi River dried up -- riverboat paddlewheels ground to a halt. A bubble of hot Midwestern air expanded to encompass the nation's capital, where the temperature exceeded 100°F (38°C). Global temperature was at a record level.

Our climate simulations were complete. Our paper<sup>1</sup> 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*.

Politicians must have been focused on the Presidential election. Early favorite Michael Dukakis crashed and burned 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. **Fix**

I called Rafe Pomerance the day before the Senate hearing. I wanted to be sure that there was good media coverage because, I said, "I'm going to make a pretty strong statement."

**I put down the phone and started writing my "oral" testimony.** A "just in time" preparation strategy allows more things to get done, but it is also risky. I assumed that composing my remarks would be easy, because my three main conclusions were simple and clear.

I wrote on a tablet of white lined paper, printing initially in large, dark square letters that would be 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's words over 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 average, 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 focused on the period since 1958, when accurate CO<sub>2</sub> measurements began. Expected warming for the observed greenhouse gas increase, if climate sensitivity was 3°C for doubled atmospheric CO<sub>2</sub> as indicated by paleoclimate data and the Charney study, 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 Mt. Agung volcanic eruption in 1963 and El Chichón in 1982 had detectable cooling effects, but the effects lasted only a few years.

By 1988 observed warming in the prior two decades was 0.4°C, three times the standard deviation. The chance of such warming as an unforced fluctuation was less than one percent, so I could say with 99 percent confidence that it was a real warming trend, not “noise.”<sup>2</sup>

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.

Other characteristics of the observed temperature change also carried a signature of the CO<sub>2</sub> 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 tight, and I was mixing long-hand with printing. The testimony was getting too long. The Senators will not cut me off, I thought, it is too important. But I had more to write. So I scratched some explanations.

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?<sup>3</sup>

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 4<sup>th</sup> page,** for a fresh beginning on my 3<sup>rd</sup> conclusion: global warming was already large enough to affect the probability of extreme events such as an unusually hot summer. 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.”

Greenhouse warming by CO<sub>2</sub> and other trace gases was changing the odds. I wrote: “In the late 1980s the probability of a hot summer is somewhere in the range 40-60%,” but I put this in parentheses. If the Chairman asked me to speed up, I would skip statements in parentheses.

I started a fifth page. I would finish it at NASA Headquarters. I arrived a few minutes late, but the scientists, about 30 of them, were still 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, high-speed computers, and research and analysis.

Rasool ignored my comment and continued with the meeting, and I resumed writing. But when Rasool stated that “no respectable scientist” would say that the human-made global warming signal had already been detected, my head jerked up 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 asked David Rind about atmospheric dynamics in our model. Was there a reason why the Midwest and Southeast U.S. often had extreme summer heat in our model runs? He noted that the ocean off the East Coast tended to warm less<sup>4</sup> 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 should not have commented on dynamics. Our model did not explicitly include ocean dynamics or allow ocean dynamical effects to change as climate changed. 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 would not notice or understand a comment on dynamics, but it would turn out to be a cause of irritation and outrage for certain fellow scientists.

**At lunch break, I rushed out and hailed a cab.** The ride to the Dirksen Senate Building was short – no time to rehearse the testimony. That was o.k. – I had planned to read it anyway.

However, I thought of a summary statement, intended for the 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. I might be able to use it during the give-and-take discussion, after the formal testimonies.

In the hearing room, a staffer pulled me aside and took me to speak with Senator Wirth. Wirth 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.

**At least half a dozen Senators were present.** They knew media would be present, providing 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



**Fig. 28.1. Hansen testifying on 23 June 1988**

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.”

**D**oubtless I was tense, but I was confident, because I could read the testimony and I knew that I could answer their questions. I wanted my three conclusions to be unambiguous, so I began:

Mr. Chairman and committee members, 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 affect 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 into 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.<sup>5</sup> 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.

**D**iscussion 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 increase in a hotter world.

My assertion of 99 percent confidence astonished some Senators. Senator Wirth said that he agreed with the 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 raised the issue of incrementalism. Is an appropriate policy, at least in early stages, incremental diminution of the problem via steps such as improved energy efficiency. He seemed to get agreement on the incremental approach from the scientists who focused on policy.

**Senator Domenici foreshadowed a great policy failure.** Incrementalism, accompanied by strategic long-term vision and action, made sense. But incrementalism, as an excuse to avoid clear policy implications of the science, sentenced future generations to climate disasters. Nevertheless, 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.

