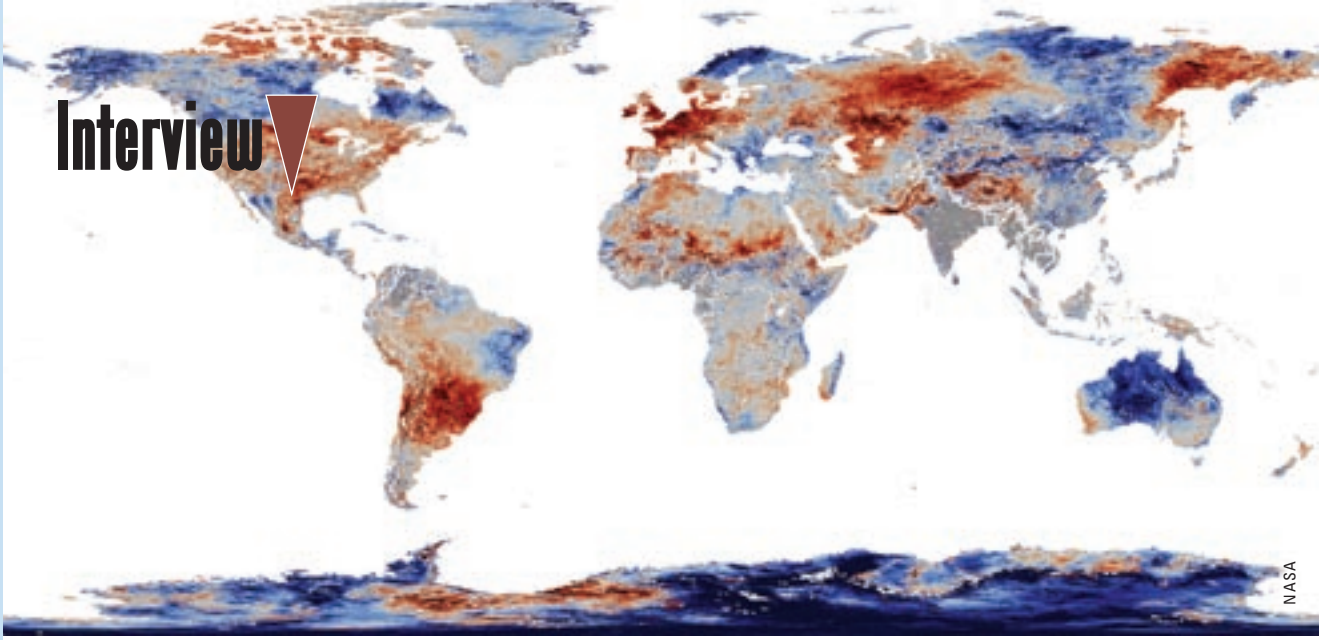
Interview



NASA

This satellite image compares July's temperatures with those of the past 6 years. The deep red tells a simple story: July was hot!

The Many Travails of BEN SANTER

One of the world's leading climate modelers has long been a target for contrarians and climate skeptics.

PAUL D. THACKER

For well over a decade, climate skeptics undercut the science on climate change by citing satellite temperature records, which showed that the atmosphere was not warming. But all of this changed in August 2005 when three papers published in *Science* (**2005**, *309*, 1548–1551; 1551–1556; 1556–1559) showed that the satellite data were not as accurate as people had reported. When the data were corrected for problems such as satellite drift, researchers found that the earth's atmosphere has been heating up.

Last May, scientists reached a consensus on the issue in a report by President Bush's Climate Change Science Program (CCSP). The planet is warming, scientists concluded, and the satellite data now show this as well. One of the report's lead authors is Ben Santer, a world-class climate scientist.

Santer normally maintains a low profile as a climate modeler at the U.S. Department of Energy's Lawrence Livermore National Laboratory (LLNL), but he does have a knack for popping up in the media and stirring up controversy. In the mid-1990s, he made headlines as a lead author for the assessment

LLNL

reports by the Intergovernmental Panel on Climate Change (IPCC).

The international body of scientists concluded in 1995 that humans were changing the climate, and industry sought to undermine this consensus by going after Santer. One scientist tells *ES&T* that it was "one of the most vicious attacks I have ever seen on the integrity of a scientist."

In an interview with *ES&T*, Santer recounts what happened to him during that stressful period, explains why people should stop knocking climate models, and muses on the media's long journey to finally "get" the science. He also notes that his work has caught the eye of U.S. senators who are working to change American foreign policy on global warming.

