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A public debate on the science of global warming: is there sufficient evidence which proves we should limit greenhouse gas emissions because of climate change?

Full transcript of inaugural AARST Science Policy Forum, New York Hilton, Friday 20 November 1998, 7–9 pm.

JAMES E. HANSEN (affirmative)
PATRICK J. MICHAELS (negative)

1. *Moderator's introductory remarks*

Dr Gordon R. Mitchell: … You know, it's been said that rhetoric of science is nothing more than a bunch of covert neo-Aristotelians blowing hot air. Tonight, we plan to test that hypothesis when AARST hosts a public debate about global warming. Before the evening's arguments cool off, it is our hope that some of the heat and the light produced by this debate will start to melt away a few of the doubts that the rhetoric of science enterprise is a rarefied and detached scholarly project, of little relevance to contemporary science policy discussions …

But before I lay out tonight's debate format and introduce the participants, I want to talk briefly about the origins of this event. At last year's AARST preconference gathering in Chicago, Michael Hyde and Steve Fuller issued a charge to those gathered in the audience. This charge basically involved a call for relevance, a plea for 'measurable outcomes' and 'public engagement' in rhetoric of science scholarship. This call to action resonated deeply with my own political commitments, because I believe that privileged members of the academy shoulder a double-sided obligation. On the one hand, we bear the obligation to translate our resource advantages into high quality scholarship, but this alone is not enough. As privileged members of the academy, we must also strive to *connect* our scholarly work to larger society. Like surveyors sitting comfortably atop a vast canyon, we should not be satisfied to record the details with binoculars and then file away the findings in pages of obscure academic journals. The ancient founders of rhetorical study would be deeply disturbed by this trend of spectator scholarship. They insisted upon the importance of public engagement and popular disputation, and we ignore their examples at our own disciplinary peril …

Does the pursuit of scholarly relevance and the embrace of public engagement necessarily entail the zealous pursuit of partisan politics? Absolutely not. This forum is designed, in part, to be a performative exhibition of the potential for rhetoric of science

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scholars to make significant contributions to broader public dialogues, without necessarily hunkering down as partisan advocates for one side or the other in scientific controversies.

Now with that in mind, I would like to introduce our prestigious guests, who have graciously agreed to take time out of their busy schedules and take sides on the question before us tonight: 'Is there sufficient scientific evidence which proves that we should limit greenhouse gas emissions because of climate change?'

I am humbled to note that right now in this room, we may have two of the most established and accomplished scientific authorities on the issue of global warming in the entire world. Defending the affirmative side, we are pleased to have with us Dr James E. Hansen, Director of the NASA Goddard Institute for Space Studies. At the Goddard laboratory in Palisades, New York, Dr Hansen specializes in the study of climate science issues, focusing on the development of climate models, analysis of the mechanisms of climate change and the study of current climate trends from observational data. Dr Hansen is a frequent witness on Capitol Hill, having testified before Congress numerous times on climate issues. Some credit him as being the 'founding father' of global warming because of his congressional testimony on the issue in the late 1980s. Dr Hansen is seated on your right. To his right, opposing him, will be Dr Patrick Michaels, a climatologist at the University of Virginia. One of the most widely published and well-respected sceptics of the global warming hypothesis, Dr Michaels has a prolific publishing record and has been a perennial voice for the coal and oil industries on Capitol Hill in the last two decades. Dr David Hingstman, of the University of Iowa, will serve as the respondent for tonight's debate.

Now finally, before I go over the format of tonight's debate, I'd like to highlight some of the aspects of the global warming controversy, as a way to set the stage for tonight's arguments. Perhaps the best way to do this would be to share a personal narrative about the trials and tribulations experienced by Tim O'Donnell and myself in organizing this event. This stack of documents right here, over an inch thick, represents a monument to the contentiousness of the scientific controversy over global warming. This is the stack of documents that we have exchanged with various people in trying to organize this event. [It includes] correspondences with organizations and individuals who are interested in actually participating in public dialogue, but who, for particular reasons, will not commit to debate other particular advocates under certain conditions. So, I wanted to tell a little bit more about the process that we went through to finally get to tonight's debate, with Dr Hansen and Dr Michaels joining us.

The idea for this event started on 3 November 1997, last year, when Fred Singer stood on the steps of the Capitol and challenged the Clinton administration to debate the issue of global warming. Acting on this cue, Tim [O'Donnell] and I began organizing this event in late November 1997. Now, things seemed to be breaking our way when we met Fred Singer to discuss the possibility of having this event when he travelled to Pittsburgh in the spring. He expressed interest in the event and he signalled that if we could recruit an advocate from the Clinton administration, he would be glad to make his way to New York to participate in the debate.

So with optimism and redoubled enthusiasm, we turned to the task of trying to recruit an advocate from the Clinton administration to defend the scientific basis of their global warming policy. We soon discovered that this task was more difficult than we first believed. Like a hot potato, our invitation was bounced from one end of the Beltway bureaucracy to the other. It started with Vice-President Gore's office. He turned us down and referred us to the President's Office of Science and Technology Policy. There,

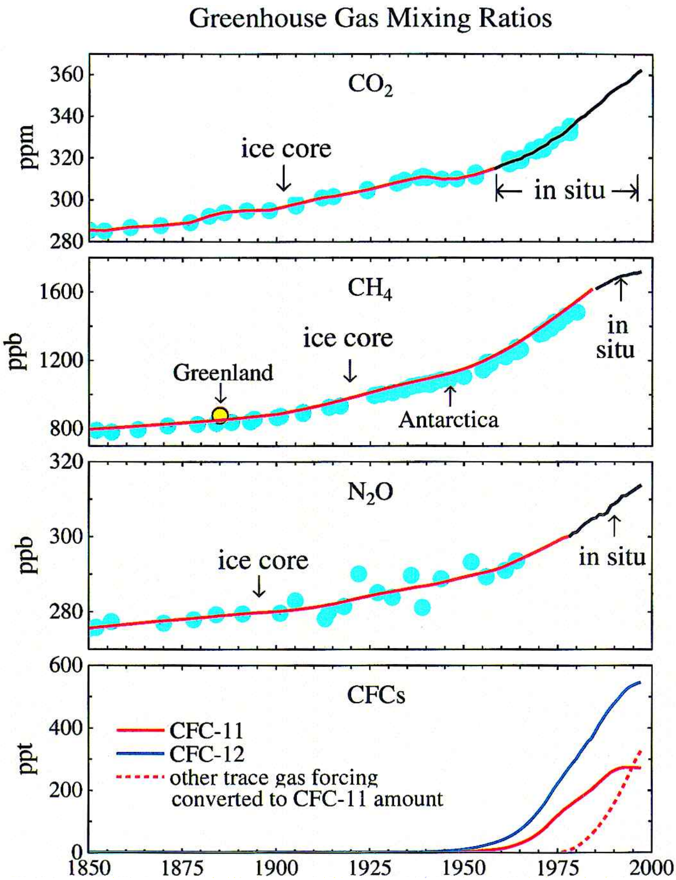


Figure 1. Principal anthropogenic greenhouse gases in industrial era.
Source: Hansen *et al.*, 1998. Climate forcings in the industrial era. *Proc. Natl. Acad Sci.*, **22**, 12753–12758.

we were turned down by Regina Bierbaum, the Acting Associate Director of Environmental Policy. 'Where should we go to find a government scientist who will defend the Clinton administration's scientific basis for global warming policy?', we asked Ms Bierbaum after she turned us down. 'Try the Council on Environmental Quality', she said. So we did. We went to the Council on Environmental Quality, where our invitations to Associate Director David Sandalow received the now familiar Beltway stall response.

From there, we shifted strategies and we went on to pursue other advocates: Michael Oppenheimer of the Environmental Defense Fund, Stuart Gaffin of the Environmental Defense Fund, George Kukla of the Lamont-Doherty Lab in Columbia, Dan Lashof, Cynthia Rosenzweig of NASA, David Rind of NASA, and Ned Leonard of Western Fuels. Each of these folks expressed varying degrees of interest in coming to participate and express their views on global warming today at this debate. Some of them actually did *commit* to debate, but only under very circumscribed and restricted conditions. Eventually, there were so many conditions put in place that there was no acceptable combination. About a month ago, we were at a loss. We had no advocates. Finally, we arrived at a combination that worked, with the gracious help from NASA and the Western Fuels Association, that helped bring Dr Michaels here tonight.

Now, you might ask, why all this jockeying? Why was it so hard to find the right combination to put this debate together? The answer is bound up in the reality that the dispute over scientific facts about global warming is shot through with *enormous* political, economic and social significance. For the Clinton–Gore administration, the political stakes in warming are immense. For scientists heavily invested in research on this issue, professional stakes are huge and for citizens all over the world, the stakes are also incredible.

These factors make the issue particularly ripe for rhetoric of science analysis. The current controversy over global warming includes disputes over scientific authority and expertise, the role of social, political, economic and rhetorical factors in the manufacture of scientific knowledge, the effective institutional constraints on the reception and communication of that knowledge, the public face of science in controversy and the intersection between science and policy-making. Tonight, I hope that Dr Hingstman will help us highlight some of these issues as he listens to the arguments advanced by the advocates, and responds at the close of the debate.

With that, I want to run through briefly the description of the format that we'll use, which is a very simple format. In part one, we will have the opening speeches and questions from the advocates. We'll be opening with the affirmative argument from Dr Hansen, who will speak for 15–20 minutes. His presentation will be followed by 5 minutes of questions from Dr Michaels. Then we will switch sides. Dr Michaels will present a 15–20 minute opening argument, followed by 5 minutes of questions from Dr Hansen. In part two, we will open the floor for questions from the audience for 30 minutes. Then finally in part three, we will have the closing arguments, starting with the affirmative, Dr Hansen for 5 minutes, and then finishing with the negative, Dr Michaels for 5 minutes. Then finally, we will turn the floor over to Dr David Hingstman for a 15-minute response to close tonight's event. So without further ado, please welcome for the first opening speech, Dr James Hansen from the NASA Goddard Institute for Space Studies in Palisades, New York.

[applause]

2. *Opening speeches and cross-examination*

Dr James E. Hansen: Actually, we're located over Tom's Restaurant on Upper Broadway, not in Palisades.

[laughter]

Dr Hansen: Okay, I'm going to use slides and some scientific charts. Perhaps that's unusual for debate, I don't know, but I hope that this prepared opening statement I've put together will serve as a good introductory summary of the debate topic.

So the issue that we've been asked to debate is: 'Is there sufficient scientific evidence that proves we should substantially limit greenhouse gas emissions because of climate change?'[1] I've taken the affirmative side, and I will interpret this question as a scientific one. I don't want to get involved in political discussion.

I will present evidence that climate is changing, global warming has started and that human-made greenhouse gases are at least partly responsible. Also, global warming tends to increase climate extremes: The frequency of droughts, fires, on one extreme,

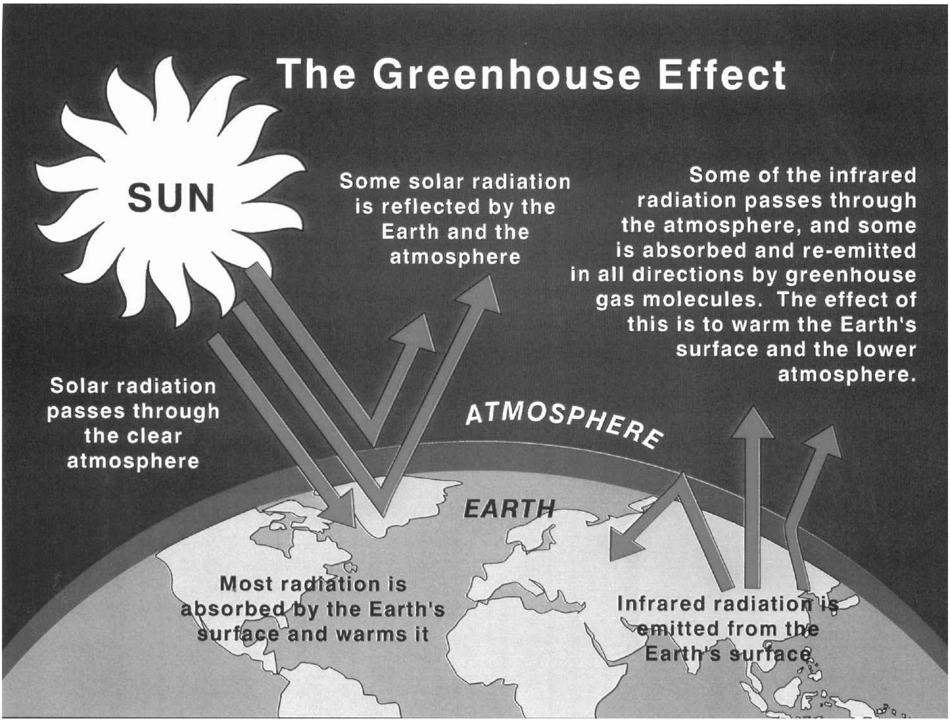


Figure 2. The greenhouse effect.

and also heavy rains and floods on the other. I will argue that the detrimental effects of large climate change probably exceed beneficial ones. So it makes sense to began to take common sense steps that help limit future climate change.[2]

During the past few decades, measurements of atmospheric composition including bubbles of old air that were trapped in ice sheets in Greenland and Antarctica, as snowfall piled up year after year and was compressed into ice, these measurements show that certain trace gases have been increasing during the industrial period, especially carbon dioxide from burning of fossil fuels, that's coal, oil and gas (figure 1). These gases are transparent to sunlight coming through the atmosphere, but they absorb heat radiation from the Earth's surface and radiate some of that heat back down, causing a heating of the surface (figure 2).

I became interested in this problem in the 1970s, when several of us at our institute calculated the heating caused by all of these gases that have accumulated in the air since the Industrial Revolution began. We found that the total heating was close to two watts per square meter. One watt is the amount of energy which is given off by a miniature Christmas tree bulb. So it's like having two of these bulbs over every square meter of the Earth, burning day and night, and slowly getting brighter. Is that important? Well, it's not obvious.

The Earth absorbs 240 watts per square meter of sunlight, averaged over the Earth. So it's as if the brightness of the Sun has increased about 1 %. The natural variations in the brightness of the Sun measured in the last 20 years are only a few tenths of a watt per square metre. So on that basis, it appears that human-made climate forcing, the greenhouse effect, is already competitive with natural climate forces.

Possible greenhouse warming was of sufficient concern that in 1979, the science

"Charney Report"*

Estimate of equilibrium global climate sensitivity:

3±1.5C for doubled CO_2

Bottom line of report:

"To summarize, we have tried but have been unable to find any overlooked or underestimated physical effects that could reduce the currently estimated global warming due to a doubling of atmospheric CO_2 to negligible proportions..."

*Carbon Dioxide and Climate: A Scientific Assessment, 1979: J. Charney (Ed.), National Academy of Sciences, Washington, D.C., 22 pp. Ad Hoc Study Group on Carbon Dioxide and Climate: Jule G. Charney (chairman), Akio Arakawa, D. James Baker, Bert Bolin, Robert E. Dickinson, Richard M. Goody, Cecil E. Leith, Henry M. Stommel, Carl I. Wunsch.

Figure 3. Climate sensitivity estimated in the 1979 Charney report

advisor to the President requested that the National Academy of Sciences study the matter. [This request] resulted in the famous Charney report from a committee of many of the most reputable scientists in the country in relevant fields (figure 3).

The Charney review focused on the question, 'How much would the world warm on average if the amount of CO_2 doubled?' That could happen next century if growth rates continue to increase. That's a hard problem. The world will take a long time to respond to such a forcing because the ocean has great thermal inertia. Also as the world warms, other things change. The amount of water vapour in the air, clouds and snow cover on the ground [change]. Charney concluded that there are at least two feedbacks that affect global climate sensitivity. One is water vapour, as the atmosphere becomes warmer it can hold more water vapour. And because water vapour is a greenhouse gas, it increases the warmth.

The other feedback is from snow and ice. Models, theory and observations all indicate that as the world becomes warmer, the area covered by snow and ice is smaller and this is a positive feedback because high albedo snow and ice surfaces are replaced by darker ocean or land, which absorb more sunlight causing additional warming.

There are other feedbacks. Clouds can cause both negative and positive feedbacks. We don't understand all the feedbacks. That's why Charney estimated such a large range for climate sensitivity, anywhere between 1·5 to 4·5 °Celsius. Charney realized the staggering implications of a climate sensitivity of 3 °Celsius. After all, the world on average was only about 5 °Celsius colder during the last Ice Age, and not more than about 5°centigrade warmer during the age of the dinosaurs. In what I think was a masterful summary statement, Charney wrote, 'We have tried, but have been unable to find any overlooked or underestimated physical effects that could reduce the currently estimated global warming due to doubling atmospheric CO_2 to negligible proportions'.

It's easy to dream up negative feedbacks that somehow will make climate sensitivity small. There are lots of Rube Goldberg ideas. Fortunately the history of the Earth

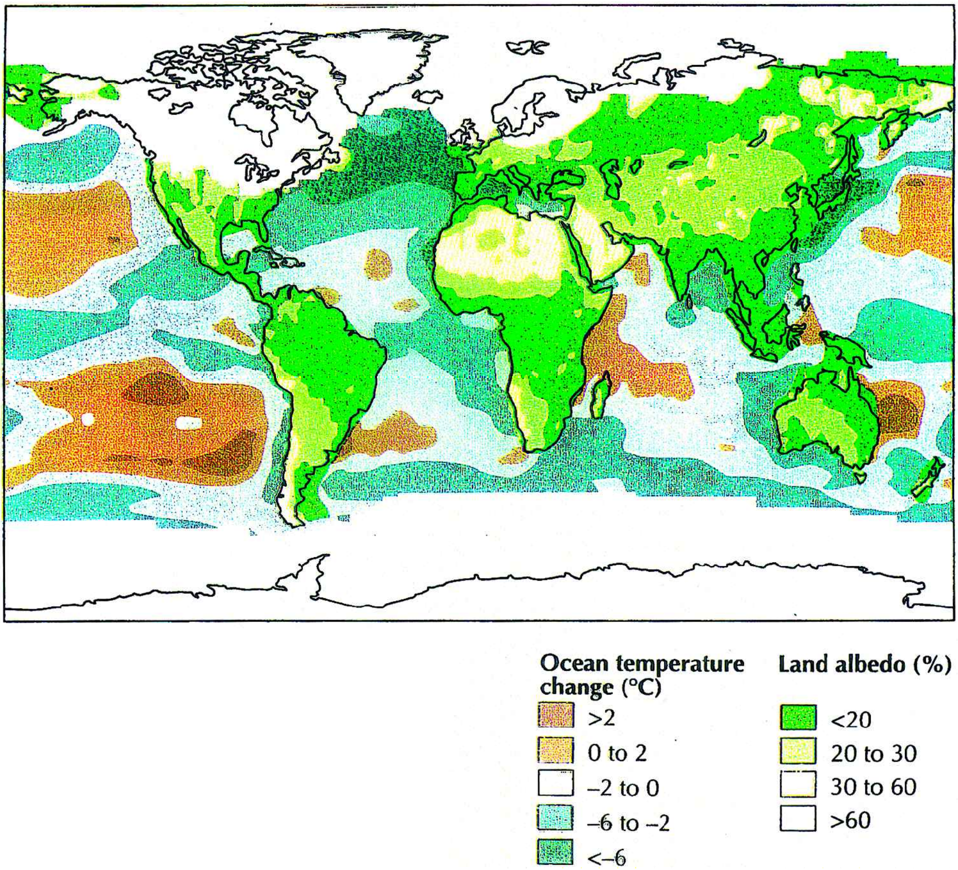


Figure 4. Surface condition in August during the last major ice age, ~ 20 000 years ago.

provides us with an invaluable check on climate sensitivity. Based on geological evidence, we know the conditions on the Earth's surface during the last Ice Age about 20 000 years ago (figure 4). For example, an ice sheet as much as two miles thick covered Canada, parts of the US, as well as Europe and Asia. Vegetation distributions were different and even the coastlines were different, because sea level was about 400 feet lower. We know the composition of the Ice Age air from bubbles of air that were trapped in the ice sheets at that time. There was less CO_2, less methane, and less nitrous oxide, and there was more dust in the air during the Ice Age. Averaged over several thousand years, the Earth must be in radiation balance with space, emitting the same amount of energy that it receives from the Sun, within a fraction of one watt per meter squared, as we can easily see by calculating the energy that it takes to melt the ice sheets or raise the ocean temperature by a plausible amount (figure 5).

