THE U.S. NATIONAL CLIMATE CHANGE ASSESSMENT: DO THE CLIMATE MODELS PROJECT A USEFUL PICTURE OF REGIONAL CLIMATE?

HEARING

BEFORE THE

SUBCOMMITTEE ON
OVERSIGHT AND INVESTIGATIONS

OF THE

COMMITTEE ON ENERGY AND
COMMERCE
HOUSE OF REPRESENTATIVES

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THE U.S. NATIONAL CLIMATE CHANGE ASSESSMENT: DO THE CLIMATE MODELS PROJECT A USEFUL PICTURE OF REGIONAL CLIMATE?

THURSDAY, JULY 25, 2002

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ENERGY AND COMMERCE,
SUBCOMMITTEE ON OVERSIGHT AND INVESTIGATIONS,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:30 a.m., in room 2322, Rayburn House Office Building, James C. Greenwood (chairman) presiding.

Members present: Representatives Greenwood, Deutsch, and Fletcher.

Staff present: Peter Spencer, professional staff; Yong Choe, legislative clerk; and Michael L. Goo, minority counsel.

Mr. GREENWOOD. On the record. Good morning. The meeting will come to order, and let me begin by apologizing to our witnesses and to our guests for the tardiness. It was actually unavoidable.

The Chair recognizes himself for 5 minutes for an opening statement.

Good morning, and welcome. This morning we will stand at the intersection of science, policymaking, and public concern about climate change to consider if an influential report provides the guidance necessary to navigate this often confusing and uncertain territory.

At issue is the use of climate models to create the regional climate change scenarios that frame the discussion in what is called in shorthand the U.S. National Assessment on Climate Change.

The national report about this assessment, prepared by scientists and researchers under a Federal advisory committee, known as the National Assessment Synthesis Team, two co-chairs of which are before us today, seeks to provide policymakers and the public with plausible pictures of regional climate 50 to 100 years from now under the impact of global warming.

Now let me note as we head into this a couple of points about my perspective. First, I tend to agree with the view expressed in some of the testimony we will hear this morning that there are some reasonable mitigation—there are some reasonable mitigation measures and other policy strategies we can take to address climate change risks, and that these do not depend upon the scientific dispute before us. Indeed, this dispute should not be used to avoid decisions on such policies.

Of course, there continues to be much debate about some of these policy decisions, how much can or should we do, when should we do it, and the debate has engaged many members of the Energy and Commerce Committee on both sides of the aisle.

The hearing today, though it will help inform the debate, is not the appropriate forum to conduct that debate, which would only distract us from the important questions before us this morning.

Second, this is not to suggest we should glide over questions of science and the scientific validity of the tools and methods used to drive understanding of inherently science based issues. We need sound science to inform our decisions and to ensure our actions in the name of science—to ensure that our actions in the name of science aren't misguided because we were more confident than we should have been.

So we begin today with a straightforward question: Do the climate models project a useful picture of regional climate? We have asked our panelists today, all scientists and all quite familiar with the controversies about climate, climate variability and impacts, and the national assessment, to comment on this and to speak to the role and suitability of the models used in this report.

In the U.S. Climate Action Report released to the United Nations this past May, reference to the National Assessment discussed the use of the models this way. "Use of these models is not meant to imply that they provide accurate predictions of the scientific changes in climate that will occur over the next 100 years. Rather, the models are considered plausible projections of potential changes for the 21st century."

Two initial questions come to my mind when I read this, and I hope the witnesses can assist us in answering these questions this morning. The first has to do with the plausibility of the picture painted by the models. This is basically a science question, which I am sure the experts here can sort out for this layman, and this is how reliable are the predictions of plausible regional outcomes, given the admitted limitations of the modeling, and what would this mean for the usefulness of the report? And given the wide variation in the projections' results that oppose each other in one area but are similar in others, is it reasonable to rely upon them to take specific actions or to adopt specific policies?

This appears to be a thoughtful report, and I believe the authors sincerely attempted to work through describing some of the uncertainty for policymakers and the public. Was it sufficient? How did the models work in the full picture here?

The second question relates to the problem of communicating the uncertainty. The reference above makes a rather nuanced description of predictions versus the projections. Yet the New York Times which reported the Climate Action Report's reference to the Assessment wrote this back in May: "The report says the United States will be substantially changed in the next few decades, very likely seeing the disruptions of snow-fed water supplies, more stifling heat waves, and the permanent disappearance of Rocky Mountain meadows and coastal marshes."

Was this the message the authors want the public to take away? We must come to grips with the fact that a scientific assessment such as this is more than an academic exercise read by the few who can grasp all the complexities. It is a document meant to guide us, policymakers and the public, though complicated policy intersections where we really rely on science as much as we can.

The stakes here are as high as any could be, the very inhabitability of our planet. The cost of reducing the stakes is also high. For both of these reasons, the reliability of our predictive models must be high indeed.

I thank the witnesses again, especially those who have traveled so far to testify this morning. I now recognize the ranking member, Mr. Deutsch of Florida, for his opening statement.

Mr. DEUTSCH. Thank you, Mr. Chairman. I believe this is our third hearing regarding climate change. Just a few comments representing south Florida. At some level I think we are probably more affected by potential climate change than anywhere in the country, and there won't be much of south Florida left.

The sea level of Florida's Gulf Coast has risen sharply, up as many as 8 inches over the last 100 years, and more sharply over the last few decades and, as people are well aware, higher sea levels can mean beach erosion, threatening homes and communities, coral reef erosion, and more intense and damaging storms and hurricanes.

Florida's average temperature since the Sixties has also risen. Higher temperatures mean more heat related illnesses, decreasing air quality. Both higher sea levels and higher temperatures will seriously affect obviously greater areas, including our Everglades restoration efforts, and can severely affect our tourism industry. Florida is a community where environment and the economy effectively are one.