Despite the controversy and politics, he says, "in the end, the science gets done."

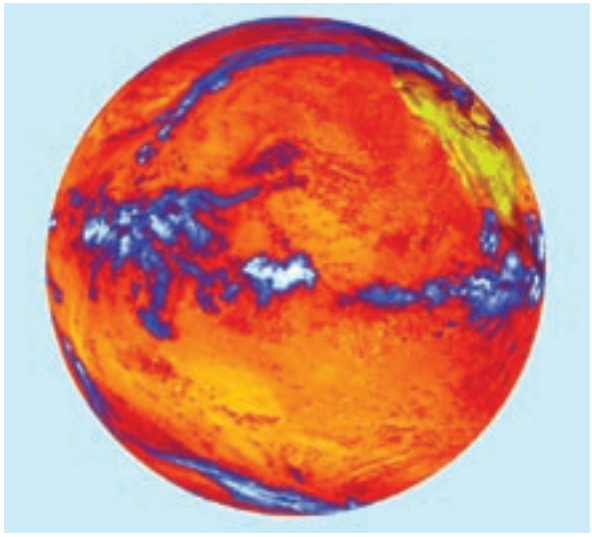
In the 1890s, two scientists, Svante Arrhenius in Sweden and P. C. Chamberlain in the U.S., independently concluded that burning fossil fuels would increase CO_2 levels in the atmosphere and lead to global warming. Now, here we are in 2006, and there's still some apparent controversy.

I'm not sure why there's controversy. We know there's a natural greenhouse effect, which makes life on our planet possible. We've enhanced this effect by burning fossil fuels, and our activities have changed the chemical composition of the atmosphere. This is immutable fact, not idle speculation.

Our best current estimates of how much the earth will warm up from a doubling of pre-industrial levels of atmospheric CO_2 are not significantly different from the estimates Arrhenius made over a century ago.

There has been a long-standing controversy and debate about the lack of consistency between the models and data collected from satellites. What was going on there?

For over a decade, the apparent cooling of the troposphere was one of the biggest stumbling blocks in our understanding of the causes of climate change. The troposphere is the layer of atmosphere that extends from the earth's surface to roughly 10 km above at the poles and to about 16 km above at the equator. The stratosphere is the layer above the troposphere.



NASA

Solar energy heats up the planet and is later emitted as long-wave radiation. Thermal radiation is fairly uniform across the oceans, with cooler areas (blue) found where thick clouds congregate around high mountains.

Scientists at the University of Alabama in Huntsville had spliced together the temperature records from over a dozen satellites. Their data initially showed cooling of the lower atmosphere from 1979 to the present. But thermometer measurements indicated that the surface of the earth had warmed.

The satellite measurements also didn't agree with the predictions of computer models. Climate models and basic theory were telling us that the lower atmosphere should warm in response to human-caused increases in greenhouse gases. This left us with a real dilemma: Why couldn't we see this warming in satellite data? And how could the earth's surface be warming but the air above it be cooling?

This conundrum has been around since the mid-1990s, hasn't it?

Yes, the first paper attempting to reconstruct tropospheric temperature changes from satellite data was published in *Science* in 1990.

And as soon as the data were published, they came into direct conflict with the models?

Yes. Some people used the lack of warming in the satellite data to argue that the surface data were wrong and that all climate models were wrong.

So what did the three *Science* papers published in August 2005 discover, and what did the CCSP report conclude last May?

The papers found that uncertainties in the satellite observations are far larger than they have been portrayed. Satellites drift in their orbits. These drifts affect the section of the atmosphere that can be observed from space and the time of day at which a satellite "sees" a particular location on earth's surface. Another problem is that satellite instruments don't perform identically when you put them in the harsh environment of space. This leads to biases between the instruments on different satellites. These biases need to be corrected.

Until the late 1990s, only one group had attempted to adjust the satellite data for these problems—the group from the University of Alabama. Then a second group—Remote Sensing Systems from Santa Rosa in California—took an independent look at the same raw data. They found a warming troposphere, not a cooling troposphere.

We've also learned more about temperature measurements obtained from weather balloons. The temperature sensors on these balloons have changed over time. So has the shielding which protects the sensors from direct sunlight, which can affect the temperature reading. The shielding has become more effective, leading to less solar heating of the sensor. You can see how such changes might cause difficulties when you compare old and new weather-balloon data.