So the world provides an empirical measure of climate sensitivity, which is simply the ratio of the observed global temperature change, which was about 5 °Celsius, divided by the forcing to maintain that temperature change which was somewhere between six and nine watts per meter squared. The result is three-quarters of a degree Celsius for one watt of forcing, which is about 3 °Celsius for doubled CO_2 forcing of four watts, in good agreement with Charney's estimate. And the great thing about this empirical measure is that it includes all the feedbacks that exist in the real world. Not only the ones we know

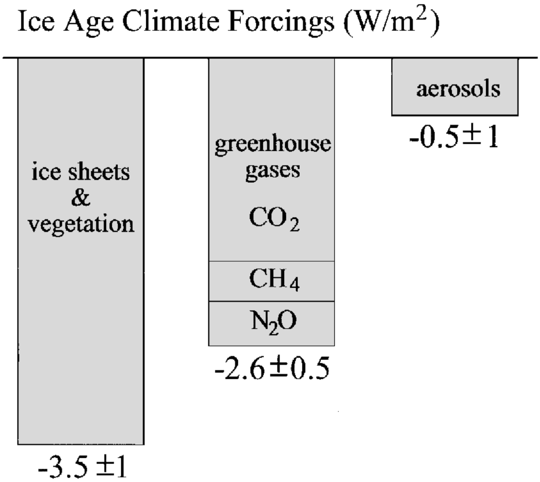


Figure 5. Global radiative forcings during the last ice age relative to the current interglacial period.
Source: Hansen *et al.*, 1997. The missing climate forcing, *Phil. Trans. R. Soc. B.*, **352**, 231–240.

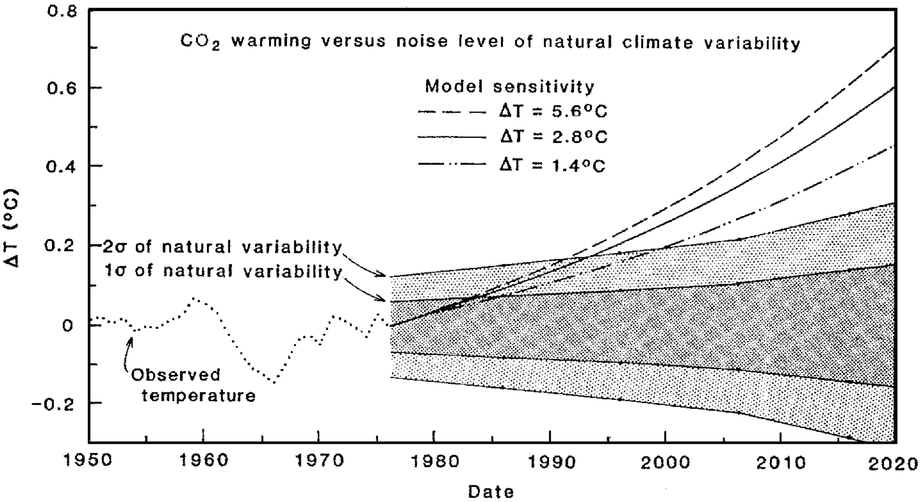


Figure 6. Comparison of projected CO_2 warming to standard deviation (σ) of observed global temperature and 2σ.
Source: Hansen *et al.*, 1981. Climate impacts of increasing atmospheric CO_2, *Science*, **213**, 957–966.

about but any Rube Goldberg feedbacks that exist. If they really occur, they're in there. Changes in clouds, water vapour, ocean heat transport, they're all in there.

The global warming sceptics pretend that warming is just a product of climate models, but in fact it arises from the most basic theory, as well as from models. And what's more important, it's well tested by empirical evidence, including other planets and the Earth's history. Nevertheless, it's important to assess how well climate models can simulate the climate. The best way to do that is to compare model predictions with the real world. Do the models exaggerate global warming?

The first model predictions of greenhouse gas scenarios were our calculations a couple of decades ago, with a simple climate model with a sensitivity of 2·8 °Celsius for doubling CO_2. We published a paper in *Science* that was reported by Walter Sullivan in a front-page article of the *New York Times*. The model prediction which is shown here was a warming of a quarter of a degree Celsius from the late 1970s to now (figure 6). We

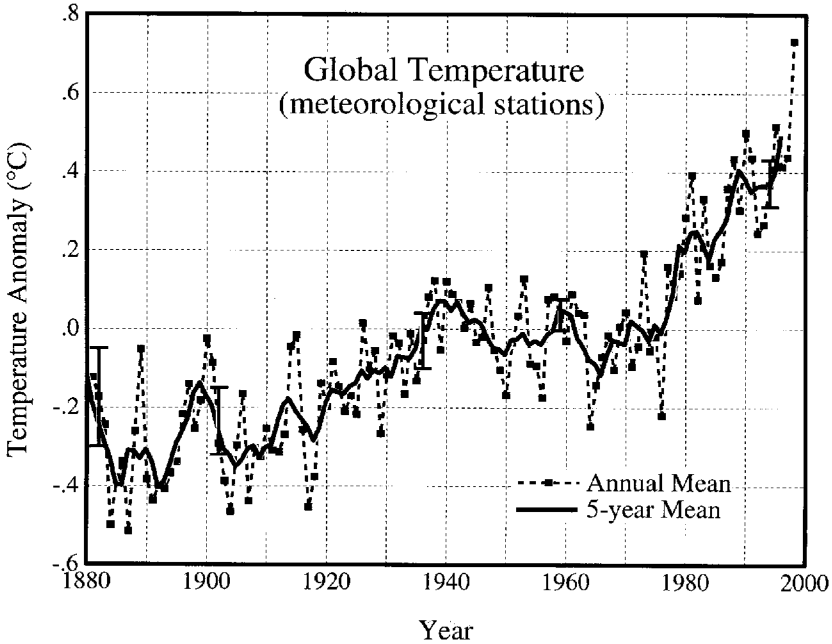


Figure 7. Global temperature (meteorological stations).
Source: Hansen *et al.*, 1999. GISS analysis of surface temperature change, *J. Geophys. Res.*, **104**, 30997–31022.

argued that would be about enough to bring the warming out of the noise level, the unforced chaotic fluctuations of climate, by the 1990s and this is the five year running mean temperature. The noise level, the shaded area, is based on the variability of observed five year mean temperatures. So what has the real world done? The five-year running mean temperatures, the red curve, has indeed warmed up about a quarter of a degree (figure 7).

In the last few years, several papers and the report of the Intergovernmental Panel on Climate Change, have all concluded that the observed warming is now probably too large to be natural variability. So the most fundamental prediction of our paper proved to be correct. and this warming is real. Contrary to claims of the sceptics, it is not urban warming. The warming is hardly changed if only rural measurements are used. And the magnitude of global warming is confirmed by bore hole data from many locations around the world, where the vertical gradient of sub-surface temperatures yields an average warming between 0·5 and 1 °Celsius in the past century. Also, glaciers have receded almost world-wide in the past century, and the magnitude of their recession has been used to infer a global warming of about eight-tenths of a degree Celsius in the past century.

This is the global distribution of temperature change in the last five decades (figure 8). The geographical distribution of the warming, with the largest change in remote Siberia, Canada and the mid-ocean areas, debunks any attempt to ascribe the warming to urban effects. Global warming is clearly real.

The first model predictions with a three-dimensional climate model and time-dependent greenhouse gas scenarios, were those we published in 1988, which were the basis for my testimony to Congress that year.[3] The climate forcings in the model were greenhouse gases and stratospheric aerosols. There were three scenarios for

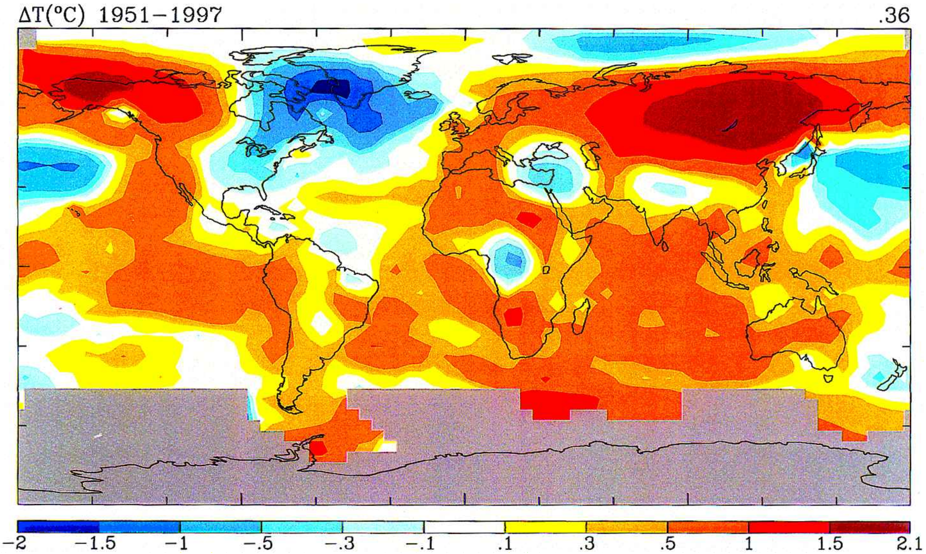


Figure 8. Surface temperature change for 1951–1997 based on local linear trends.

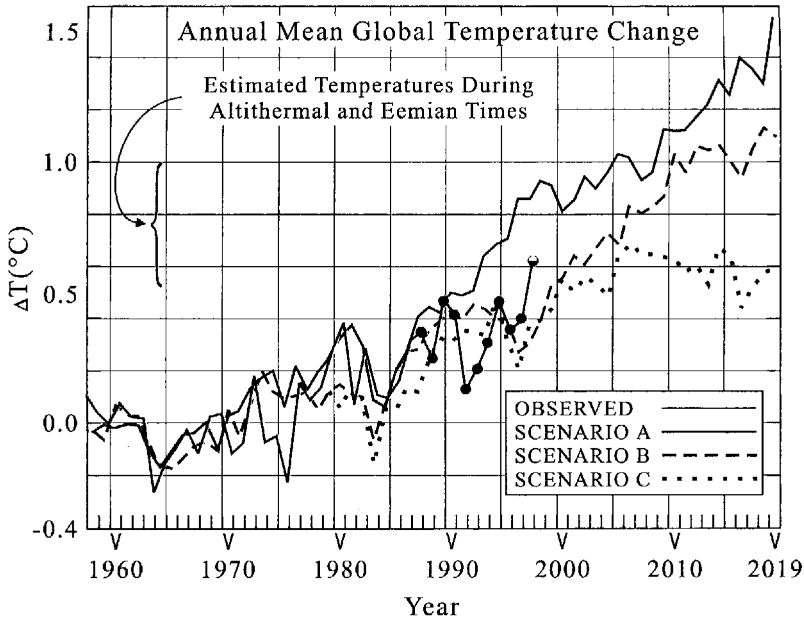


Figure 9. Climate model calculations carried out in 1987.
Source: Hansen *et al.*, 1988. *J. Geophys. Res.*, **93**, 9341–9364.

greenhouse gases, A, B and C, with B and C being nearly the same until the year 2000, when greenhouse gases stopped increasing in scenario C. Real-world forcings have followed the B and C greenhouse scenario almost exactly. The model scenario had one large volcano in the 1990s, in 1995. One volcano actually occurred, but it was in 1991. If we shift the date of the volcano, the model and the data fit remarkably well. This

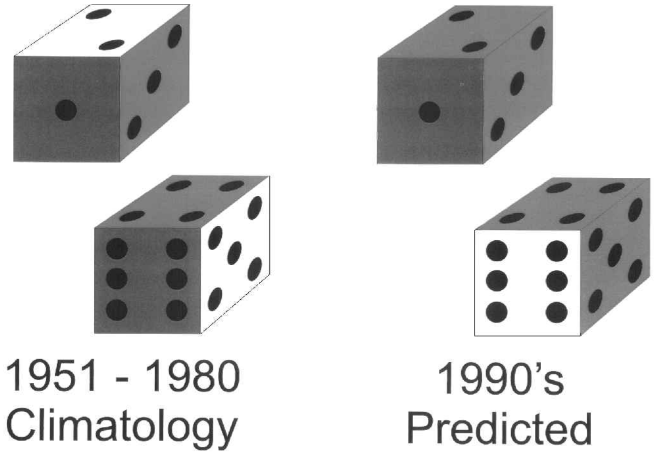


Figure 10. Dice used to illustrate the change in the probability of unusually warm (red) and cool (blue) seasons as a result of global warming.

record by itself is too short to serve as a conclusive test, but again there is no hint that the model exaggerates global warming. In fact, the real world has warmed slightly more than in the model using actual greenhouse gas changes.

In 1988, and 1989, in testifying to the US Senate, I asserted that number one, the world was in a period of real long-term global warming. Number two, the warming was probably due at least in part to human-made greenhouse gases. Number three, in our climate simulations, global warming was accompanied by increasing climate extremes (figure 9). An increase in both droughts and forest fires, on the one hand, and heavy rain and floods, on the other. I think that makes sense, although climate fluctuates chaotically at any given place, at times when it is dry, added greenhouse heating intensifies the dryness. But over the ocean, and in other places when it is wet, and on the global average, increased surface heating increases evaporation and thus rainfall, which falls increasingly in more intense events, causing enhanced flooding.

I soon realized that there was a possible misinterpretation of my testimony by the public, perhaps with them inferring that every season would be unusually warm. So I made a set of coloured dice, to illustrate that global warming is smaller than unforced chaotic fluctuations of climate (figure 10). But by the 1990s, there could begin to be significant loading of the climate dice. This analogy to the dice was based on a 1988 paper, in which we calculated that the frequency of unusually warm seasons in locations such as Omaha and Washington, would increase from 33 % for the 1950–1980 period, to 50–80 % in the 1990s, depending on the greenhouse gas scenario (figure 11). In the B and C scenarios, which observed greenhouse gases have actually followed, the increase was from 33 % to 50–60 %. This is real world data (figure 12). The frequency of warm seasons, although it's highly variable from year to year, has increased to 50–60 % at middle latitudes where we made predictions as shown on the left, as well as the global average shown on the right.

This frequency of unusually warm seasons begins to touch a key point. When will climate change be obvious to most people? I'm not certain whether or not people can notice a change in probabilities from 33 % to 66 %, but I think that we are at least getting very close to a level of change that will be noticeable to the perceptive person. Should we expect these probabilities to continue to increase? Yes, we should, for two

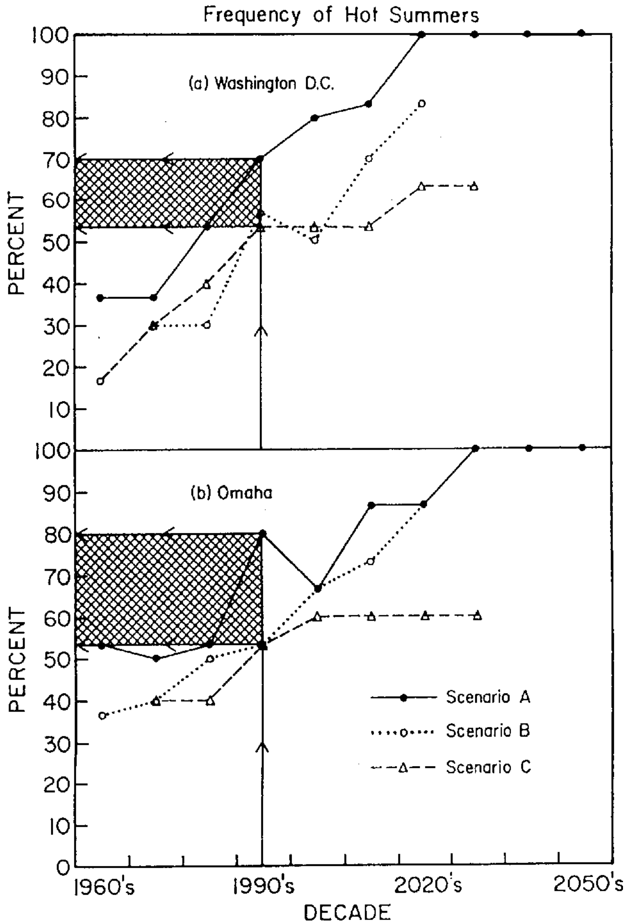


Figure 11. Calculated probability of the summer being 'hot', shown at two locations for greenhouse gas scenarios A, B and C.