As the hearing adjourned at 4:15 p.m., I realized that I had not used my “waffling” comment. Several reporters waited in the back of the room. Phil Shabecoff of the New York Times asked 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.”<sup>6</sup>

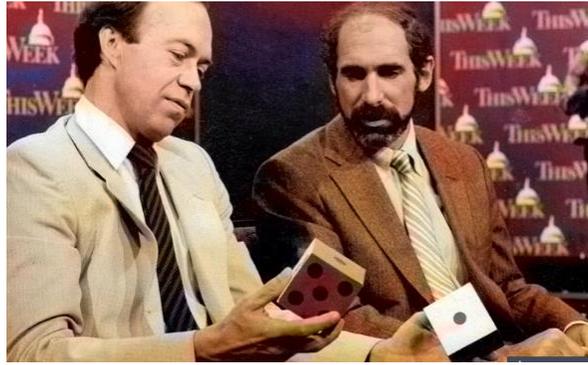
The next day, Friday morning, that quote – along with our graph of global temperature from 1880 to 1988 – was prominent in Shabecoff’s front-page article in the New York Times, which was headlined “Global Warming Has Begun, Expert Tells Senate.”

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. The front page also had an article titled “Pollution raised risk of drought,” with subhead “NASA expert blames ‘greenhouse effect’.”

The Shabecoff article portrayed accurately the message I meant to convey. It was an exception. Most stories – including television newscasts – said that I ascribed the drought to the greenhouse effect. Widespread misimpressions were probably unavoidable, given the massive ongoing heatwave and drought. I minimized interviews after the hearing, but when invited to go on a popular Sunday morning news program, I saw an opportunity to clarify the message.

I already had 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, was 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.



**Fig. 28.2. Hansen and Oppenheimer on This Week news program, Sunday 26 June 1988**

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

From a friend we learned of a doctor at Columbia Presbyterian Hospital, supposedly 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 her children were adults. We did not expect Erik and Kiki to be subjected to such trauma, yet the first thought that enters one's mind is how to reduce the chances to the absolute minimum. Anniek 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 rate between mastectomies and conservative minimal surgery to remove the cancerous lump followed by treatment with radiation and chemotherapy. Anniek chose that course. The small cancerous lump and some lymph nodes that proved to be cancer-free were removed and she has been cancer-free ever since.

The episode, especially Anniek's withholding of information until after my testimony, was a sobering reminder of all her efforts that aided my career. My priorities changed temporarily, but, once the crisis was over, the effect faded and life mostly reverted back to what it had been. I focused on research and tried to avoid the time-consuming distraction of interviews and politics.

**I wanted especially to avoid media hoopla.** Even if I prepared beforehand, I found it difficult to string together sensible sentences, especially during television interviews. I almost forgot the "waffling" line, even though I had it written on a piece of paper. Why not leave it to others who were talented at communication. Michael Oppenheimer and Steve Schneider said they were happy to do interviews, if I preferred to divert requests to them. I was glad to do that.

Wally Broecker called. He was at a meeting of the National Academy of Sciences where, Wally said, Jerry Namias was “on the warpath.” Namias was 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 effects of modeled ocean temperature on atmospheric dynamics. Namias was the nation’s most respected weather forecaster. I knew he was partly right: it was a mistake to comment on atmospheric dynamics in my testimony. Such speculation detracted from my main conclusions, which I was sure were rock solid.

Broecker delivered a message: I was requested to write down a clarification of what I was trying to say in my testimony and he would read it at the Academy meeting. An admission of fault was necessary to satisfy Namias.

I refused. First, my position would not satisfy Namias, who insisted that the drought “has no connection whatever with the greenhouse effect.”<sup>7</sup> I did not agree with that. Second, focus on even a minor flaw might get in the news, cast doubt on my testimony, and perhaps spoil any good produced by the testimony.

**T**here was a real problem with my testimony, however. I did not give equal emphasis to both extremes of the hydrologic cycle. Global warming pumps up both extremes.

On the one hand, at times and places where it is dry, the warming makes heat waves and droughts more extreme and makes fire seasons longer, with fires that burn hotter.

On the other hand, a warmer atmosphere holds more water vapor. Rain, when it comes, tends to be in more extreme events. So-called “100-year floods” occur more often than once a century in a warmer world, and the largest floods are more extreme. Also, storms driven by the latent energy in water vapor or by a warm sea surface – including thunderstorms, tornadoes and tropical storms – have more fuel and thus the potential to be stronger as the planet becomes warmer.