I imagine that even tiny errors can make it difficult to find a temperature trend?

That's exactly right. Some of the corrections that have to be made to the satellite and weather-balloon data are much larger than the trends we're actually looking for.

So you've got huge error bars . . .

Yes, and I think that's what we've learned. The uncertainties in the data are very large. These uncertainties arise because groups make different processing choices when they try to adjust raw temperature measurements for known problems.

So how many models did scientists look at for the CCSP report?

We used results from models that were performed in support of the fourth scientific assessment of the IPCC. These results will be published in 2007.

We had access to IPCC results from roughly 22 climate models developed at research institutions around the world. Our analysis concentrated on simulations of 20th-century climate in which the models were run with our best estimates of historical changes in greenhouse gases, ozone, aerosols, the sun's energy output, and volcanic dust.

But I think a continuous belief exists that whenever models and data conflict, the models are always suspect. I called two researchers—one who studies disease transmission and one who works on population biology—and both said that was not true in their fields.

Some folks think that you can only confront models with observational data. And they think it's heretical to confront and question observations with models. I disagree.

Our own work has showed that models and theory can be helpful in attempting to discriminate between different observational datasets with very large uncertainties.

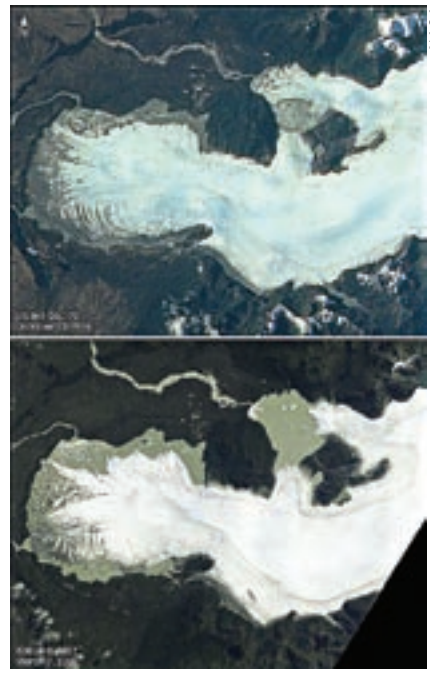
Do you think that this report released by President Bush's CCSP will halt the automatic dismissal of models?

I don't think it's going to end here. There is this old chestnut out there that models are just numerical constructs and that scientists never confront them with reality and data. Nothing could be further from the truth.

At Lawrence Livermore National Lab, I work at the Program for Climate Model Diagnosis and Intercomparison. Our job is to confront climate models with reality. That's what we do every day. We have access not only to U.S. models but essentially to all the climate models in the world. There are a whole suite of hoops we ask models to jump through. We ask how well they simulate the present-day climate, the daily temperature cycle, the march of the seasons. We see how well they capture modes of climate variability that we care about, such as El Niño. We test their ability to reproduce changes in climate over the 20th century. In some cases, we even ask how faithfully they can reproduce climates of the distant past—like the last ice age.

Another chestnut is that models are not falsifiable. Well, that's also incorrect. Back in the late 1960s, Suki Manabe and his colleagues at Princeton were performing some of the first climate-model experiments. One of their earliest predictions was that if you doubled pre-industrial concentrations of atmospheric CO_2, the stratosphere should cool and the troposphere should warm.

When Suki made his prediction, we had no satellite records or weather-balloon records of sufficient length to monitor slow changes in atmospheric temperature. But the satellite and weather-balloon data have now confirmed Suki's prediction. The stratosphere has cooled, and the troposphere has warmed. Suki could have been proved wrong—but he wasn't.



The San Quintin Glacier in Northern Patagonia continues to shrink. The two pictures were taken 7 years apart, and scientists suspect the change is caused by global warming.

The CCSP report contained this statement: "The evidence continues to support a substantial human impact on global temperature increases. This should constitute a valuable source of information to policymakers." Why was there a need to make this statement when scientists had consensus back in 1995?

I think it's fair to say that here in the U.S., a number of our elected leaders continue to express skepticism about our understanding of the nature and causes of climate change. Our charge in the report was to advise members of Congress with "science-based knowledge to manage the risks and opportunities of change in the climate." We fulfilled this charge to the best of our ability.

Clearly, there was a need to reiterate the finding of many previous national and international scientific assessments—human activities have affected historical climate, are now influencing current climate, and will shape the future climate.