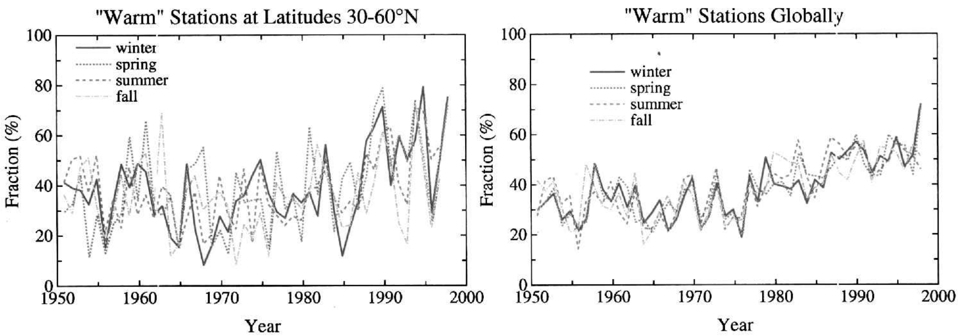


Figure 12. Percentage of meteorological stations that were unusually warm in a given year for middle latitudes in the Northern Hemisphere (left) and averaged over all stations (right).

reasons. First, the warming due to the gases we've already added to the atmosphere is only partly realized, because of the long response time of the climate system, and second, greenhouse gases are still increasing rapidly (figure 13). This last slide shows that

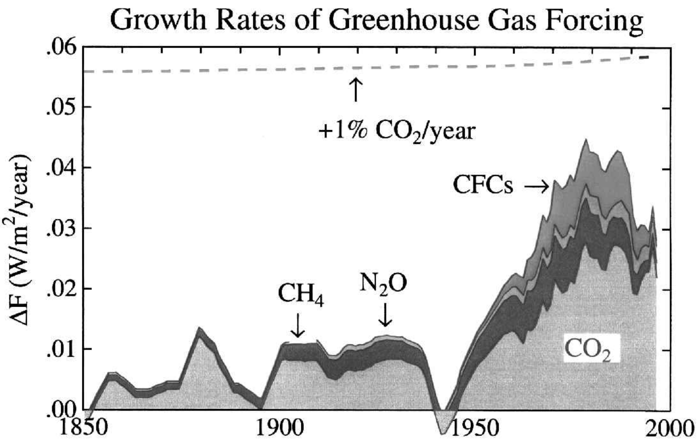


Figure 13. Growth rate of greenhouse climate forcing based on gas histories.

climate forcing by greenhouse gases is continuing to grow, but not as fast as ten years ago, because CFCs are being phased out, methane increases have slowed, and the CO_2 growth rate has flattened out. This is an encouraging result, because it shows that greenhouse gas growth rates do not have to get larger and larger. They have in fact declined during a period of economic prosperity. But further decline is needed to prevent the equivalent of doubled CO_2 in the next century.

This is my summary statement.[4] There is abundant empirical evidence, especially from climate records, that climate is sensitive to forcings. There is no doubt that greenhouse gases are increasing rapidly, giving rise to a strong climate forcing. Global warming is observed. It seems to be rising above the noise level of natural climate variability and it is consistent in magnitude with the warming expected from the climate forcings. There are large uncertainties about future climate change, especially because uncertainties about different climate forcings will continue to change. But as long as we let greenhouse gases continue to increase rapidly, we are almost surely headed to a much warmer planet. What the impact of that will be is uncertain, but we are adapted to the current climate. For example, if sea level goes up by one meter, that will be very detrimental to much of our coastline, not to mention, essentially wiping out the Maldives, Marshall Islands, Nile Delta and Bangladesh. So it seems to me that given the potential dangers that we can foresee, a common sense strategy would be to take steps that slow down the planetary experiment,and then adjust that strategy as we see how climate continues to unfold. There are many opportunities to slow down this experiment, things we can do that would make good common sense in any case. For example, steps to improve energy efficiency would reduce the rate of growth of greenhouse gases and make good economic sense.

We should invest in clean renewable energy technologies, so that if the evidence continues to mount, we will be in a position to move more expeditiously on our longer-term choices of energy sources. Thanks.

[applause]

Dr Mitchell: The format now calls for five minutes of questions from Dr Michaels to Dr Hansen.

Dr Patrick J. Michaels: First of all, I'd like to thank Jim for a very nice presentation. I'd like to ask a few questions if I could. Dr Hansen, you said that increasing the

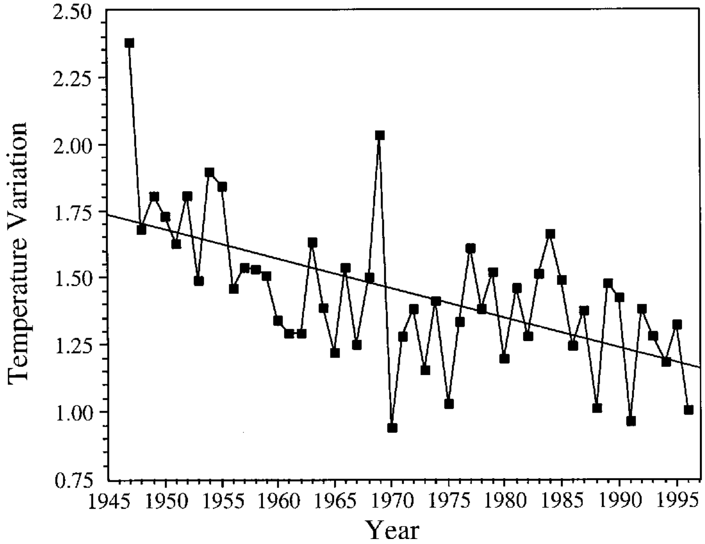


Figure 14. Global temperature variability.

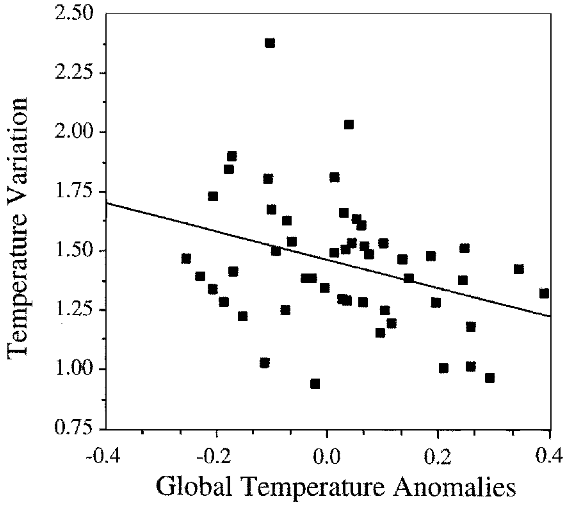


Figure 15. Global temperatures and temperature variability.

atmospheric greenhouse effect when warming the planet results in increased variability of temperature. In fact, increasing the greenhouse effect, as you will see in my discussion later on, primarily increases the winter temperature and the temperature of the very, very coldest air masses. If we take a look at a mathematical measure of temperature variability within years, and between years, we get the following result, which I published in the journal *Climate Research*, earlier this year (figure 14). Over time, there has been a statistically significant *decline* in global temperature variability as the climate warms. In fact, we can plot the variance versus the mean temperature from year to year, some years are above the mean, some years are below the mean (figure 15). We get this very significant relationship, in which variance declines as temperature increases. So Jim, I'd like to ask you opinion as to whether that's wrong.

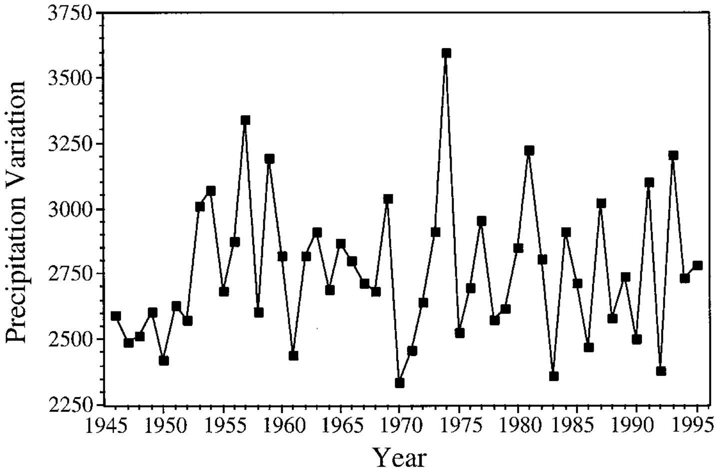


Figure 16. Global precipitation variability.

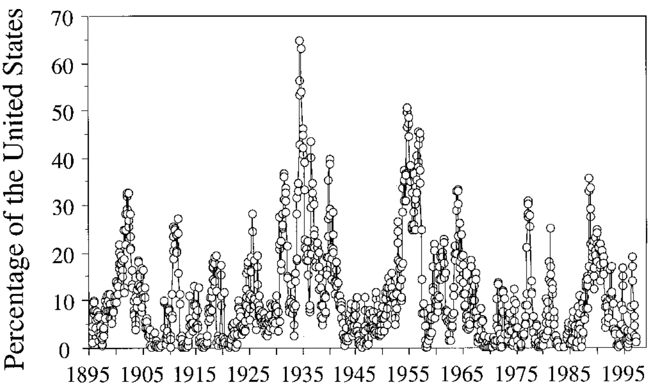


Figure 17. Percentage of the USA experiencing severe or extreme drought.

Hansen: I never said today, nor any other time I know of, that increasing greenhouse warming would increase the variability of temperature. I said that it would increase climatic extremes, specifically in the hydrological cycle, on the one hand, increasing the frequency and intensity of droughts and forest fires, and on the other end of the hydrologic cycle, increased intensity of extreme heavy rainfall and floods, but I did not say that it increases variability of temperature. I never said that.

Michaels: Okay, well, with regard to that then, this is the graph of precipitation variability, within years and between years, published in *Climate Research*, and it shows nothing (figure 16). If we take a look at the only place where we keep the drought index very well, which is in the USA, and take the record back as far as it goes, which is one hundred years, we see the 1930s, which were spectacular, and we see the 1950s. Overall, we see no trend whatsoever (figure 17). We do however see, one other trend, with regard to moisture. We do see a slight increase in wetness, over the course of the 20th century (figure 18). But is this wetness expressed in the extreme? Recently Harry Lins and Slack published a paper in which they looked at stream flow in unimpounded catchments, which is natural stream flow, and they divided it into deciles, and what they found was

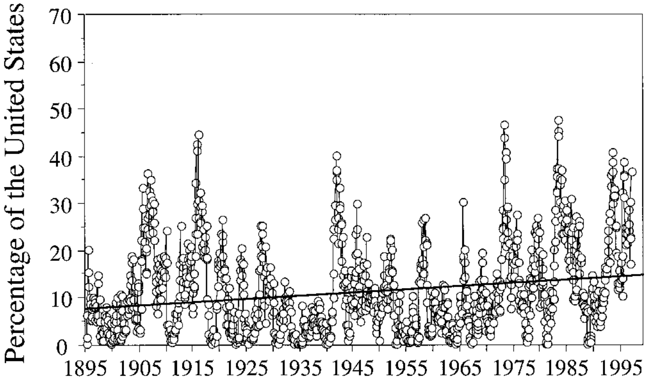


Figure 18. Percentage of the USA experiencing severe or extreme wetness.

that there was no increase in the highest decile flow (that means flood). And there was a statistically significant *decrease* in the lowest decile of flow (which is drought). In other words, this is another example of what I would call the *meaning* of climate, in which the variance of climate collapses, as we increase the greenhouse effect, rather than vice versa. Do you agree with Slack's result?

Hansen: The change in the frequency of precipitation is not the first place you would expect to see the impact of global warming. I published [a paper] this past year on the global distribution of both the changes in temperature quantities and those related to moisture. In both cases, on the global average, there are changes in the sense that are predicted for global warming. But in the case of moisture, the changes are small, compared to the natural variability. That's not surprising. Precipitation is an extremely noisy, chaotic quantity, so you would expect to see changes in temperature, such as the frequency of the seasons that are warmer than normal, such as increases in heating degree days. Where you're averaging over a whole season, you have much better chance of getting a signal above the noise for those type quantities. You do see changes in those quantities, so I'm not surprised that in the case of precipitation, there are not obvious changes, but the small changes that are there, are in the sense that we could expect.

Mitchell: One more question.

Michaels: In 1989, you told *Science* magazine that there would be a 'statistically significant increase in frequency of drought' by the mid-1990s. What happened?

Hansen: I don't recall saying that there would be a 'statistically significant increase in drought' …

Michaels: … Actually your words were, 'increase', but a scientist cannot say that anything is changing from zero, unless it is statistically significant. So, speaking as a scientist, you had to have meant a statistically significant increase …

Hansen: … No, a change can be very important, before it rises above the level of natural variability.

Michaels: You can't define it as a change.

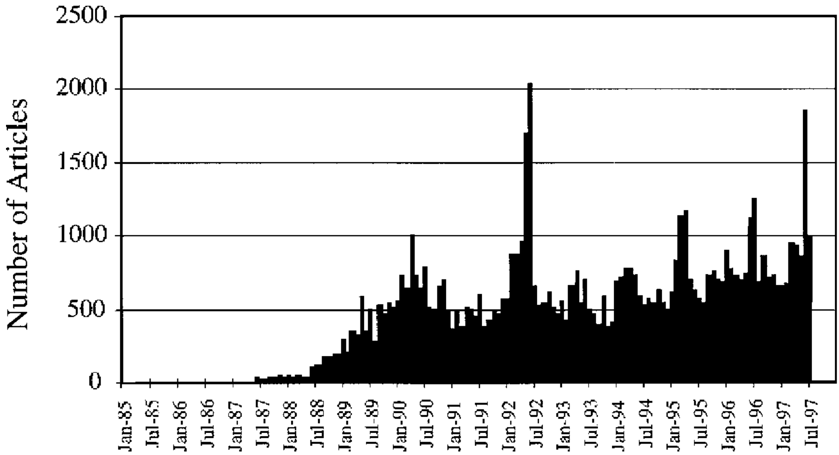


Figure 19. Number of news articles containing the phrase 'global warming' or greenhouse effect'.

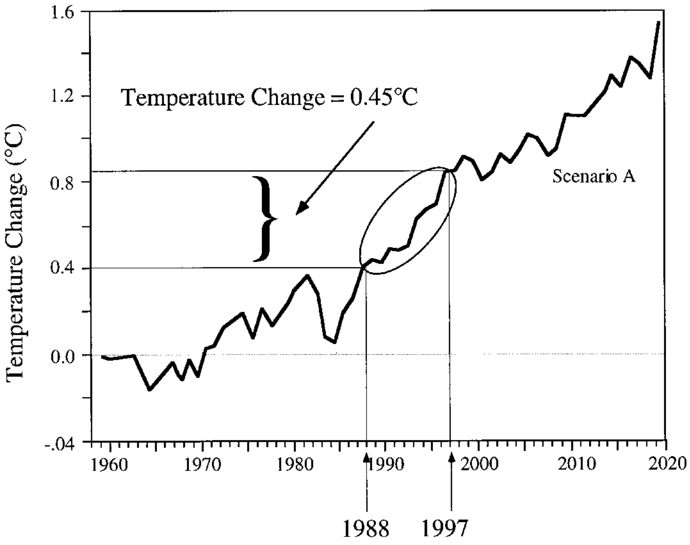


Figure 20. Hansen's 1988 predicted temperatures.

Hansen: Sure you can …

Michaels: … You cannot define it as a change. It does not exist.

Mitchell: Thank you, Dr Michaels. Now let's move into the second opening argument by Dr Michaels, taking the negative, and disproving the question, 'Is there sufficient scientific evidence to support a reduction in greenhouse gas emissions because of global warming?' …

Michaels: … I think that's a very good question. It certainly has raised public concern about this issue. This is perhaps a familiar graph of global warming, but [maybe] it's not (figure 19). It is the number of newspaper stories published monthly, saying that global

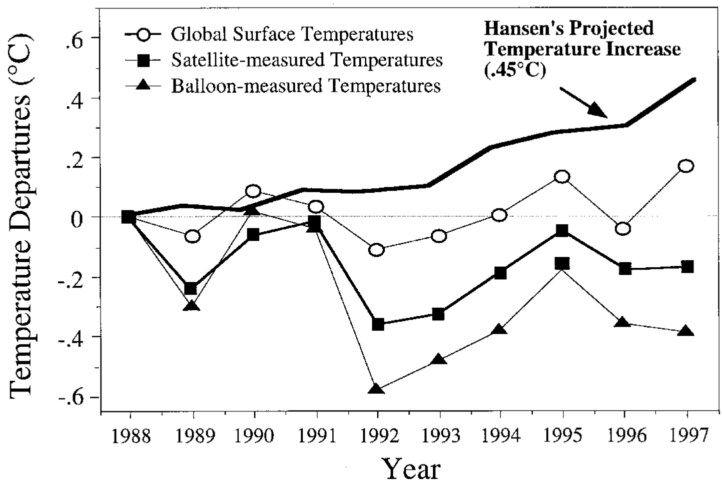


Figure 21. Observed and model-predicted warming (Hansen Scenario A) in the decade following the year that this prediction was made.

warming is a serious problem. And it takes off all after July 1988, seven days after Jim Hansen's famous testimony, which he said was based upon the following model. This slide is taken from the same graph that he showed in 1987 (figure 20). It is the projected change of temperature given no significant reductions in greenhouse gases. The change in forcing that Dr. Hansen referred to, resulting from the phase-out of chlorofluorocarbons, has only been in the last three years and is minimal. It wouldn't change his result at all. This was the forecast that was made if we did nothing, and it said the temperature would change 0·45 °C between 1988 and 1998.[5]

In fact those models were very believed. The Intergovernmental Panel on Climate Change for the United Nations wrote in 1990, 'when the latest atmospheric models are run with present concentrations of greenhouse gases their simulation of climate is generally realistic'. That is one of those models, and they were all very, very similar. They used greenhouse gases only to force a change in climate. This is what happened in the last ten years (figure 21). This is the projected temperature increase from the model that served as a basis for the testimony, 0·45 °C and this is the surface temperature change. It is statistically insignificant. If you want to call it an increase, we could debate that rhetorically, but it's 0·11 °C. There are two other measures of temperature, satellite measure temperatures, which mimic balloon measured temperatures between five and thirty thousand feet in the atmosphere, and they both declined.

You all are astute students of this debate and you know that satellite data has recently been challenged as having an orbital drift and induced a false cooling. All the satellite data shown here has been corrected, and sent to me by John Christy from NASA. Now the problem with this issue is that global warming is a very real thing, and you really mis-introduced me [referring to Dr Mitchell] when you said that I was some sceptic who didn't believe in global warming; I surely do. You can see it in the temperature history in the course of the 20th century. That's not the problem. The problem's not whether the planet warms, it's how it warms and I want to take a few minutes to tell you how the greenhouse effect changes the climate. It absorbs infrared radiation, emanating from the surface of the Earth after the Sun heats the surface of the Earth. Carbon dioxide absorbs some, which redirects some of that radiation down, warming the planet. Carbon dioxide is not the most common greenhouse gas on the planet. The most

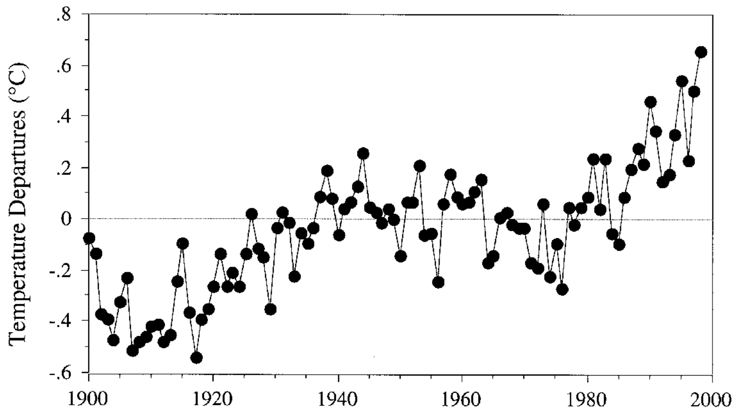


Figure 22. Northern hemisphere surface temperature departures (°C).