How to make that story clear? Global warming produces stronger heat waves, droughts and a more extreme, longer fire season. That sounds logical. But it also causes heavier rains, more extreme floods and stronger storms? This total story might sound fishy to the public.

Fortuitously, in early 1989 I received a phone call from Rick Adcock, Senator Al Gore’s assistant. Could I testify at a new hearing on global warming? Ah, this was my chance. This time I would be better prepared, and things would go smoothly. So I thought.

## Chapter 29. 1989: The Whitehouse Effect

**America's two-party political system** still functioned in the 1980s, to a degree. The United States was not yet fully immersed in echo-chamber monotony of political extremes, when global warming burst onto the global scene. The bipartisan cooperation on climate policy that emerged, however, was not designed. It just sort of happened.

Ernest Hollings, Chairman of the Senate Committee on Commerce, Science and Transportation, sent the official requests to testify. A hearing was planned for April 1989, to be conducted by Senator Al Gore, Chairman of the Subcommittee on Science, Technology and Space.

The hearing was postponed, though, because 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 letter to me requested that I testify on my "research on global climate models." Specifically, "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."

**That was an open license, again.** I based my testimony on a paper we were just finishing.<sup>8</sup>

We found that dry places get drier and wet places wetter with global warming. Also, warming is greater in the dry places. Summers in the Southwest United States and the Mediterranean and Middle East regions, which are in the dry subtropics, become 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. A clear picture emerged: an intensification of both dry and wet conditions as global temperature increases. As far as I know, our paper was the first one to reach the conclusion wet-will-get-wetter, dry-will-get-drier conclusion, and we made clear the physical basis for that conclusion.

These results were obtained with a specific model, the GISS climate model, but we showed that results from other models, such as Manabe's at the Geophysical Fluid Dynamics Laboratory, were consistent with ours. Furthermore, intensification of dry and wet extremes was a logical result of increased surface heating and more rapid 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 followed for the very different model of Manabe.

These changes lead to increases of deep moist convection, with associated heavy rainfall. In our model, doubled CO<sub>2</sub> 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 gentler rainfall from large-scale stratiform clouds.

Increased storm strength is not limited to thunderstorms. Kerry Emanuel of MIT, a world expert on tropical storms, used sea surface temperature changes from our doubled CO<sub>2</sub> 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.

Tropical storm surface pressure and wind speed depend on many factors, and seldom approach their maximum potential intensity. However, storm damage increases exponentially with wind speed, so the infrequent most intense storms cause the lion's share of storm damage.

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

The picture becomes more alarming, however, when we consider these effects in combination with rising sea level. Most of the world's large cities are on coastlines. Coastal population and infrastructure continue to increase.

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 (Office of Management and Budget) 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. Most important, we were careful to focus on basic physics of climate processes, not on detailed model results, 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<sub>2</sub> emissions than was the case for CFCs, there are many policy options which would reduce atmospheric CO<sub>2</sub> 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<sub>2</sub> emissions than was the case for CFCs, any policy options which should reduce atmospheric CO<sub>2</sub> 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 expecting me to make their policy statement, as if I agreed with it and as if it were my own statement.

**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 had already been thinking about what I would do if OMB insisted on their changes. I asked my secretary to make the one change that OMB 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.<sup>9</sup>

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.<sup>10</sup>

In this note to Senator Gore I suggested that he query me during the hearing about the first OMB insertion. I would 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 him, 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 was to draw attention to the practice of White House censorship, as well as to our views on the science.

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.”

Unwittingly, I played the straight man: “Oh? What's that?”

“If they can't take a joke, fuck '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 size and minimal regulations.

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 agree that other things are required to make this approach work, including universal women's rights and sensible regulations. Let's call this the “growth” perspective.

The “antigrowth” perspective is exemplified by *Limits to Growth*,<sup>11</sup> a study commissioned by the Club of Rome to explore consequences of finite world resources. *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. Nevertheless, it can be argued, much real-world data remain consistent with the business-as-usual scenarios in *Limits to Growth* that lead to economic and societal collapse in the latter part of the 21<sup>st</sup> century.

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

Sununu’s political perspective was simple. He saw an international global climate agreement as a threat to the conservative worldview. Such an agreement would be used by the antigrowth crowd to promote the command and control, antigrowth, policies that he feared. The United States, with its 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.

However, the skepticism must be unbiased. If preference or ideology affects a person’s analysis, that practitioner is likely to be exposed as a second-rate scientist or even a quack. The dominant characteristic of the biased scientist is cherry-picking, choosing data that supports, or seems to support, a preferred conclusion, while down-playing or ignoring contrary data.