Do you think this report will change policy?

Yes, I do. A recent press release by Sen. Lugar actually mentions our report, and recognizes "the April 2006 findings of the U.S. Climate Change Science Program that there is no longer a discrepancy between the rates of global average temperature increase at the earth's surface and in the atmosphere, thereby strengthening the scientific evidence that human activity contributes significantly to global temperature increases." So people are listening.

I want to take you back to the IPCC Second Assessment in 1995, when you wrote . . .

Oh yes, it's engraved on my memory: "The balance of evidence suggests a discernible human influence on global climate."

I didn't need to repeat it to you. That was verbatim. I've spoken with several climate scientists. . . . If there's

been this consensus going back to 1995, then how odd is it that we're still discussing it today?

Well, it's been a long road. I thought that our 1995 statement was very cautious and entirely justified by the then-available science.

But even that cautious statement caused some pretty healthy ripples in the ponds of science, politics, and the media. And it caused me a number of problems. I'd guess that about a year of my life was spent defending that scientific conclusion and my own personal scientific reputation.

Didn't the Third Assessment in 2001 confirm what had previously been stated?

Actually, they went quite a bit further. They attempted to quantify the size of the human effect on climate, which we had not done in the Second Assessment. The Third Assessment report concluded that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."

This criticism of you and your work on the Second Assessment is still propagating itself across the Internet like some sort of meme.

This is rather frustrating. I can't alter what people wrote about me on some op-ed page. It's unfortunate but beyond my control. Likewise, I have no control over the weird and wacky motives that climate-change skeptics ascribe to me.

NOAA

A growing body of research finds that hurricanes, such as Katrina, are becoming more powerful as sea surface temperatures rise.

In 1996, at the time of publication of the IPCC Second Assessment, I was a messenger bearing news that some very powerful people did not want to hear. So they went after the messenger. They were very good at it. I'm sure there was no personal animus involved. I just happened to get in the way and had to be discredited.

Any apologies from these people as the science became clearer?

No. No apologies. The Global Climate Coalition [GCC] was the major instigator of the unfounded allegation that shenanigans had gone on during the IPCC's Second Assessment. The GCC accused me of "scientific cleansing" at a time when "ethnic cleansing" was being committed in Bosnia.

My paternal grandparents died in concentration camps during the Second World War. They were subjects of Hitler's "ethnic cleansing". So maybe you can understand why the "scientific cleansing" charge was so abhorrent.

The GCC was one of the many now-defunct industry groups?

Yes. The GCC was a consortium of energy interests. It was heartening to see—even back in 1996—that a number of GCC members were very unhappy with the "scientific cleansing" charges. BP, Shell, and a number of other companies eventually resigned. They stated that the GCC was not conducting a responsible debate on climate-change science and was not representing their best interests. This felt like a small but significant victory.

In 2002, you did a Q&A with *Essential Science Indicators*, which rated you as one of the top 15 scientists in global-warming research according to citation numbers. They ranked a paper you coauthored as number three in the field. Yet you don't pop up much in the press.

I've always felt that the biggest contribution I could make as a scientist was by doing good science. I'm happiest when I have the luxury of time to do my own research.

I'm not particularly enthusiastic about my interactions with the press. But I also recognize that an important component of my job is to tell people what we know and what we don't know about climate change. The real irony of my scientific career is that I'm a very private person but somehow have the unfortunate knack of getting into very public situations.

Do you think the media has been doing a good job? I've spoken with a number of scientists who say that journalists like to highlight controversy and ignore consensus.

That's been my experience, too. But I also think that things have changed a bit over the last year or two. Increasingly, the debate on climate change is shifting. We're now discussing what to do about it, not "Is it happening?" That's very encouraging.

Over much of the last decade, it seems as if "journalistic balance" has been much more important than a search for the truth. Those who shout loudest receive the most media attention—even if they have little or no scientific expertise on climate change.

Any last words?

Anyone who has kids must be a little bit concerned about the climate future we're leaving behind for them. The choices that we make today on the "what to do" about climate change will have long lifetimes. I hope our elected representatives make wise choices, based on the best available scientific information—not on disinformation or wishful thinking. I hope they recognize that our actions are changing the climate on a global scale. It's happening now. We can't pretend it's not there.

We need a rational debate on climate change. All of us—policymakers, public, media, and scientists—have important roles in that debate. Let's hope it takes place sooner rather than later.

Paul D. Thacker is an associate editor of ES&T.