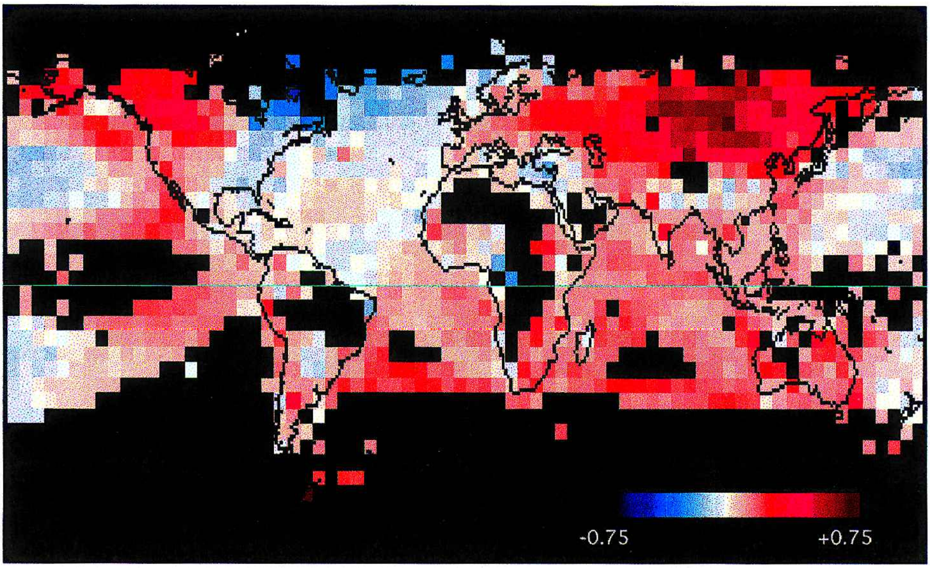


Figure 23. Cold season temperature trends, 1946–1995 (°C/decade).

common greenhouse gas on the planet by far is water vapour. Water vapour and carbon dioxide act very similarly over a portion of their absorption spectrum. The corollary to that if that you have an atmosphere that has very little water vapour, you will get a very large change in temperature for a change in carbon dioxide. If you have an atmosphere that is loaded with water vapour, you won't get very much change at all (figure 22). Well, the coldest air masses on the planet are the driest air masses on the planet, and that's where you should see the human change in the greenhouse effect. This is the temperature history of the winter since World War II (figure 23). There is a stunning change in the winter temperature in Siberia. It has gone from −40 to −38 degrees. North-western North America has warmed from −30 to about −29 degrees. How much of this warming is confined to the absolute coldest air masses? Well, I just made a calculation yesterday (figure 24). Look at the air masses where the dewpoint

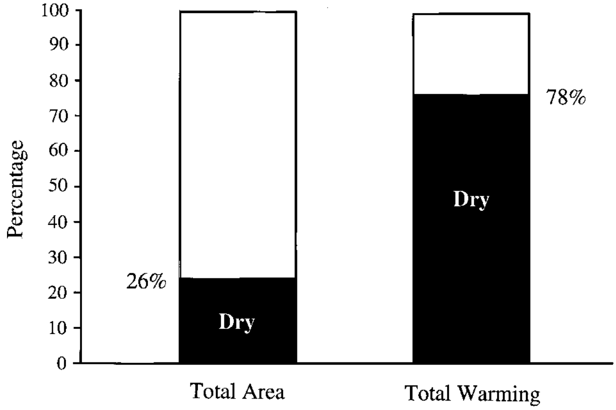


Figure 24. Warming in dry (dewpoints ⩽ 0 °C) airmasses: northern hemisphere winter (1946–1995).

Figure 25. Common sense index of climate change.

temperature was below zero. These are very dry. How much of the warming of the Northern Hemisphere in the cold half-year, remember the mean temperature of the atmosphere is about 10 °Celsius in the cold half-year, it's not that cold, how much warming is confined to those air masses? It is a phenomenal amount; 95 % of the warming of the Northern Hemisphere is in the absolute coldest air masses.[6] And that is really more than you would expect from greenhouse theory, according the models, but the models are very incomplete beasts, as we all know. Five percent of the warming is in areas where the dewpoint is greater than zero. It's nice to talk about global warming, but the fact is that it's largely in the winter. Since World War II, on a century basis, the winters have warmed; 0·84 degrees per century, that's the rate. The summers across the planet have warmed 0·42 degrees. In 95 % of the winter warming in the Northern Hemisphere is in the absolute coldest air masses.[7]

Hansen and Michaels agree, greenhouse warming confined to cold air masses!! This is from your paper [referring to Dr Hansen] on human detection of the greenhouse (figure 25). This is where Jim [Hansen] says what he calls the 'common sense greenhouse index' shows significant change, and it's in Siberia, and north-western North America, just like I showed you. Had this been divided into winter and summer, you would have seen this is only in winter. Here's the summer temperature change, which, by the way, is one-half the value of the winter change, because the summer

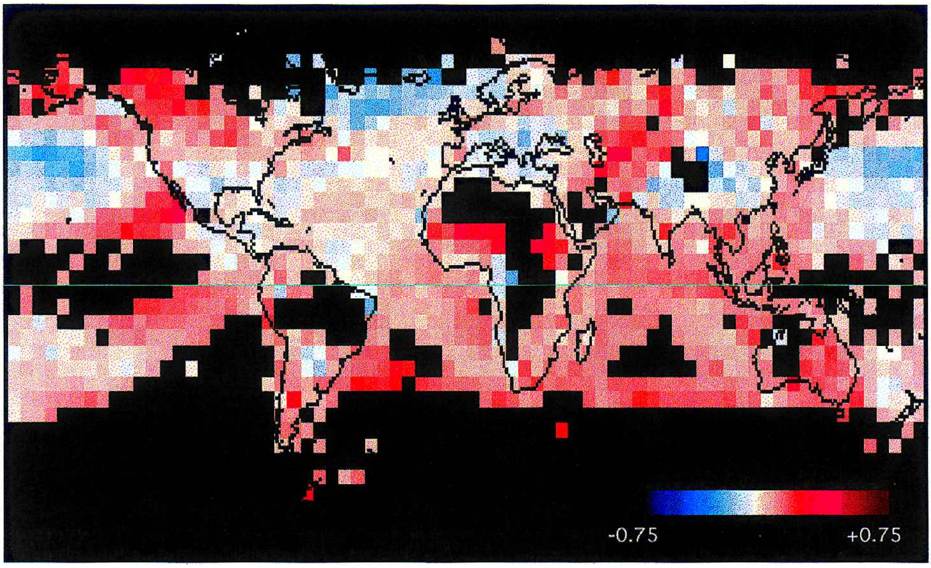


Figure 26. Warm season temperature trends, 1946–1995 (°C/decade).

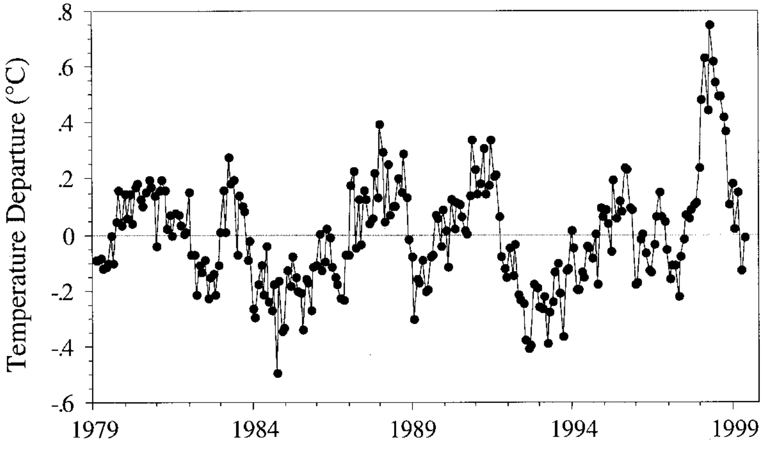


Figure 27. Global satellite-measured temperature departures.

atmosphere is a moister atmosphere (figure 26). Now we have the satellite measure temperatures, which have caused a real problem (figure 27). The satellite temperatures show no increase at all, until you blow the big warming from the El Niño into it. This is through October, and it's going to fall back down into its mean value pretty soon. In 1983, there was an El Niño. I think it was as large as the current one, but the El Chichon volcano went off here and cooled this temperature record this much. If we had that El Niño without the volcano, the temperature would have been higher there, and would have duplicated what occurred recently.

Anyway, these satellites show a very interesting record, which I'd like to show you (figure 28). Like the ground-based record, it shows that it's not a global warming. By and large, it's a warming of the winter, coldest air masses in the mid latitudes (figure 29). If you take the satellite data and divide it into five-degree latitude bands, everywhere

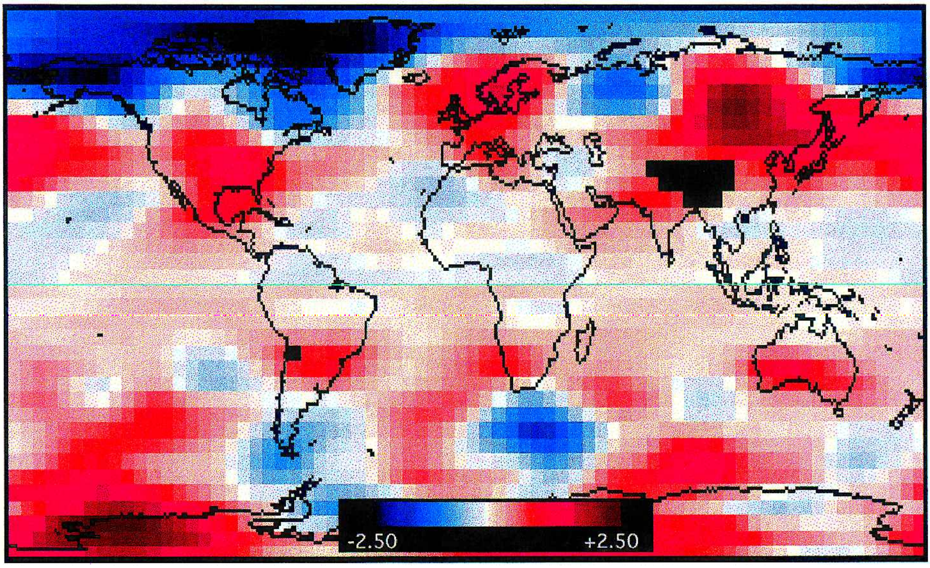


Figure 28. Cold minus warm season temperature trends: satellite-measured data, 1979–195 (°C/decade).

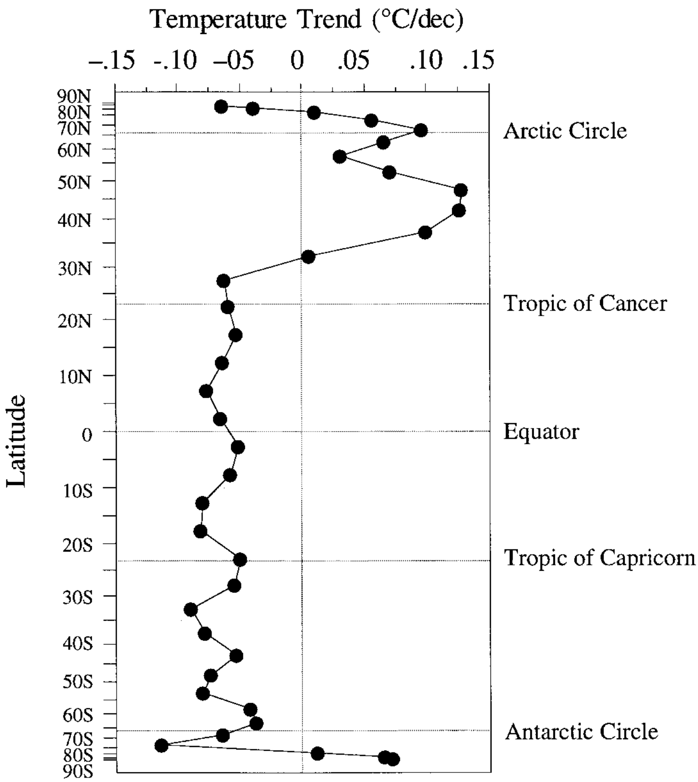


Figure 29. Satellite temperature trends by latitude.

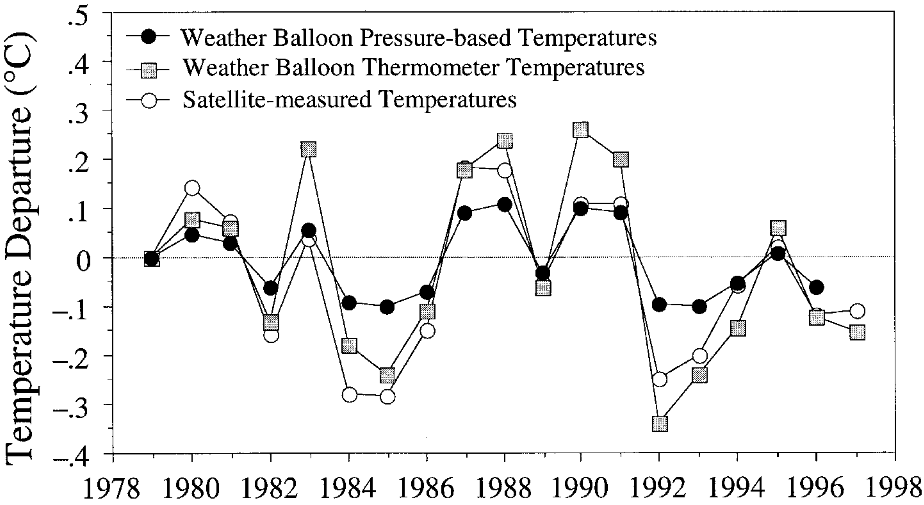


Figure 30. Three independent temperature measures of global temperatures.

to the left is cooling, everywhere to the right is warming. Warming is in latitude 25–30, 35–40. You know, there was this argument that was often made: 'All you guys were talking about global cooling a while back, and now you're talking about global warming, and we can't trust you'.

I think we're both right, I think Jim's right, I think I'm right. It's a matter of degree. There is a slight global cooling trend. Superimposed on that global cooling trend is a warming of the mid-latitude land areas, primarily in the winter. I think people did that. The problem is that when we look at the last twenty years, we don't see very much at all. We have three independent measures of temperature in the free atmosphere between five and thirty thousand feet (figure 30). They are totally independent. Every computer model predicts a large warming in this layer, unless a couple of assumptions are made, and I'll talk about them, and Jim and I will debate on them, I'm sure. Weather balloon temperatures behave exactly like the satellite temperatures, and weather balloon barometers, which measure the temperature (totally independent, separate instrumentation), find the same thing, since 1979.

Well, this argument does come down to the following.[8] It's now agreed; Jim [Hansen] agrees, everyone agrees, that the climate models that served as the basis for the Rio climate treaty, when they were forced with greenhouse gases only, predicted too much warming. The United Nations, in their latest report on the Intergovernmental Panel on Climate Change said, 'When the increases in greenhouse gases only are taken into account, most climate models produce a greater mean warming. There is growing evidence that sulphate aerosols are partially counteracting the warning'. Therein lies the problem. Science is trying to find an excuse as to why it didn't warm like it was it was forecasted. And sulphate aerosols, the emission that goes in the atmosphere along with any of the greenhouse gases, are fingered as an excuse.

I want to talk to you about sulphate aerosols. They reside in the atmosphere about five days, and then they fall out, on the average. They're produced primarily in the Northern Hemisphere. There is very little air exchange between the Northern and the Southern Hemispheres at the surface. If you're a spaceship over the South Pole, you see this big thing of ice and no land; there are no people and very, very few sulphate emissions. So if the sulphate hypothesis is true, the Southern Hemisphere should be

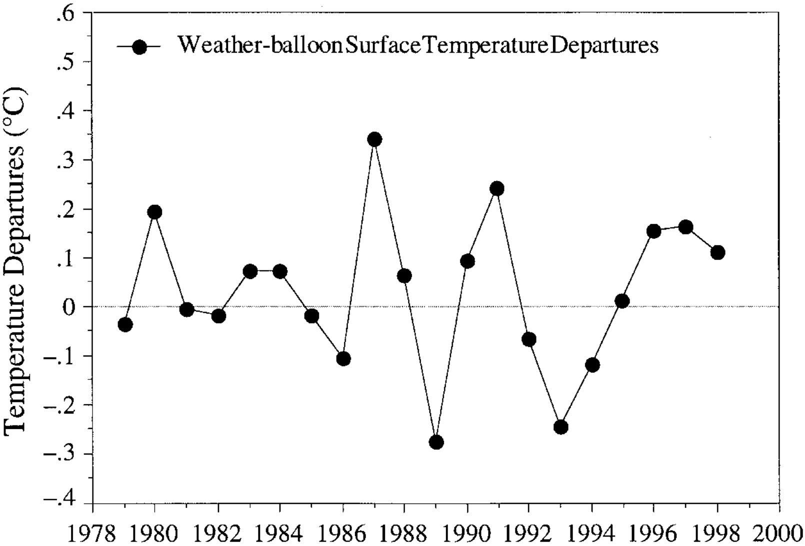


Figure 31. Weather balloon surface temperature record for southern hemisphere, 1979–1998.