Sununu zeroed in on an important climate model issue: ocean mixing and its effect on surface climate response. He thought that the huge heat capacity of the ocean would reduce human-made warming to a negligible amount. Warren Washington, leader of the National Center for Atmospheric Research (NCAR) modeling group, explained to Sununu that only the upper layers of the ocean would come into play on short time scales, but Sununu wanted to have his own climate model to play with on his Compaq 386 desktop computer<sup>12</sup> and he badgered Bromley to extract a model from NCAR. Eventually they provided Sununu a simple one-dimensional model, which would allow him to mix heat into the ocean as he chose.

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. Decades 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 for the purpose of stabilizing global shorelines.

However, Sununu had no such model. He did not need it. His main interest was not science. He had become a politician. He aimed to thwart antigrowth environmentalists. There is no evidence

that he used his little model for any meaningful studies, but he did use his knowledge of scientific terminology to cast doubt on credible science and on the climate change issue.

**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<sup>13</sup> of British climate modeler John Mitchell, Bromley concluded "my answer is that I simply don't know."<sup>14</sup>

Mitchell showed that the doubled CO<sub>2</sub> 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 identify 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."<sup>15</sup>

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. As a result, models, by themselves, do not practically constrain climate sensitivity. However, real world climate sensitivity is constrained, and shown to be high, by paleoclimate data.

Bromley should have tossed 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 support an international framework convention on climate change. That would require agreement that the world must avoid dangerous human-made climate change. A framework convention would be the crucial first step toward effective climate policies. Treaties would be expected to follow.

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. Sununu 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.



**Fig. 29.1. Hansen and Jerry Mahlman at 8 May 1989 Senate Hearing.**

**I had to get up early in Ridgewood, New Jersey to catch the 6 AM Shuttle** from LaGuardia on Monday morning. As I boarded the plane I failed to grab a free copy of the New York 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.”<sup>16</sup>

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 some of the climate science, my assertions of censorship, and the internal battle between Sununu, Bromley and Richard Darman, the head of OMB, on one hand, and Reilly 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 was disappointing to me.** Unlike the 1988 hearing, there was no focus on climate science – only on censorship. I failed to get Senator Gore or the media to pay attention to the other half of the global warming science – the fact that increased global warming would lead to greater extremes at the wet end of the hydrologic cycle, more heavy 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<sub>2</sub> 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<sub>2</sub>.



**Fig. 29.2. Impromptu news conference outside Senate hearing room.**

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?”

**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 must 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 microphones just outside the hearing room door – so it was unavoidable.

If I had been media-savvy I would have prepared a few lines while Jerry was talking. I could have noted that global warming was pumping up both ends of the hydrologic cycle. I kicked myself later – I missed an opportunity to focus on the science in 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 was told that I appeared in cameo and that Gore castigated Bush. An Administration spokesman said that I was entitled to my opinion, and there would be no retaliation against me. Hmm. More on that topic later.

**I escaped the news conference**, with just time to stop at home and then get to Erik’s game.

My car needed an oil change before a long trip that evening, so, from our barn, I took an oil filter, cans of oil, and a pan to catch the old oil, and parked beside the ball field. I watched the game when Erik was pitching, and got under the car when his team was batting. Changing the oil was strangely pleasurable. I was out of Washington, politics and the media – back in Ridgewood, on the ground in jeans and a T-shirt. It was a beautiful day. Erik pitched well, as a sign of things to come. The next two years he was the number one pitcher on the varsity team, pitching a complete game in almost every game he started, and making the league all-star team.

When I got back 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 to the media about having more hearings over the next week or two, bringing in the OMB censor, using me and other scientists to confront OMB.

That was a bad idea. Other scientists were unlikely to support me. Scientists are skeptical by nature. A workshop in Washington after my 1988 testimony included a “get Jim Hansen” session, an observer told Richard Kerr.<sup>17</sup> I accepted that as normal scientific skepticism. As I told Kerr “When we’re at this level of signal to noise, anyone can disagree with me.”

My concern was how the public would perceive debate. I could claim that paleoclimate data, climate modeling, modern data, and basic physics together make a strong case for a human role in ongoing climate change, but others would disagree. It would be an argument among experts. OMB and Sununu would find justification for turning my testimony into wishy-washy mush.

**I had no time to call Senator Gore.** I barely had time to eat and pack a travel bag before Kiki’s softball game. I was co-coach of her team. Coaching softball was easy. 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, for a workshop that had already begun. I knew from the agenda, focused squarely on my 1988 testimony, that I would be under continual fire. 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 picked up my coffee. I could only wonder about the conversations that morning.

My talk was low key. I addressed the two 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<sup>18</sup> 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 heated 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. Weather stations in urban areas thus record a spurious local warming not caused by the greenhouse effect. Was our global analysis spoiled by inclusion of 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.

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 Alaska and Hawaii, 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: (1) the world is in a real warming trend (99 percent confidence), (2) the warming is due to increasing greenhouse gases (high degree of confidence), and (3) global warming will cause an increase of hydrologic extremes (more extreme heat waves, droughts, and wildfires as well as heavier rainfall and floods).

Andy Lacis, laughing, showed me Kerr's article "Hansen vs. the World on the Greenhouse Threat" and said "they have you shouting angrily into 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 more relaxed in 1989 than I had been in 1988.

Although Kerr reported unanimous criticism of my testimony, 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 apparent. 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, one is praised for extensive caveats and calls for more research.

Kerr also exposed a misplaced focus on 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. Inference of the role of the greenhouse effect was based on knowledge of the climate forcing by greenhouse gases and its dominance over natural forcings. My conclusion about increasing climate extremes was based primarily on fundamental physics, not on climate models.

The workshop would continue all week, but I decided to leave following the Tuesday afternoon session. Mother nature would judge whether our interpretation of the data was correct. I had other work to do. I had got into another problem by criticizing NASA's proposed large satellite, "battlestar galactica," approach to Earth observations. I wanted to make the case for relatively inexpensive small satellites, especially a satellite to measure the aerosol climate forcing, which was and is very uncertain.

**The political hullabaloo in Washington lasted a week.** I drove back to Ridgewood Tuesday evening, still concerned that Senator Gore may want more hearings to hammer the White House. However, the situation was changing, as revealed by the Wednesday morning New York Times.

"White House Says Bush Will Call Meeting About Global Warming" read a headline. Then another article in the Friday New York Times: "U.S., in a shift, seeks treaty on global warming." President Bush had become involved – it seemed that he would honor his campaign pledge.

Indeed, 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.

Let's not give Bush too much credit. His administration fought to make any agreement as weak as possible in practical terms. Also, the Earth Summit was not his doing – it was in preparation before he took office. The person deserving most credit is Gro Brundtland of Norway.

However, there was a real danger that the United States would not participate in a Framework Convention – as with the League of Nations – thus spoiling the realistic possibility of later agreements to phase down fossil fuel emissions. That was Sununu's intent.

In "Losing Earth" Nathaniel Rich suggests that the decision to reverse course and work toward a framework convention was the product of a dialogue between Sununu and Reilly. I disagree. Certainly, President Bush encouraged the interactions among Sununu, Reilly, Darman, Baker and others that Rich describes, but he did not grant them the right to make his decision.

President George H.W. Bush made the decision to live up to his campaign promise, to go to Rio, and to agree to and sign the Framework Convention on Climate Change. Bush was an honorable person, and when he was pushed, he made the decision. However, Senator Gore deserves much of the credit for deftly using the censorship hullabaloo to pressure Bush.

That accomplishment was significant. Not only did Bush sign the Convention for the United at Rio in June 1992, the United States Senate ratified the agreement unanimously on 7 October in a division vote.<sup>19</sup> The stage was set for political action to address climate change – if and when the most powerful nations decided that it was time to cooperate on a common threat.

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 have been against a Framework Convention. Sununu remained an ardent global warming denier throughout the Bush Presidency.

**Senator John Heinz, Republican of Pennsylvania**, provided a glimpse into the politics behind the scenes. 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 sent 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 Andrew Solow – I anticipated disagreement about mathematical "confidence" in assessment of global warming<sup>20</sup> – I had decided to let nature demonstrate the physics of what was happening.

Senator Heinz assured me that was not his intent, and, of course, I "reconsidered." At his town hall meeting, Senator Heinz made clear that he supported the environment and the economy, saw no conflict between them, and his aim was a bipartisan approach to climate and energy policy. He had spoken with the President, and Bush agreed that the U.S. should take a leadership role.

I do not know exactly what happened behind the scenes, but I suspect that Senator Heinz influenced President Bush. Nevertheless, given the sudden change of the Administration's position following Gore's hearing, it is likely that Gore's front-page, top-of-the-evening-news pressure 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.<sup>21</sup> Senator Heinz was viewed as a possible Republican candidate for President. A Heinz Presidency in say 2000 is imaginable, but we can only dream about how history would have been altered.