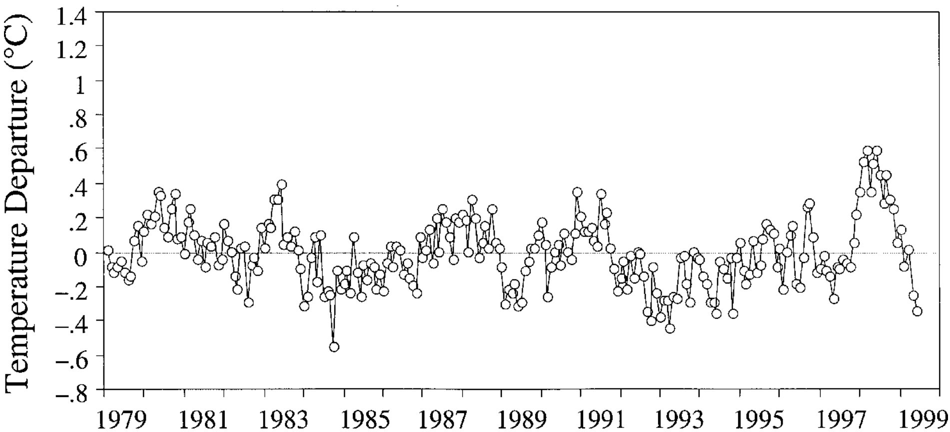
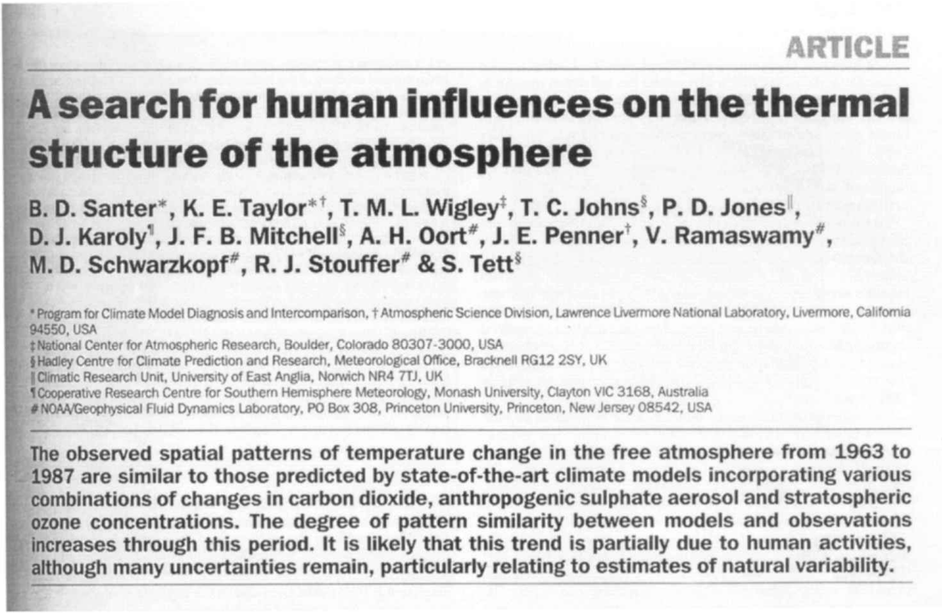


Figure 32. Satellite temperature record—southern hemisphere.

warming up with reckless abandon, because there's nothing to stop it, if the models are correct. And this is the weather balloon temperature history, at the surface in the Southern Hemisphere (figure 31). This is an extremely valuable record because the weather balloon thermistors are highly calibrated instruments. They're uniform instrumentation and they're launched from all over the Southern Hemisphere, from the South Pole, to the Kuril Islands, everywhere. And there is no warming in this record. So sulphates are not the reason that it didn't warm. And here's the satellite temperature record itself for the Southern Hemisphere (figure 32).

Here's the same thing. You see the El Niño bubble getting into the atmosphere in the latter part of the record; again, there's nothing there. Well, the problem is that the sulphate hypothesis has a great deal of currency, and it has served as sort of the last redoubt of the large warmers; It says that when you take the sulphates out of the atmosphere, we will have a major and rapid warming. Perhaps the key paper on this was published by Ben Santer *et al.* in 1996, right before an important climate change


ARTICLE

A search for human influences on the thermal structure of the atmosphere

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The observed spatial patterns of temperature change in the free atmosphere from 1963 to 1987 are similar to those predicted by state-of-the-art climate models incorporating various combinations of changes in carbon dioxide, anthropogenic sulphate aerosol and stratospheric ozone concentrations. The degree of pattern similarity between models and observations increases through this period. It is likely that this trend is partially due to human activities, although many uncertainties remain, particularly relating to estimates of natural variability.

Figure 33. This highly cited paper erroneously concluded that the sulphate-greenhouse explanation was accurate.

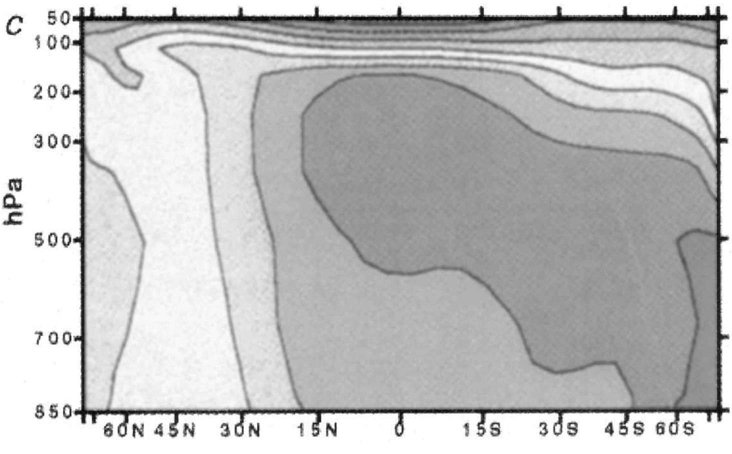


Figure 34. Warming predicted by models used by Santer et al., *1996.*

meeting (figure 33). It was a stunning paper that said that if we take sulphate aerosol and carbon dioxide and mix it in with the atmosphere, that's the way it looks—we have warming being compromised by sulphate cooling. This is the equator, this is the South Polar Region, this is the North Polar Region, this is up (figure 34).

The models said the climate should look like this. Note the large warming of the free atmosphere in the Southern Hemisphere, because there are no sulphates there. Well, how in the world could they have said that this worked that well? The study covered 1963–1987 and it prompted a number of headlines. Nobody asked a question : 'Why did you stop the study in 1987?' Because if you did stop the study in 1987, this by the way (figure 35) is the correspondence between the model and reality, from 1963 to 1987. This is the data that was used, and this is all the data that exists (figure 36).

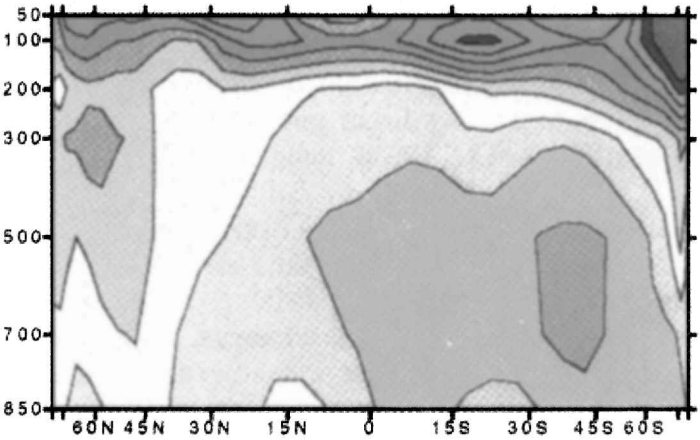


Figure 35. Observed warming in data used by Santer et al., *1996.*

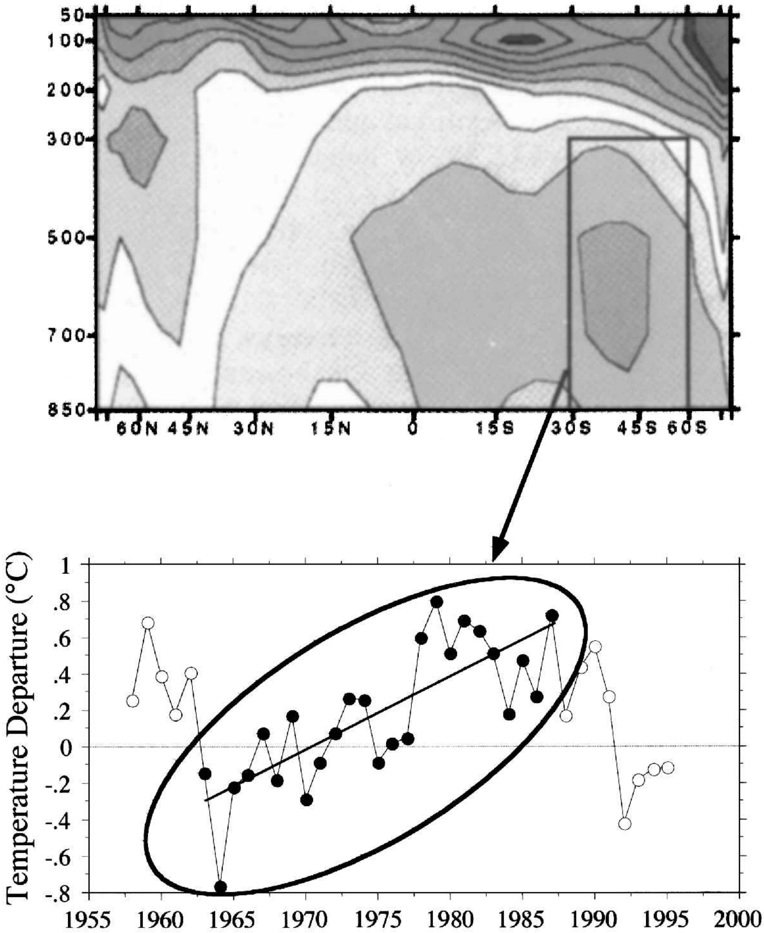


Figure 36. Complete temperature record (including data not used by Santer et al., *1996).*

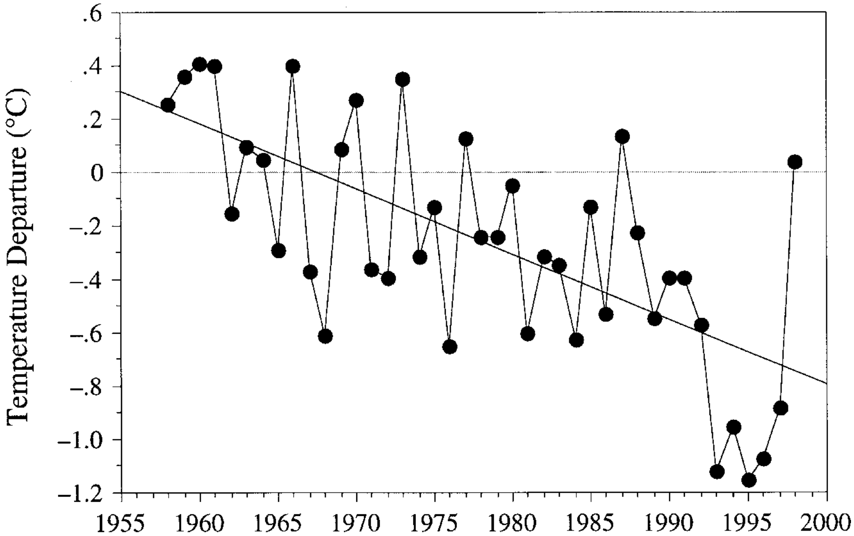


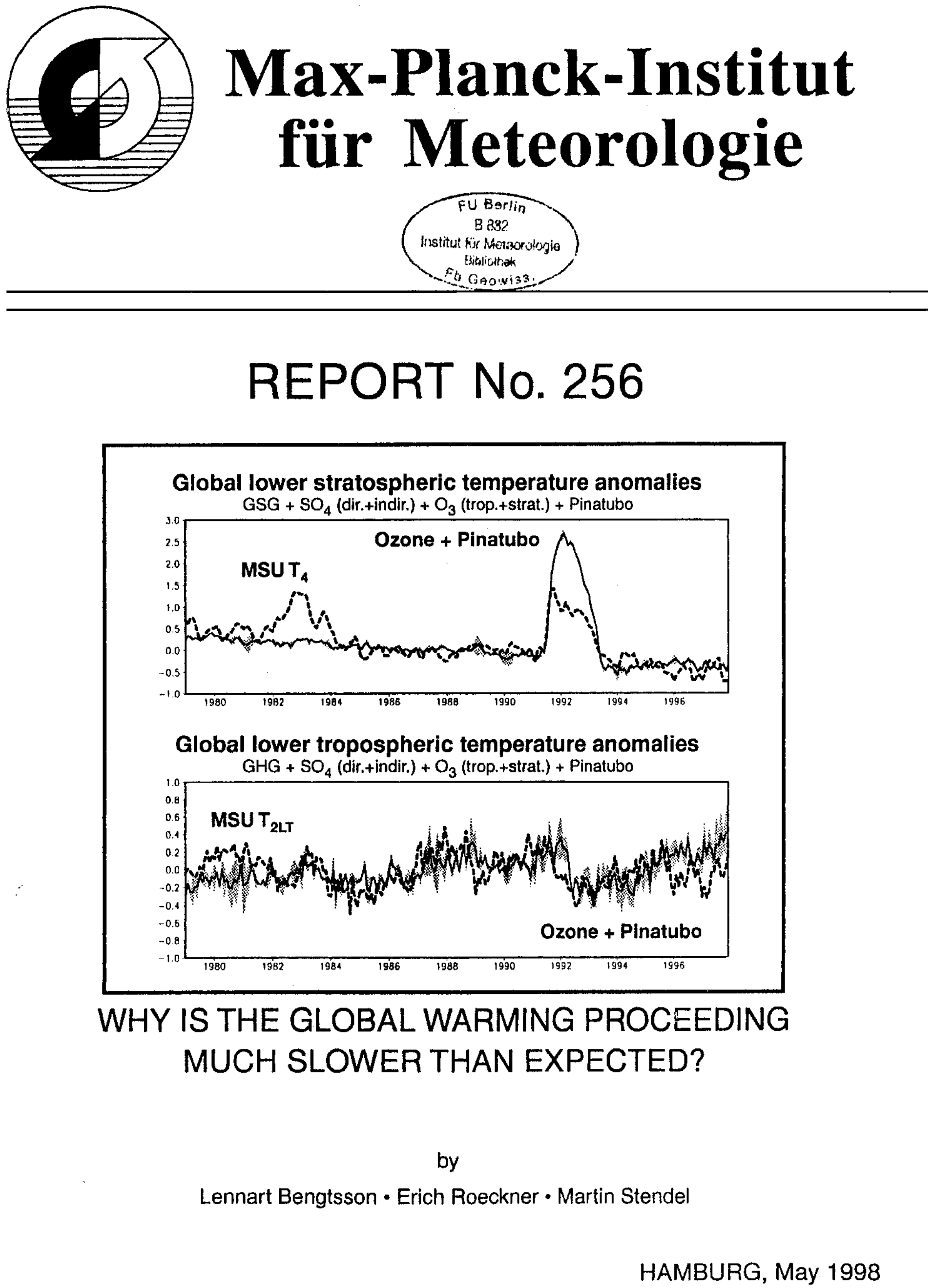
Figure 37. Stratospheric temperatures–northern hemisphere.

In other words, statements about the atmosphere responding in a way that was consistent with model X or Y are highly dependent upon the data that are chosen to examine the hypothesis. By the way, the next argument that is coming up the pike is that okay, it wasn't sulphate aerosol. The Southern Hemisphere argument is fatal to the sulphate hypothesis. One entire half of the planet with virtually no sulphates in it showing nothing. The half that should be warming with reckless abandon.

The next argument that has surfaced as an explanation is that ozone depletion is the reason that it has not warmed up, and that the cooling from ozone depletion is leaking out of the stratosphere and into the troposphere, and that's why the free atmosphere doesn't show the warming. There's only one little problem with that. Stratosphere temperatures have been in uniform decline for quite sometime, and I'll tell you why. Because of the greenhouse effect. Human beings put this stuff in the atmosphere that absorbs infrared radiation and lets a little bit less of it out through the top of the atmosphere, and the top of the atmosphere gets cold. And it's been going down uniformly *since the record begins* (figure 37). The upper air records begin in 1957, and you can see this is the pre-ozone hole, if you will, this is the post-ozone hole, the decline has been the same, so it's not ozone comprising the post warming.

Which leads us to a remarkable report that has just come out in the scientific literature, from the Max Planck Institute for Meteorology (figure 38). 'Why is the global warming proceeding much slower than expected?' I haven't seen any reports on this, but this just came out. Their response was that it is ozone and sulphates that are responsible for the lack of warming, but I want you to appreciate the dilemma that we are all in on this issue. These authors say: 'Our model says that the free atmosphere should have warmed more than the satellite and the weather balloon says' and 'The surface could have actually warmed less, therefore there's something wrong with the data'. Now, are we at the point where we trust computer models so much that we no longer bother to verify the facts? I don't think so.

I think instead we are at the following point. I am not going to take all of my time, because there are many things that I would like to be discussed here. I have many more slides, and I'm sure I will get to some of them in response. But I want to tell you what


Max-Planck-Institut für Meteorologie

REPORT No. 256

WHY IS THE GLOBAL WARMING PROCEEDING MUCH SLOWER THAN EXPECTED?

by

Lennart Bengtsson • Erich Roeckner • Martin Stendel

HAMBURG, May 1998

Figure 38.

the United Nations said in that 1995 report, and I want you to read this carefully. 'With the increases in greenhouse gases only taken into account, most climate models, the type that we used in 1988, produce a greater mean warming than has been observed unless a lower climate sensitivity is used. There is growing evidence that increases in sulphate aerosols are countering the warming'. Let's translate this statement into English.[9]

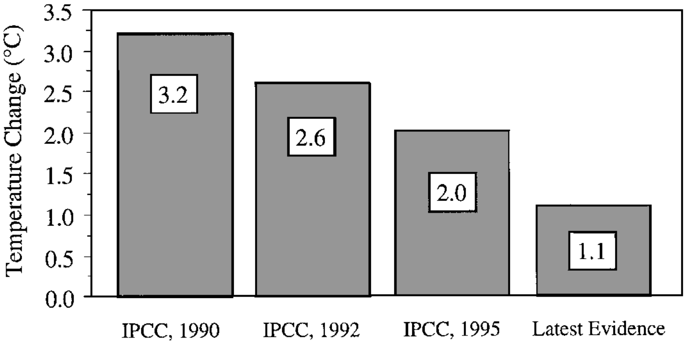


Figure 39. Best guess temperature forecasts to the year 2000.

Either it's not going to warm up as much as we said, because the sensitivity is less, or, sulphates are hiding the warming or something else is hiding the warming.

Well, we just dispensed with sulphates and ozone, and right now, we are going to dispense with a few other things. Methane, the second most important human greenhouse gas, began to level off in 1988, and is now not expected to increase in the next century. That was supposed to contribute to 30 % of the expected warming of 2·5 degrees by the year 2100. You have to take that warming out of it.

The observed post-war warming is largely confined to the cold air masses.[10] That's what I talked about in my question to Jim, the intra-to-inter annual variability of temperature is declining, and not increasing. The carbon dioxide increase is about one half of the median UN forecast.[11] Why? Jim Hansen just wrote a paper about this in the *Proceedings of the National Academy of Sciences*. He said largely because there's been an increase in uptake by the soils and the vegetation. The planet is taking out the carbon dioxide faster than it was assumed it would. Now, when we take all these factors into effect, and the last one, which was calculated by Tom Wigley from the US Centre for National Atmospheric Research, the Kyoto Protocol, the treaty to reduce greenhouse gas emissions, will have no effect on climate.[12] If every nation on the planet agreed to what it said it was going to agree to in Kyoto, the change in mean global temperature by the year 2050, if you believe the United Nations warming scenario, would be five-hundredths of a degree Celsius. You couldn't find it. The only way that you could achieve these changes in temperature under those scenarios is to reduce emissions to values that no one knows how to do economically or with any political effect. Fortunately, it's not going to have to happen. Forecasts of global warming are coming down, down, down, down, down (figure 39).

IPCC in 1990 forecast 3·2 degrees of warming by the year 2100, median scenario. By 1992 after taking into account the chloroflourocarbon treaty, they reduced the forecast to 2·6 degrees. Adding sulfate aerosols to the mix in 1995 got them down to 2 °Celsius. Now we have a lower rate of carbon dioxide increase, we know methane is not going to increase and the overall warming of carbon dioxide we know is overestimated by 15 % in the atmosphere.

We have brought the warming down to 1 to 1·5 degrees, which is exactly what the so-called 'sceptics' first testified to Congress ten years ago, as to the course of the next century. The ratio of winter to summer warming is two to one. If we have 1·5 degree warming, that gives you two and a quarter degrees of warming in the winter, and less than a degree of warming in the summer. Polar ice caps don't melt in the winter, they only melt in the summer.

Then you have the other problem, which is something we haven't even talked about, or we just touched on, mainly the gas that we are putting into the atmosphere, carbon dioxide, demonstrably makes vegetation grow better. The planet is getting greener, whether you like it or not. There is evidence all over the place that the uptake rate of carbon dioxide, some of which is from Jim [Hansen's] lab, by the way, has increased dramatically over the course of the last fifteen years, at a rate much larger than several people thought it would. So that's your problem.

What do you do about this? What do you do about one and a half degrees of warming, primarily in the winter, primarily at night, not the growing season, when it harms things. Do you do something about it, or do you do nothing? I will go gladly on the record that the best thing to do, the healthiest thing to do, is to simply do nothing, and I'll close my argument with a non-scientific but an historical reason why I believe that's true.

It's very foolhardy for human beings to try to predict, or to try to prescribe rather, the energy structure of a society one hundred years from today. One hundred years ago, the energy structure of our society was *dramatically* different than it is today. Nobody really heard of the internal combustion engine, you're riding around on horses, life span was 42, and crop yield was a mere twenty percent of it was today. All those things happened over the course of the 20th century.

In the course of the 19th century, we switched from water power to rail power, with dramatic changes in our society. I can't tell you what the energy structure is going to be like in the year 2100, and anybody who can, is not being very candid with you, or has visions that no one could possibly imagine. But I can tell you this, it will be different. I see no reason to take large expenses to reduce our economic growth now, when we know that in one hundred years that society will be dramatically different. I would rather that we didn't take money out of your pocket at all, and that you instead invest it in the energy technology of the future. Government is not a good investment, international agreements are not good investments, but you know what? There is someone in this room that is going to make a fortune off of Ballard Power Systems in Vancouver, Canada, and their fuel cell technology. I don't who it is, anyway. That's what's going to happen in the future. The best thing to do is to leave it alone, rather than to force major reductions in carbon dioxide emissions. Thank you.

[applause]

Mitchell: Let's hear five minutes of questions from Dr Hansen to Dr Michaels.

Hansen: Pat [Michaels] has raised many issues, a few of which are valid, many of which are misleading, or half truths, some of which are just plain wrong. I don't really intend to try to respond to all of those. I hope you caught some of them yourself. For example, he started out showing the results of our scenario A, even though the scenario that I used in my testimony was scenario B, and the facts show that the world has warmed up more rapidly than scenario B, which was the main one I used.

I want to ask a few questions that relate to the bottom line; I hope that these are fair questions. I know that neither of us have expertise in energy or economics, but perhaps when the audience participates, we can come back to these topics. Just after I was asked to participate in this discussion, I saw a newspaper article, that seemed relevant, about British Petroleum. BP's statement came out that announced a firm target of cutting emissions ten percent, of 1990 emissions. Of course they realised that large scientific

British Petroleum (BP) Statement

(John Browne, Chief Executive)

➜ **BP announced a "firm target" to cut emissions by 10% of 1990 levels by 2010.**

➜ **"... science of climate change is not proven... ...but there is mounting evidence that the concentration of carbon dioxide in the atmosphere is rising and the temperature of the earth's surface is increasing."**

➜ **Expected savings from: technology improvements, energy efficiency, less flaring, ...**

➜ **BP has initiated an internal program enabling units within the company to trade emissions rights.**

Figure 40. Information gleaned from a British Petroleum announcement of their chief executive, John Browne.

uncertainties remain, but they are going to take aggressive, common sense steps, introducing and improving technologies, higher energy efficiency, less flaring of gas and they plan an internal emissions trading scheme that they think will get results in the most economically advantageous way (figure 40). So my question to you, Pat [Michaels], is, do you think these guys are wackos or do they know what they are talking about?

Michaels: I do know that BP just bought Amoco and BP had very little natural gas, Amoco has a lot of natural gas and BP had a lot of natural gas to sell. Your first observation about your scenario A vs scenario B must be addressed; I view that as a question. Hansen is saying, in scenario A, that the change in total greenhouse forcing that human beings will have heaped on the atmosphere by 1995, would have been somewhere around 2·75 watts per metre squared. By knocking out the CO_2, and with the absorption of carbon dioxide that occurred as the Earth got greener than it was supposed to, the forcing drops about thirteen hundredths of a watt per meter squared. I do not believe that the warming in your computer model dropped from forty-five-hundredths a decade to twenty-five hundredths a decade, for merely changing the total forcing by less than five percent. So, I object to your objection there. Next question.

Hansen: You should look at the paper. The other difference was volcanoes, as I explained, and there was a very large 'volcano of the century' that occurred in that time period. But those predictions for the real world were published, so we couldn't have changed anything, and we happened to hit the real world on the money. My second question: I saw another article in the newspaper that raises an even more interesting question, it was from the Pew Centre, which I hadn't heard of, so I checked into what they are. The Pew Centre was established this year by the Pew Charitable Trusts, one of the largest philanthropies in the US. They're involved in preserving the environment. They have organized a business environmental leadership council, it includes as you can

Pew Center on Global Climate Change
Business Environmental Leadership Council

Air Products and Chemicals, Inc. * American Electric Power * Baxter International Inc. * Boeing Company * BP America * CH2M HILL * Dupont * Enron Corp. * Holnam Inc. * Intercontinental Energy Corporation * Lockheed Martin * Maytag Corporation * The Sun Company * 3M * Toyota * United Technologies * U.S. Generating Company * Whirlpool

➔ **"... every country.. ..needs to work to the best of their ability in addressing the climate change issue."**

➔ **"... countries that must lead the way.. ..those that emit the most, enjoy highest standard of living.. ..or have most opportunities to reduce their emissions."**

➔ **All countries should be able to maintain or improve standards of living as they work to address climate change**

Figure 41. Statements by the Business Environmental Leadership Council of the Pew Center on Global Climate Change. Membership of the Council is listed above the statements.

see twenty companies, Boeing, BP America, Enron, 3M (figure 41). Their statement says that 'every country needs to work to reduce emissions', but my question concerns the last of these points that they made, 'all countries should be able to maintain or improve standards of living' [even while reducing emissions]. So do you believe that these guys know what they are talking about? They seem to contradict what you are saying.

Michaels: I haven't seen one econometric model, even in the [Clinton] Administration's, that does not say that meeting the Kyoto Protocol does not induce significant economic damage …

Hansen: … I have not mentioned the Kyoto Protocol. By the way, I'm from Iowa, so I can assure you that Maytag is not a subversive company.

Dr Michaels: That's not the point, Jim. The point is that our own [Clinton] Administration's EIA, tells us that the cost for reducing emissions in the USA, a mere 7% below 1990 levels, will be on the order of one to one and a half percent of GDP. Perhaps these companies are smarter than they are, I don't know, but that is what the administration's figure is. I've seen much higher, but it doesn't matter …

Hansen: … Anyway, my point is that the figures of these businesses, which include major ones, are very different than yours. Okay, another question. I want to ask some questions about the potential of clean, renewable energy sources. These graphs show some examples of clean energy, renewable energy sources that do not emit greenhouse gases (figure 42). These numbers are for the world. You can see that energy from wind and photovoltaics is increasing rapidly throughout the world. In the US, they are not increasing nearly this fast, in fact at one time the US was selling almost all the devices

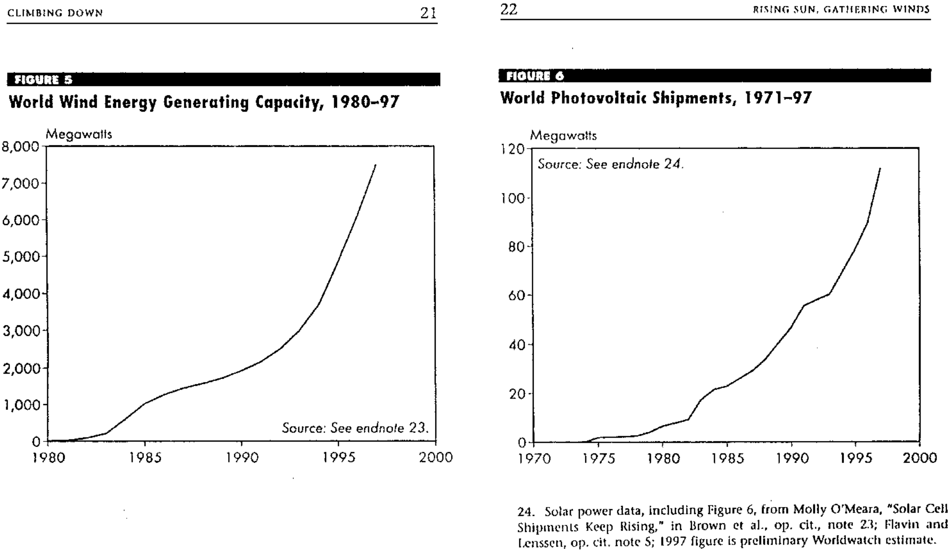


Figure 42. Data on world wind and photovoltaic energy-generating capabilities, based on Worldwatch publications of Brown, Flavin and Lenssen.

that produced power from wind. But now we only produce 30 %, probably in part because other countries take the climate issue more seriously and they are encouraging their industries. So my question concerns the potential of renewable energy. If we would encourage these sort of industries, do you think that they might provide good jobs to people, which are competitive with jobs in fossil fuels, like coal mining?

Michaels: No, the problem is that the cost of solar and wind is much higher than the cost of so-called non-renewable alternatives, and when we take money from people, to invest in these technologies that have demonstrably not proven themselves, we cost the future. How many decades Jim, have you and I been told that solar energy was just around the corner? Why don't we instead let individuals invest in energy technology in the future that will mean something? I guarantee you that whatever displaces fossil fuels, Jim, is not going to something that produces less energy for the population as a whole; it will be something that produces a lot more, cheaper. That's why these technologies are never going to cut it. By the way, wind energy is really, really ugly.

Hansen: One last question.

Mitchell: Dr Michaels, will you take one more question?

Michaels: Whatever, quick.

Hansen: You have been, at least in years past, a vocal sceptic about ozone depletion, as well as global warming. So my question is now that ozone depletion has been observed, especially the Antarctic ozone hole, and has recurred every year for more than a decade, do you still believe that the scientific warning about possible ozone depletion was a concoction of models, was a hoax?

Michaels: No, but you know, it's unfair to conflate ozone depletion and global climate change. The issues are not at all analogous. In fact, they're totally different. In ozone depletion, what we had were projections of something that would happen, and it happened, according to the early models, even larger than it was supposed to. In global warming, we have projections of warming, and the warming is *less* than it was supposed to be, so those issues are not analogous in my mind.

Hansen: You keep saying that, but the warming is not less than we calculated.

3. *Questions from the floor*

Mitchell: Now let's move into the next stage of the debate, where we entertain audience questions and just a couple comments before we enter this stage. First of all in the interest of getting as many possible questions out there, if you could, direct your questions to either Dr Michaels or Dr Hansen, when you ask them. That will facilitate moving through a large number of questions. Dr Michaels and Dr Hansen, if you would like a reply to an answer that is given by your opponent, a two-minute reply will be allowed for each question. So let me open up the floor for audience questions and please speak up and direct your questions to one side or the other, or if you want to direct it to both sides, indicate that as your preference. Any questions? Yes sir.

Audience member: A key term never got defined here, as far as I can tell. Could each of you tell us in short, plain English, what a definition is of global warming?

Michaels: Warming of the planetary mean temperature, right?

Hansen: Usually it refers to the surface air temperature, which is measured in meteorological stations two metres off the ground. The temperature is measured at that level, and you average it over the world.

Michaels: We should say a warming of the troposphere, how's that? Because the stratospheric temperature cools when you change the greenhouse effect and the real problem here is that we see warming in those very cold air masses that are trapped near the surface and once we get above 5000 feet in the last 20 years we don't see anything. If you took, Jim, with all due respect, knowing that the warming is trapped in this very small layer, if you took this warming and diffused it throughout the troposphere, all the way up to fifty thousand feet, it would be much, much less than any model had ever predicted and all models predict that the troposphere should be warming rapidly in the last twenty years, what happened?

Hansen: Pat continues to refer to a short period of time from 1979 to last year …

Michaels: … That's the only period for which we have records …

Hansen: … That's the time when there are some satellite measurements. In fact if you look at the full period, he also refers to the radiosonde measurements, which go back and measure not just the surface but the troposphere, all the way back to the International Geophysical Year. You look at the last fifty years, the warming has been just as large in the troposphere as it has been at the surface. In a short period of time there have been a number of reasons why the temperature does not have to change exactly the same amount in the troposphere several miles up as it does at the surface. But over the long time periods you'd expect the warming to be comparable in those two mediums and it has been.

Mitchell: We'll take another question, yes sir.

Audience member: Both of you can probably address this. Dr Michaels, you said that with the increase in CO_2, the planet is getting greener. Is this a good thing?

Michaels: I think so. Let me try to throw the question back on you. If we get much colder, we go into an Ice Age. If we get much warmer with the CO_2 in the air, the planet gets greener. We can't stay in the steady state. The climate itself will not stay in the steady state. If there were no human beings on this planet, we would go back into an Ice Age probably somewhere, who knows, God knows when that would happen, and it would also get very warm. And yes, I think a greener planet is a better place. See, food grows better. Sylvan Wittwer, who used to direct the National Research Council Board on Food and Agriculture, has written that the carbon dioxide increase in the atmosphere has already resulted in directly a 10 % increase in global crop yields. That's a pretty big number. That feeds an awful lot of people.

Hansen: I don't see any problem with CO_2 and growth of plants. [CO_2] certainly does stimulate the growth of plants, but basically it's giving you more carbon in the plants. It doesn't tend to increase the amount of nutrients that you have, so that whoever's eating the stuff has got to eat more of it. So I don't see a big impact. But I don't see anything negative about it. I don't think we really know, but the world has had a lot more CO_2 at times in the past, so I don't see a problem.

Michaels: With all due respect, you brought this up in your original talk, in the Cretaceous period you said the climate was 5 degrees warmer than it is today. Yes it was. The carbon dioxide concentration of the atmosphere was, depending on who you read, between four and fourteen times higher than it is today. The planet was so green that it supported the largest herbivores that ever developed in the history of the planet, the dinosaurs,and the climate was so stable that the dinosaurs were *cold blooded*. This argument about increasing variability becomes very strange when you realise that.

Hansen: If we let the world go to such a climate it would imply some drastic changes for things living on the planet …

Michaels: … 5 °Celsius, not necessarily …

Hansen: It may not bring back the dinosaurs, though …

Mitchell: Can we try another question? Yes, sir, back there.

Audience member: This one's for Dr Michaels. You seemed to talk a little bit about the free market solutions, the market incentive solutions, for finding new fuel alternatives. I was wondering if you could provide an example of any energy technology which developed itself and became commercially mass manufactured without the use of government incentives, whether they be tax subsidies or anything like that. Certainly your baseline that you continue to reference, fossil fuels, is not a good example …

Michaels: … Henry Ford did not have a government grant when he developed the automobile. Orville Wright did not have a government grant when he did this. These radically changed the energy structure of society …

Audience member: … But they weren't fuel technologies themselves, correct?

Michaels: I think you're splitting a hair.

Mitchell: Dr Hansen, would you like to speak on that? [Noting a lack of affirmative response] Okay. Let's move on to another question. Any other questions?

Audience member: I'll offer one. I would like Dr Hansen to help me out, because I'm basically on your side. But your advocate over here [Dr Michaels] is so persuasive. Could you address his point about the chart where emissions go up in the Northern Hemisphere and don't appear in the Southern Hemisphere? He made the point that the air masses of the two heads of the Earth don't communicate much. It seemed to me that you think that at that point, warming largely takes place in dry, cold, winter atmospheres. That seemed to be an important point, not being an expert on this, simply a layperson. Could you say something about that point?

Hansen: Sure, the first models that we published showed that warming would be larger in the winter than in the summer, the warming will be larger in high latitudes than in low latitudes, the warming will be larger at night than in the daytime. So all of those are confirmations of the model, rather than contradictions. Now, the point that [Dr Michaels] wants to make is that, therefore, the warming is not important because it's larger at times when it's naturally colder. But that doesn't follow. In fact, the attempts to look at climate impacts have used the model simulations which add those characteristics. So although the warming is less in the summer, it's not negligible. And you know, the thing is that the amount of warming to date is not large enough to really have detrimental effects. It's large enough to begin to be noticeable, but the point is, if you go on to doubled CO_2, and he showed these bar graphs with these things getting smaller and smaller, but as I show, the rate of greenhouse gases, even though we've had declines in methane, CFCs, it's still increasing at a rate of three watts per century. So by the end of the next century we're still going to get the doubled CO_2 climate, which is what Charney looked at, which is what people looked at and tried to understand the impacts and that is a dramatic climate change. It's taking us more than halfway from today's climate to these other extremes that we've talked about: the Ice Age and the Cretaceous. So we're talking large climate change. We really don't know how serious the impacts will be, but certainly it is something that we are not adapted to. The world has been existing the last ten thousand years in a climate that's only varied by plus or minus a degree.

Michaels: I would ask if you thought, Jim, if you took the period of October through March in the entire Northern Hemisphere, if you really thought that 95 %[13] of the warming would occur in air masses that were below freezing. Did you really think that?

Hansen: You keep quoting statistics that are very highly selective and always supporting your case. … I don't frankly agree with that 95 % number. The warming is much more pervasive than that, it's not all …

Michaels: … I'm sorry Jim, I did not make that up. It's a real number, you take all the grid cells of the United Nations climate data set, in the Northern Hemisphere from October through March, and you ask …

Hansen: … You just have to look at the data. There is data available that there is less warming in the summer than in the winter, but the magnitude of differences is not anywhere near this 95 %.[14]

Michaels: Yes it is, I will ask anyone, I will verify that for anyone who wants to see that. Very, very shortly, I will send you the data and I will show you how to find it.