**The anomalous pleasure of lying under the car changing the oil** was not only because it was a beautiful spring day and Erik pitched so well. It was because I had resolved to get out of the public and political side of climate change. Steve Schneider, Michael Oppenheimer and others could deal with that. I would get back to the pleasure of finding out how things work.

Finding things out – that's what science is about, right? Science and the scientific method are remarkable. We had learned a lot in one decade. That was the important thing, I thought.

It seemed that we had made the right decision in 1978. That was when I resigned as Principal Investigator for our polarimeter on Pioneer Venus, which was launched from Earth that year. Planetary research was left to the Iowa mafia, Larry Travis and Andy Lacis. I was able to hire Gary Russell onto the government staff in 1978 and David Rind in 1979. During the 5-year hiring drought that followed, which was related to the uncertain future of GISS, Inez Fung and Tony Del Genio stuck with us, until the brief but fruitful "Space Science spring" under Frank Martin in 1984-1987, when I could hire six scientists, including Inez and Tony, on civil service.

The result was a notable team of relatively young scientists that stood behind the testimonies that I delivered in 1988 and 1989, as acknowledged in the first paragraph of my 1989 testimony. Our principal product was a set of global climate simulations for three scenarios for the period 1958-2019. It took a few years to squeeze those out of our old Amdahl 470/V6 computer, but we did.

One merit of publishing predictions based on alternative scenarios for the future is that, when the future arrives, we can learn something from comparison with the real world. Science is objective and clear. The comparison would not depend upon communication ability. So we thought.

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<sup>1</sup> Hansen, J., I. Fung, A. Lacis, D. Rind, S. Lebedeff, R. Ruedy, G. Russell, and P. Stone: [Global climate changes as forecast by Goddard Institute for Space Studies three-dimensional model](#). *J. Geophys. Res.*, **93**, 9341-9364, 1988.

<sup>2</sup> My language, "99 percent confident" and "high degree of confidence," was meant to be as a lay person would understand the phrases. Beware that formal, sometimes esoteric, definitions of confidence may include arbitrary assumptions that obscure practical interpretation.

<sup>3</sup> 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.

<sup>4</sup> Decades later, when climate models included ocean dynamics, we found that the ocean along the East Coast of the U.S. warmed more than average as the Atlantic Meridional Overturning Circulation began to slow down.

<sup>5</sup> A 9-second youtube [video](#) should suffice, as I read my testimony.

<sup>6</sup> Shabecoff, P., [Global warming has begun, expert tells Senate](#), New York Times, 24 June 1988.

<sup>7</sup> Namias, J., [Cold waters and hot summers](#), *Nature*, **338**, 15-16, 1989.

<sup>8</sup> 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.

<sup>9</sup> Hansen, J., Memo to Senator Al Gore, 05 May 1989, 3 pages, available [here](#).

<sup>10</sup> The testimony, including OMB's alterations, is available [here](#).

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- <sup>11</sup> Meadows, D.H., D.L. Meadows, J. Randers and W.W. Behrens III, *The Limits to Growth*, Potomac Associates, 205 pp., 1972.
- <sup>12</sup> Warren Washington, private (e-mail) communication to the author, 2019.
- <sup>13</sup> Mitchell, J.F.B., C.A. Senior and W.J. Ingram, [CO<sub>2</sub> and climate: a missing feedback?](#) *Nature* 341, 132-134, 1989.
- <sup>14</sup> Sun, M., [Global warming becomes hot issue for Bromley](#), *Science*, 246, 569, 1989.
- <sup>15</sup> Bernstein, J. *The New Yorker*, 5 November 1990, p. 154.
- <sup>16</sup> Four articles and a lead editorial that appeared that week in the New York Times are available [here](#).
- <sup>17</sup> Kerr, R.A., [Hansen vs. the World on the Greenhouse Threat](#), *Science* **244**, 1041-1043, 1989.
- <sup>18</sup> 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.
- <sup>19</sup> A, rather uncommon, division (or standing) vote occurs when a Senator requests the Presiding Officer to count the “yea” and “no” votes, usually after a voice vote. In a voice vote the names and the exact tally are not recorded.
- <sup>20</sup> As an example of an arbitrary assumption in formal confidence calculations, Solow removed the trend in global temperature before looking for a human fingerprint (Kerr, R.A., *Science* 244, 1041-1043, 1989).
- <sup>21</sup> 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.