Mitchell: Another question, yes ma'am.

Audience member: This is for Dr Michaels. As I was listening to your talk, I'm thinking to myself, there are probably a number of reasons, a number of justifications I could articulate, that motivate your scepticism. At the beginning of your speech, you clearly say that it seems your motivation is protecting taxpayer money and economic growth and the free market. And I was just kind of curious why those were your motivations; why they are so powerful and compelling to drive your scepticism.

Michaels: Because we have created unparalleled prosperity in this century and we have, in a way, created Marx's dream in the USA; the workers really do own the means of production. Fify percent of the people in this country own stocks, for God sakes. That's a remarkable transfer of wealth, and I am very grateful for it as a person, and I have great fears about compromising the ability of my children to pursue, and to achieve similar dreams.

Mitchell: Dr Hansen, would you like to respond to that? Another question?

Hansen: No.

Mitchell: OK, in the back, and then we'll come back up to the front here.

Audience member: I have a question for Dr Hansen, and I just thought of a little spin for Dr Michaels, as well. In the beginning of your presentation, you said that you would attempt to suggest that there was sufficient scientific evidence to reduce global warming by relying, I can't remember the exact words, entirely on the science, rather than political arguments or economic arguments. I was wondering if you thought it was possible to make a decision strictly on the scientific evidence, without considering potential societal consequences, that there is a kind of cost-benefit trade-off. Is there sufficient scientific evidence to take a given policy proposal that may have economic gains or economic losses, and both of you cursorily touched on this [by saying], well, I think this would not be economically harmful, or I think it would be. Dr Michaels, you suggested zero, that there would never be any rationale to do this …

Michaels: … The question is at this time. Excuse me …

Audience member: Can we decide this scientifically alone, or do we have to look more at the societal consequences?

Hansen: I have always said from my first public statements until now that I think we should take those steps which make good economic sense anyhow. There are a lot of ways that we could improve energy efficiency and reduce the emissions of greenhouse gases, with no economic cost. I'm not an economist, there are people who can make the argument and present the facts much better than I can. But that's one comment. I also think that we need to encourage technologies that may be needed in the next century, because it takes several decades to replace energy systems. If we start down a path in which fossil fuels are going to be the replacement fuel as oil begins to be depleted in the next few decades, and there is some disagreement on exactly when that will be, but clearly there are limitations, geologically, on the oil supply. Then we could get into a situation in which we're forced to have eventually very large increases in CO_2. And so the two things I recommend are do those things that make good economic sense anyway, and pay some attention to investing in possible long term energy sources that don't produce greenhouse gases.

Michaels: Can I respond?

Mitchell: Sure.

Michaels: I did not realize that people were so silly that they would miss all these economic advantages from this cost-free or cost-beneficial reduction in greenhouse gases. What gun is being held to their head that's preventing them from doing this? I don't know. Secondly, the government has an atrocious record in encouraging technology. I will give you an example of nuclear power, which people don't seem to think very much of. I'm sufficiently Neanderthal that I *like* it, but it costs a tremendous amount, didn't produce nearly what it was supposed to. In response to the Arab oil embargo of 1973, what we decided on was Project Independence, which resulted in the generation of large numbers of fossil fuel power plants, particularly in the Ohio Valley and upstream from the mountain-covered areas of the Eastern USA. The irony of that is that that's what's responsible for the major increase in the USA greenhouse gas emissions. That is where we get to. On the other hand, I will say it again, when there is economic incentive to produce more energy at low cost in a form that out-competes the current mix, that's going to take over the system like wildfire. I don't know what it's going to be, but unless history has been lying to us for hundreds and hundreds of years, something is about to happen out there, and it's not necessarily fossil fuels.

Mitchell: Yes, sir.

Audience member: Dr Michaels, if I got this right, you said that the amount of warming that has occurred was just what the sceptics had said …

Michaels: … No, that's not what I said.

Audience member: Oh, then I misunderstood your point.

Michaels: I said that if you adjust the United Nations projections for the fact that methane has flattened out and for the fact that as Jim has said, and Jim's right, CO_2 is not accumulating in the atmosphere at the rate that it was thought to be accumulating. If you adjust those projections, those projections are now 2 degrees by 2100. You wind up shaving them down into the range of one and a half degrees or so, maybe one and a quarter. That is what the so-called 'sceptics' testified to 10 years ago. The so-called 'sceptics' haven't changed their tune at all over the past decade and it's because the Earth is on a warming trajectory that will produce about one and half-additional degrees by the year 2100. But again, careful. So what? It's got to be confined primarily in the summer, rather than the coldest winter air masses, for that to be a meaningful figure. It's got to occur over a course of time that human beings and their systems won't be able to adapt to. I don't buy the sea level rise argument very much at all, and I'll tell you why and that will be the end of my answer. That's what always comes out, 'Well, aren't you concerned about sea level rise?' The median level sea level rise projections have come down. The United Nations is now down to 18 inches, plus or minus 9, something like that, over the course of the next century. When the Charney report came out, we were kicking around a metre, I believe, or something like that. Now, there's a place not very far from here, in which the sea level, for reasons that have nothing to do with global warming and that have everything to do with Earth tectonics, has risen a foot in the last century. Did you know that? It's in Tidewater, Virginia, and no one noticed.

Mitchell: Dr Hansen, would you like to respond to that?

Hansen: Yes. I should perhaps comment on the sea level issue. Sea level can change by much larger amounts than that. When the world was five degrees colder, sea level was about 400 feet lower. In the previous interglacial period, when it was perhaps a degree warmer, sea level was about five or six metres higher. There is enough ice on Greenland and Antarctica to raise sea level by a few hundred feet, but the thing is, it takes the ice sheets a long time to respond to the change in environmental conditions and that is the reason that they calculate only half a metre change in sea level in the next century. Those calculations are highly suspect. Those include only a 5 cm change due to the change in the ice sheets. The actual sea level rise that they calculate is based on thermal expansion of the ocean water, and some Alpine glaciers that happen to be receding globally. But the truth is that we don't know. If the climate gets a few degrees warmer, it's very possible that you have non-linear effects, you get some rainfall in the summer over the edges of the ice sheets, and it could melt much faster. So it's an extremely dangerous situation to assume that we can even calculate what the sea level change will be. We do notice that even with only a half a degree of warming this century, there has been an increase in sea level by about 15 cm. So, I'm much less sanguine about how much sea level might change in the next century. Furthermore, even if it does only change half a meter, we'll be building in a much larger change in the next centuries, because it just takes so long for the ice sheets to respond.

Michaels: But human beings respond very interestingly to sea level rise. I often hear the argument that there's major concern, and you expressed it for the Maldives, where the current mean elevation is something like three feet above mean sea level, or something like that. Assuming about a sea level rise of, well, twelve inches in a hundred years, or something like that. In fact, a lot of human beings have adapted to, and prospered to, sporadic sea level rises of twelve feet in ten minutes. They're known as hurricanes. People change their way of life gradually. If you look at the evolution of the building structures on the outer banks of North Carolina, when they realized they had to adapt to this, all they did was drive their property values up and up and up and up by building their homes on pilings. It seems to me that over a course of a hundred years, people are wonderfully adaptable to things like you're talking about.

Mitchell: Could we have another question? Yes, sir?

Audience member: I'd like to ask Dr Michaels a question, again on sea level. What do you do when the sea level rises above all the land in the Bahamas or the Maldives; how do you adjust to that?

Michaels: That's not going to happen. There's nobody that sees that.

Audience member: IPCC says that's going to happen …

Michaels: … No they don't. What do you do when the sea level rises six feet above a major metropolitan area? New Orleans is six feet below sea level, adapted to it over the course of the hundred years in which it has subsided. People do these things; it's below sea level, Bill [Stevens].

Mitchell: Dr Hansen, would you like to jump in there?

Hansen: Well, it is true that places have adapted. The Netherlands has adapted. But the thing is, that *additional* sea level rise, they're very concerned about, because if you get more saline water backing up into estuaries and rivers and things, it gets into the water supplies, there are a lot of potential problems. I think that you'd rather not have to adapt to a large sea level rise.

Michaels: Do you think the change in estuary saline freshwater boundaries in large, heavily populated regions such as Tidewater, Virginia, has not changed more *naturally*, simply because of the human use of the water system and changes in local drainage and recycling systems? You're missing the argument that somehow, people could do this down there in Chesapeake, Virginia, over a hundred years, but they can't do it anywhere else.

Hansen: Well, the change there is relatively moderate, and I know that on Long Island, planners have looked at the issue and they did express a lot of concern about that.

4. *Closing remarks*

Mitchell: Okay then, let's move on to the third stage of the debate, which is the closing arguments. The affirmative started off the debate with the opening arguments, so we'll start off with the affirmative this time and give the negative speaker, Dr Michaels, the last say in today's debate, and then we'll hear from Dr Hingstman for a brief response to finish us out. So without further ado, let me introduce Dr Hansen for a five minute closing argument.

Hansen: I'm going to demand an extra minute for reasons that I'll explain. Okay, I wanted to thank Pat for participating in this discussion with me and congratulate him for being such a dynamic speaker. Also, I want to be clear that I believe that greenhouse sceptics like Pat, Dick Lindzen and others, overall, I think they're a benefit to the science of the climate change debate. Science actually thrives on questioning and dissent and that's the nature of science. Despite that comment, that does not mean that I'm entirely happy with Pat's position. In a recent book review which I wrote in the *Journal*

Role of Scientists in Global Warming Debate

Houghton quotes Albert Einstein as saying 'The most incomprehensive thing about the universe is that it is comprehensible' and Houghton connects this with a responsibility of scientists to be stewards of the Earth. We can all agree on the need for environmental responsibility, and even relish the prospect that our research might contribute to environmental well being. But I believe that Einstein's statement is more a marveling at the fact that it is possible, at least to a degree, to figure out how the world works. This marvel, and the implied fun and excitement in research, drives scientists in their pursuit of understanding. The essence and the beauty of iterative scientific inquiry is its logic and objectivity, and its success depends upon open-minded unbiased interpretation of each new piece of data.

Injection of environmental and political perspectives in midstream of the science discussion cannot help the process of inquiry. I believe that persons with relevant scientific expertise should concentrate, with pride, on cool objective analysis, providing information to the public and decision-makers when it is found, but leaving the moral implications for later common consideration, or at most for summary inferential discussion. I am not implying bias on the part of any particular scientist. But the global warming debate has plentiful examples to illustrate my thesis, especially, at least on a per capita basis, among the most vociferous greenhouse 'skeptics', i.e., those who challenge the reality or interpretation of global warming. Many of the participants in this debate have ceased to act as scientists as defined above, but rather act as if they were lawyers hired to defend a particular perspective. New evidence has no effect on their preordained conclusions. This is abhorrent to science and spoils the fun of it.*

* Hansen, J., 1998: *J. Atmos. Chem.*, **30**, 409-412 [Book review of Sir John Houghton's Global Warming: The Complete Briefing, Cambridge University Press].

Figure 43. Role of scientists in global warming debate.

Key Differences with Skeptics

1. Observed global warming: real or measurement problem?

Hansen: global warming is 0.5- 0.75°C in past century, ≥ 0.3C in past 25 years.

Lindzen: since about 1850 ".. more likely .. 0.1±0.3°C" (*MIT Tech Talk*, 34,#7, 1989)

2. Climate sensitivity (equilibrium response to 2×CO_2)

Lindzen: ≤ 1°C **Hansen: 3±1°C**

Comments: paleoclimate data, improved climate models, and process studies may narrow uncertainties; observed climate change on decadal time scales will provide constraint if climate forcings are measured; implicit information on climate sensitivity can be extracted from observed changes in ocean heat storage.

Figure 44. Key differences with sceptics.

of Atmospheric Chemistry, I offered some criticism of both extreme sides in this debate (figure 43). I asserted that some participants in this debate have ceased to act as scientists and rather have acted as if they were lawyers, hired to defend a particular perspective. New evidence has no effect on their preordained conclusions. This is not only abhorrent to science, but it spoils the fun of it. I think the beauty of scientific inquiry is its logic and its objectivity.

I must also say that I'm afraid that this debate forum is not well suited to evaluating scientific issues. It depends too much on rhetorical skills rather than scientific merit. So how can I deal with this? We can't solve the scientific issues here. What I can do is list the scientific questions to try to pin down the sceptics, because the scientific community can decide these issues over the next several years. I made such a list a few weeks ago for

3. Water vapor feedback

Lindzen: negative, upper tropospheric water vapor decreases with global warming
Hansen: positive, upper and lower tropospheric water vapor increase w global warming

References: (these include references by Lindzen stating that, in response to global warming, water vapor will decrease at altitudes above 2-3 km)

Comment: accurate observations of interannual changes (several years) and long-term changes (1-2 decades) of upper tropospheric water vapor could provide defining data

4. CO_2 contribution to the ~33°C natural greenhouse effect

Lindzen: "Even if all other greenhouse gases (such as carbon dioxide and methane) were to disappear, we would still be left with over 98 percent of the current greenhouse effect. Cato Review, Spring issue, 87-98, 1992; "If all CO_2 were removed from the atmosphere, water vapor and clouds would still provide almost all of the present greenhouse effect." ***Res. Explor.*** **9, 191-200, 1993.**

Lacis and Hansen: removing CO_2, with water vapor kept fixed, would cool the Earth 5-10°C; removing CO_2 and trace gases with water vapor allowed to respond would remove most of the natural greenhouse effect.

5. When will global warming and climate change be obvious?

Lindzen: I personally feel that the likelihood over the next century of greenhouse warming reaching magnitudes comparable to natural variability remains small.

Hansen: "With the climatological probability of a hot summer represented by two faces (say painted red) of a six-faced die, judging from our model by the 1990s three or four of the six die faces will be red. It seems to us that this is a sufficient 'loading' of the dice that it will be noticeable to the man in the street." ***J. Geophys. Res.*** **93, 9341-9364, 1988.**

6. Planetary disequilibrium

Hansen: Earth is out of radiative equilibrium with space by at least approximately 0.5 W/m^2 (absorbing more energy than it emits)

Comments: This is the most fundamental measure of the state of the greenhouse effect. Because the disequilibrium is a product of the long response time of the climate system, which in turn is a strong function of climate sensitivity, confirmation of the disequilibrium provides information on climate sensitivity and an indication of how much additional global warming is "in the pipeline" due to gases already in the atmosphere.

This disequilibrium could be measured as the sum of the rate of heat storage in the ocean plus the net energy going into the melting of ice. Existing technology, including very precise measurements of ocean and ice sheet topography, could provide this information.

Figure 44. (*cont.*).

a discussion with Dick Lindzen and then they changed the format, so I didn't have a chance to show them. Today I was told there was going to be a viewgraph machine here, so I brought the same list with me, and now they tell me that there is no viewgraph machine. But I nevertheless would like to quickly list those and that's why I need the extra minute. I'm going to have to just quickly say these, because I'd like to make them part of the record (figure 44).

The key differences with the sceptics: first of all, was that on observed global warming, that there's a measurement problem. I've said it's between half a degree and three-quarters of a degree. Dick Lindzen published that it was about one-tenth of a degree, plus or minus three-tenths of a degree, and I have a reference for that. Climate sensitivity: I say it's about 3 degrees (by the way, these are made up for Lindzen, I didn't have time to change them). He says it's less than one degree for doubled CO_2. Water vapour feedback, he says it's a negative feedback, while I say it's a positive feedback. Carbon dioxide contribution to the 33 °Celsius natural greenhouse effect that exists on our planet now, he says that less than 2% of that 33 degrees is due to CO_2, while I say a large fraction of it, more than ten degrees, is due to CO_2. When will warming be obvious? Lindzen says, 'I personally feel that the likelihood over the next century of greenhouse warming reaching magnitudes comparable to natural variability remain small', while I've argued that, as I've showed, it will begin to be noticeable on a seasonal mean basis in the 1990s, or soon thereafter. Now the most important point of planetary disequilibrium, where I make the argument that the planet is out of radiation balance with space by about half a watt per meter squared, or larger, This again is something that can be determined. These are the fundamental scientific issues, and they really need to be decided in a scientific way and we can make progress on those in the next couple years.

Now let me go to my last affirmative closing argument.[15] I'll say that the scientific community has looked at the greenhouse issue for a long time, with major reports over at least two decades, from the Charney report, through the IPCC reports. The vast majority of the relevant scientific community believes that even though it is a very complicated issue, with many uncertainties, the evidence is compelling enough that we should take steps to slow down the experiment, while we try to understand it better. Perhaps the most important point is that we should encourage competing technological developments. It takes, as I said, decades for energy infrastructure to be developed and replaced.

Let's see, I'll skip my call for research. I do want to finally mention, though, scientific education. I think that all students don't need to be scientists, but they should recognize the difference between astrology and astronomy, even if they enjoy using horoscopes. Students and the public need to have an accurate perception of how research works, so that they can participate well in the decision-making process. Climate itself, I think is a good topic to include in general science classes, and it has a lot of potential for teaching.

One other point that you might think about. If Pat were right, if his criticisms were valid, then why wouldn't he publish these in a refereed scientific journal? Because that's the ultimate success for a scientist. If he had valid evidence that I was wrong, it seems to me it would be a feather in his cap to show that our model calculations had actually overstated warming, which is what he has asserted. Now, I'm not a famous scientist, but I am a member of the National Academy of Sciences and so it seems to me that that should be a nice trophy for him, to prove me wrong. I think the answer is that he knows his charges can't pass scientific review. He's an excellent debater and he's honed a number of statements that sound good, but many of them are not scientifically going to pass review.

[applause]

Mitchell: Okay, Dr Michaels, now you'll have one extra minute for your closing argument.

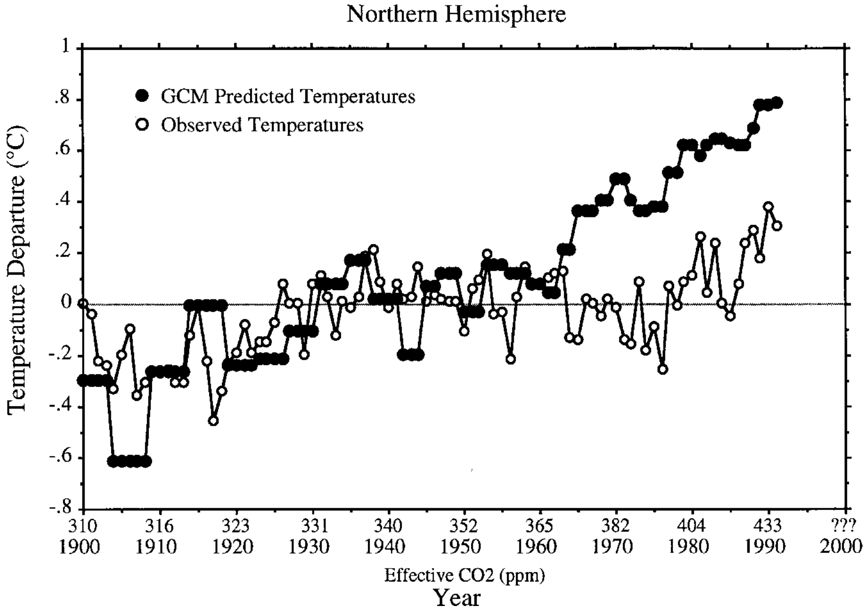


Figure 45. Climate model forecasts vs observations.

Michaels: That's fine, I won't need it. I must say that I object to the last statement by Hansen. I'd be happy to supply you my CV, with all my refereed articles on this subject. Unless you consider publishing in *Nature*, *Science*, *Journal of Geophysical Research*, *Climate Research*, *Geophysical Research Letters*, and just about every other journal I can think of in the last five years, I think you [Dr Hansen] owe me an apology. But that's okay.

Here's the problem. I was looking for a slide like this in my deck today and, unfortunately, I couldn't find the one that I wanted, so you're going to have to bear with me. This is a typical climate model that served as the basis for the Framework Convention on Climate Change, the models that did not have artificial cooling induced in them by sulphate aerosols (figure 45). The difference between the models and reality is large, and growing. What we did was, we put sulphate aerosol in the model, as an attempt to come up with an explanation for a lack of warming. I don't know where Jim [Hansen] is talking about this, but if you look at *Nature* magazine on 13 December 1996, you would see the argument that the sulphate hypothesis did not work and the response to that argument admitted that we had a point that would not change the conclusions. Thank you very much. Sulphates don't explain the lack of warming.

What does explain the lack of warming is when models have a reduced sensitivity to climate change. Here is the latest model from the US Centre for Atmospheric Research (figure 46). It shows a temperature change, when we run the model out for the next hundred years, of about 1·8 °Celsius. However, this model assumes that the increasing carbon dioxide forcing is effectively at 1 % per year. Dr Hansen has just published a paper, which I agree with, [stating] that the rate of the increased forcing is much less than that. So you have to reduce the forecast of warming to somewhere around one and a half degrees for the next century. When you do that, and you realise that the ratio of winter to summer warming is two to one, (published in the journal *Climate Research*, in April, by me) and the variability is declining, (published in the same journal a month before, by me), that leads you to the conclusion this problem was overstated, which is

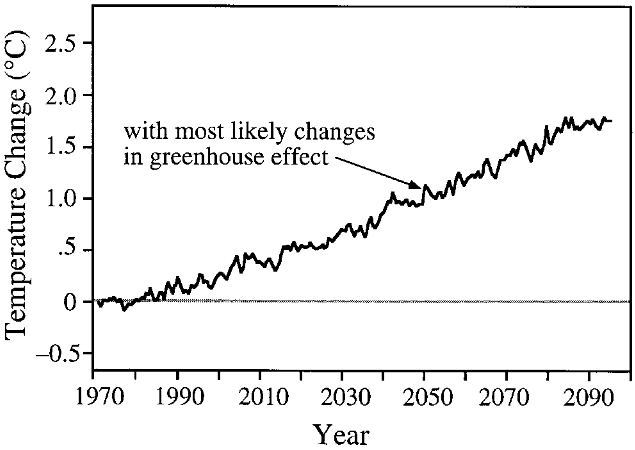


Figure 46. Global tempertaure change (from NCAR 1999).

good, because it means that there is time for the technologies to develop that will naturally develop over the course of the next one hundred years. If *only* we'll get out of the way and *let it happen. Thank you.*

Mitchell: Now for the fourth and final part of the debate, please welcome Dr David Hingstman from the University of Iowa for a fifteen minute reply from a rhetorical perspective.

Hansen: Could I say however, that I did not mean to denigrate Pat's science. I mean, he has published in scientific journals. My comment was with regard to his assertions that our models have overstated the warming, when in fact they were on the money. Actually, I meant to be complementary; I think that your [Dr Michaels'] contribution to this debate is positive and useful to science.

Michaels: Jim, with all due respect, I wrote an article awhile back, which we sent, that showed this disparity that was in one of these slides. I got the review back from *Science* magazine, I should have brought it with me. It said, 'The modellers know this error is there, there's no reason to publish this'. *There* is a model that corresponds more to reality and it has a lot less warming. Now if your model corresponds to reality *and* that model corresponds to reality, and that model has half as much warming…

Hansen: That's not my model, but…

Michaels: …That's NCAR's CCM3.

Hansen: …The very interesting thing was, you actually wrote scenario A on our model result, but you took it from a graph which had a scenario B and a scenario C, and you *removed* those, you only showed scenario A.

Michaels: Again, the discussion we had earlier was that the change in that greenhouse forcing over the last ten years between those two scenarios is so small, that if your model is producing half as much warming with that change, it is dynamically unstable.

Hansen: Anyway, sorry.

5. *Respondent*

Hingstman: Thank you, gentlemen. I'm Dr David Hingstman of the University of Iowa and I am pleased to be here this evening to see such an outstanding example of scientific argument in the public sphere. It's not often that we rhetoricians get the opportunity to see our subjects in the flesh, and so we want to thank them for giving us something to study.

Audience member: Hear, hear.

[applause]

Hingstman: Now, you can call me Aristotle, or maybe you can call me Cicero, because I think that in this debate, a lot of what was interesting had to do with points of *stasis*. But before I get into that, I wanted to try to give them [Dr Hansen and Dr Michaels] an indication of where some of us [in the field of rhetoric] might be coming from and in particular, what kinds of questions we would look at in evaluating both the quality of your performance tonight, and maybe the broader social significance of what we think you folks are up to.

I think most of us in this room believe in the possibility of practical reason, that scientific work can be discussed in public settings of risk assessment and action. We think you agree, or I don't think you would be here tonight. We also assume that there are shared meanings for some key terms and that the results of scientific research can become a relevant part of argument that is pointed toward social action. We are particularly concerned, I think, with the warrants that connect scientific hypotheses, data and the interpretation of data, with recommendations for action and so that will be part of the focus of my statements tonight.

We are also suspicious and aware of the fact that the demands on you from the media to simplify and to make your messages more accessible could result in systematic distortions in both the direction and the quality of social discourse on this issue. But what we appreciate from you tonight is a recognition that there are in fact two sides to this question, because sometimes we wonder whether the media believes that, that they prefer to think that it's one side one day, and another side the next day, and they never engage the controversy. I did a paper a couple of years ago where I talked about the seemingly annual debate about whether short-term weather phenomena had anything to say about the probability of global warming. To me, that was an example of the kind of distortions that the media can impose.

Let me try to discuss some of the questions that some of us in the audience might look at after having a chance to hear you tonight. The first one came out very well in several points during the debate and that is the distinction between a scientific discussion and a political discussion, that whether what we're talking about is purely scientific, purely political, or [deals with] questions that lie somewhere in between. So what I have done is to take a little time to try and create a kind of progression of activities that could be characterized as being either science or politics and I'll leave it up to you to decide how it relates to some of the things you've heard tonight:

- Taking measurements and constructing hypotheses. Pure science?
- Interpreting data. Pure science?
- Making projections.
- Publishing data in a scientifically respectable place and having that research accepted, peer reviewed.

- Gaining support for and reviewing programs of research within institutions of higher learning, or government institutions.
- Publicizing the results of research to the media.
- Attributing motivations to others who are participants in a scientific debate.
- Testifying as to questions of scientific fact in deliberative settings such as a congressional hearing.
- Making recommendations for action.

At what point can you say that science ends, and politics begins? That's a question that we're fascinated with. When you gentlemen talk about 'logic and objectivity', when people cease or begin to act as 'scientists, and not as lawyers', that it is 'the nature of science to allow dissent to flourish', we take your performance tonight and we read that performance against claims like this and, sometimes, we may come up with some very interesting and disturbing answers to that question, which I don't have time to go into tonight. But again, thank you for giving us the opportunity to ask that question.

Another kind of question that a lot of us are interested in is: what does your performance tonight tell us about standards of evidence and how they relate to the intersection between science and politics? Significantly, neither of you wanted to address the question directly of what constitutes *su cient* evidence for justifying action. So that's a question that we might well take up in some of our own work. Should we apply the standard of the null hypothesis? Should falsifiability be the standard of evaluation in this debate? Should we go on the basis of scientific consensus (that was suggested at several points in the debate)? Should we go on the *preponderance* of evidence, or the visibility or force with which certain examples or statistics are presented? Finally, is there a relationship between the standard of evidence and contingencies of action? In other words, are your arguments about risk and irreversibility, and the costs of having to take action, related to the standard of evidence that we should apply in order to determine sufficiency?

A third area that we're interested in are questions of advocates' responsibilities. Again, I think there are a number of instances tonight where we have a lot of food for thought. For example, what is appropriate caution in the magnitude of the claims that one makes on the basis of the data and your interpretation of that data? Both Dr Hansen's statistics about the probability of the rate of future warming, and Dr Michaels' objections to them, require selection of evidence. You two quarrelled, to some extent, about how to select that evidence. That's an issue we're very interested in examining. Another question is the question of the scope of predictions. The global climate debates have relied on General Circulation Models, and other computer-generated predictions. How does one decide what an appropriate scope of prediction is in a debate like this, given that we're dealing with predictions that are over a century [time period]? You both addressed the question of where presumption should lie, with different conclusions. One [Dr Hansen] said that since we don't know, it's only common sense that we take precautions. The other [Dr Michaels] said that since we don't know, and our past predictions about technology have been poor, that we shouldn't rely on such predictions based on historical evidence. We're very interested in those questions. Also, the accuracy and the effects of certain attributions of motivation for the way in which you interpret data, present data in a hearing and so on, is a question that is very interesting to us. To what extent should an advocate be allowed to change his or her mind as a result of accumulating data, or changes in the debate? If you go over the history of the climate debate, you will see that there is great change in what arguments have received emphasis.

I coach debaters and [use] books like this [holding up a copy of Brian Prestes' handbook, *Debater's Climate Guide*]. We also have stacks of sheets that chronicle the history of the climate debate. If you go through the table of contents of things like this, you see [chapter headings such as]: Global warming is occurring, the extent of the warming, positive feedbacks, causes of global warming, agriculture, ecocide, sea level rise, water wars, disease, whether various measures such as tradable permits, clean technologies, etc. will have any effect. It seems like a few years ago, the debate was not so much about the pace of warming, as whether other feedbacks and offsets, like sulphur dioxide and ozone depletion, would actually counterbalance the warming effect, and that has changed substantially. So the question is, with the pace of science both dictating what is a consensus belief about science and, also, which issues are most important to discuss, can an advocate change emphasis without being accused of bad faith? Tonight's debate allows us to ask that question.

Another question we're interested in is the rhetorical strategies [involved] in the use of physical analogies. I remember seeing Dr Hansen's article with the loaded dice and I think that's a two-edged sword, because loaded can also mean assumptions that one has to question. We wonder, when looking at the graphs that Dr Michaels provides us, and in analogies like the loaded dice, whether or not those physical analogies hide more than they disclose, or whether they disclose more than they hide.

Questions about the scientific methodology, and debates about methodology, are also very interesting to us. When Dr Michaels indicted the Southern Hemisphere studies on the ground that they chose an inappropriate cut-off date, that kind of rhetorical strategy also interests us a lot. Where do you stop in the regress to challenge methodology? To us, that is a rhetorical decision that a scientist-advocate has to make.

Finally, [consider] the question of what constitutes expertise in the various contexts in which arguments occur. You'll notice that the advocates went forward to make recommendations about action, and then retreated on the question of economic feasibility, by saying, 'This is not our area of expertise'. So the question we're interested in, is what does constitute such expertise? Since advocates in the climate debate often rely on the work of other scientists, again the question becomes, when is it appropriate to claim expertise and when is it important to disclaim expertise? That is a rhetorical question that we're very interested in.

Finally, the question of multiple audiences. This very debate tonight is a multiple audience debate, because not only do we have the members of our audience here, who presumably have some familiarity with the arguments that have taken place in the climate debate. We also have a camera recording this. The tape of this debate tonight will go out to many other audiences, probably to some of the students that Dr Hansen was concerned about when he talked about science education. So the question that we're interested in, is how do you decide where to start, and where the appropriate points of *stasis* are, when you're dealing in a situation with multiple audiences. That's particularly important to us as scholars of rhetoric of science, when we go back to the question of what happens to scientific argument when subjected to the pressures of media coverage. So, the question we would want to think about in your performance tonight, would be, how did you decide where was the appropriate place to start and how did you decide where the appropriate points of *stasis* were?

Let me sort of suggest where I think the major points of *stasis* were in this debate and you can agree or disagree with me. On the question of fact and definition, it seems to me that there were two major points of *stasis*. On one side, Dr Hansen is saying that global warming is occurring, and that it is primarily attributable to a rise in greenhouse gases. Dr Michaels, on the other hand, is replying that there is no *harmful* warming occurring, that it is not global, but regional, and that it is also differentiated in time. It is a winter/summer phenomenon and presumably winter warming is not harmful. Now, it is possible that Dr Hansen might be able to come back and say that certain species are affected by changes in winter temperature, or certain plants. We didn't have time to get into that question tonight. Also, Dr Michaels suggested that variability is decreasing, and that's good, in connection with the agriculture argument.

We also have to question and I think this is just as important as the question whether or not global warming is occurring, on what basis do we make long-term predictions and what is the risk that we face? Dr Hansen says that since climate forcing takes a long time in order to engage, there is a possibility of runaway effects from large rises in temperature that may occur in the next century. Dr Michaels responds that the rate has been slower than previously predicted, for a number of reasons which he set forth and that justifies the belief that the warming rate will be slow, and that it will be no more than 1·5 degrees by 2100.

There's also the *stasis* of quality, or action. Dr Hansen is saying that, and this is implied, given the irreversibility of climate effects, given the possibility of runaway impacts, it is only a common sense measure to invest in renewable technologies and energy conservation, and other measures to adapt to changes in climate that are already taking place, and of course scientific education. Dr Michaels, on the other hand, [is] arguing that common sense measures will fail, they're not enough to overcome the effects, we cannot predict whether global warming is reversible or not, and given the cost of making these changes, we should do nothing.

Finally, there was a point that Dr Hansen got to at the very end, about the suitability of this forum in order to make decisions, suggesting that the rhetorical skills of the advocates become more important than scientific merit, and that Dr Michaels needs to publish in scientific journals. Dr Michaels responded that, of course, he does publish in scientific journals and you can check his CV. But he did not choose to contest directly the question of whether it's appropriate to decide this question on the basis of rhetorical skills, perhaps believing that ability is enough of a guarantor.

So, gentlemen, these are the kinds of questions that we put to your performance tonight. But we know, perhaps as well as anyone does, how difficult it is to engage in these kinds of performances, so I hope that the suggestions and questions I've offered tonight will be taken in the spirit of investigation in which they're offered (as you can see, I can be as much of a rhetorician as you can), and that you will continue to do your good work, and allow us to do our work as well. But we are ready to hear your criticisms of our questions as well. Thank you, and good night.

[applause]

Mitchell: Thank you, Dr Hingstman, for those fine remarks, thank you all for coming.

Notes

1. Hansen displayed a slide that stated the debate proposition.
2. Hansen displayed a slide titled 'My Opinion', previewing the major positions he intended to take in the debate: (1) climate is changing (global warming); (2) human (greenhouse gas) role is probable; (3)

global warming increases hydrologic extremes (droughts/fires and heavy rain/floods); (4) with large climate change, detrimental effects probably exceed beneficial ones; (5) common sense steps to limit climate change are warranted.

3. Hansen displayed a slide titled 'Senate Testimony, 1988 & 1989', summarizing the main points he made during that testimony: (1) global warming underway (99 % confidence), (2) probably due to greenhouse effect (high confidence), (3) model predicts increasing frequency of extremes: (a) high temperatures, droughts, fires (b) heavy rain, floods.
4. Hansen displayed a slide titled 'Summary Statement', containing a review of the major points he had made in his opening presentation: (1) empirical evidence: climate sensitive to forcings; (2) greenhouse gases increasing rapidly; (3) global warming observed and consistent with expectations; (4) large uncertainties regarding future climate change; (5) impacts of climate change uncertain, but we are adapted to current climate; (6) common sense strategy: slow down the planetary experiment and adjust strategy with experience; (7) many opportunities to slow the global experiment exist (e.g. energy efficiency, renewable energy technologies).
5. Michaels revised the ending point of this date range to 1997 during transcript editing.
6. Review of this calculation for publication in the refereed literature revealed a miscalculation of this figure. A total of 78 %, not 95 %, of the total winter half-year post-war warming is confined to the very cold air masses of Siberia and north-western North America. These comprise 26 % of the area with reliable data, meaning that over three-quarters of the warming is confined to one-quarter of the area.
7. This 95 % figure was later revised to 78 %. See note 6.
8. Michaels displayed a slide entitled, 'The Current Paradigm', which contained the following quotation from the IPCC in 1996: 'When increases in greenhouse gases only are taken into account… most GCMs produce a greater mean warming than has been observed to date, unless a lower climate sensitivity is used … There is growing evidence that increases in sulphate aerosols are partially counteracting the [warming] due to greenhouse gases'.
9. Michaels displayed a slide entitled, 'The Current Paradigm (in English)', containing the following list: '(1) Either its not going to warm up as much as we said, or, (2) Sulphates are hiding the warming, or, (3) Something else is hiding the warming'.
10. Michaels displayed a slide that featured two citations: 'Observed post-war warming is largely confined to winter in the cold continental airmasses (Balling *et al.* 1998)' and 'Intra- and inter- annual variability of temperatures have declined significantly (Michaels *et al.* 1998)'.
11. Michaels displayed a slide that featured one statement and a citation: 'Carbon Dioxide Increase Around One-Half of UN Median Forecast' (Hansen *et al.*, 1998. A common-sense climate index: Is climate changing noticeably? *Proceedings of the National Academy of Sciences*, **95**, 4113–4120).
12. Michaels displayed a slide that contained two statements and citations: 'methane began to level in 1981 and should not change in the next century (Dlugokencky *et al.* 1998)' and 'he Kyoto Protocol will have no discernible impact on global temperatures by 2050 (Wigley 1998)'.
13. This 95 % figure was later revised to 78 %. See note 6.
14. This 95 % figure was later revised to 78 %. See note 6.
15. Hansen displayed a slide summarizing his major points: '(1) There is strong basis for concern about human-made climate effects, but there are also many scientific uncertainties; (2) Evidence sufficiently compelling to warrant slowing down the 'planetary experiment' by reducing greenhouse gas emissions'; (3) Common sense strategic approach—invest in: alternative energies and energy efficiency, research reducing uncertainties, public science education/how research works, adjust policies as we learn'.