I look forward to the testimony. I am just somewhat disappointed. As you are well aware, this is our last week in session, and we were in session until about two o'clock yesterday evening, and I don't really expect many members to be here this morning, which is unfortunate. But I am sure their staffs can review the record. I yield back.

Mr. GREENWOOD. Thank you, ranking member.

[Additional statements submitted for the record follow:]

PREPARED STATEMENT OF HON. PAUL E. GILLMOR, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF OHIO

Mr. Chairman, I wanted to quickly add my comments regarding climate change. In particular, I appreciate the opportunity to learn about the role of climate models as well as to discuss whether the U.S. National Climate Change Assessment should continue to serve as a benchmark with regard to potential impacts of climate change on our environment and human health.

I also look forward to hearing from our panel of witnesses. I should also point out that in a time when the U.S. economy is so dependent upon energy, and so much of our energy is derived from fossil fuels, reducing emissions poses major challenges. Like many Members, I feel that rushing to judgement on these matters could be very costly, both socially and economically. In an effort to produce sound environmental policy while maintaining steady economic growth, I am hopeful that we will continue to review scientific information about climate change to evaluate potential economic and strategic impacts of a warmer, and perhaps more variable, climate.

Again, I thank the Chairman and yield back my time.

PREPARED STATEMENT OF HON. W.J. "BILLY" TAUZIN, CHAIRMAN, COMMITTEE ON ENERGY AND COMMERCE

Thank you Chairman Greenwood. And, let me also thank you for putting together what promises to be an informative hearing—one that gets to the heart of a controversy that has lingered over this national assessment for a couple of years now.

I can tell you I have a pretty good appreciation, as does everybody from the Bayou State, for what Mother Nature can do to us. And she sure does remind us in a variety of ways.

The U.S. National Assessment also reminds us about the ways our country may someday be affected by climate change—whether that climate change is natural or influenced by man. But it also conveys some pictures of the future that, as we'll hear this morning, might not be quite what they seem.

I look forward to learning more about the use of climate models in the assessment. I'm curious to know whether the inherent uncertainties in these models—uncertainties I understand to be widely accepted within the science community—were properly accounted for when using the models to sketch out the climate change scenarios in this report.

I'm also curious to learn whether, if they weren't properly accounted for, whether they undercut what was otherwise a well-intentioned, and potentially useful report. Did the models, in effect, send all this good research focusing on the wrong impacts?

Nobody has perfect foresight. But we do have scientific assessments and other tools to help us reduce the odds that our decisions about the future are more than wild guesses. What troubles me, and I believe many Members who must confront difficult and potentially expensive decisions about climate change, is that something that is asserted to be sound science, is not as sound as it was portrayed to be. This creates false assurance where perhaps knowledge of what we don't know would be more useful to guard against risks. It also threatens to undercut public trust in the science policymakers use to make their decisions.

We have before us today a distinguished panel of experts who can explain the role of climate modeling in this assessment. They can put matters in proper perspective for us. We have them all here on one panel, too, so that perhaps we can generate some discussion to get further to the bottom of this controversy.

I thank you again, Mr. Chairman and yield back the remainder of my time.

Mr. GREENWOOD. It is the case that we were in session until two o'clock this morning. It is not an excuse, just an explanation for why some of the members may come in a little later than otherwise.

To the panelists, you are aware that the House—this committee is holding an investigative hearing, and I think you have been informed that when we hold investigative hearings, it is our custom to take our testimony under oath. Do any of you object to giving your testimony under oath? Okay.

Not normally for this kind of hearing but for other hearings we must inform you that you are entitled to have a counsel, have a lawyer represent you, be represented by counsel. Do any of you wish to be represented by counsel? Okay. In that case, if you would all stand and raise your right hand, I will give you the oath.

[Witnesses sworn.]

Mr. GREENWOOD. Thank you. You are under oath. Let me introduce the panel. From my left to right, Dr. Anthony C. Janetos, Senior Fellow with the H. John Heinz Center for Science, Economics, and the Environment; Dr. Thomas Karl, Director of the National Climatic Data Center in North Carolina; Dr. Daniel Lashof, Deputy Director of the Climate Center, the Natural Resources Defense Counsel; Dr. James J. O'Brien, Director of the Center for Ocean-Atmospheric Prediction Studies at Florida State University; Dr. Roger Pielke, Sr., President-Elect of the American Association of State Climatologists, Colorado State Climatologist, and Professor in the Department of Atmospheric Science at Colorado State University; and Dr. Patrick J. Michaels, Professor and Virginia State Climatologist, Department of Environmental Sciences, University of Virginia.

We welcome you all. Thank you for helping us this morning. Dr. Janetos, we will begin with you. You are recognized for 5 minutes to give your testimony.

TESTIMONY OF ANTHONY C. JANETOS, SENIOR FELLOW, THE H. JOHN HEINZ III CENTER FOR SCIENCE, ECONOMICS, AND THE ENVIRONMENT; THOMAS R. KARL, DIRECTOR, NATIONAL CLIMATIC DATA CENTER; DANIEL A. LASHOF, DEPUTY DIRECTOR, CLIMATE CENTER, NATURAL RESOURCES DEFENSE COUNCIL; JAMES J. O'BRIEN, DIRECTOR, CENTER FOR OCEAN-ATMOSPHERIC PREDICTION STUDIES, FLORIDA STATE UNIVERSITY; ROGER A. PIELKE, SR., PRESIDENT-ELECT, AMERICAN ASSOCIATION OF STATE CLIMATOLOGISTS, COLORADO STATE CLIMATOLOGIST, AND PROFESSOR, DEPARTMENT OF ATMOSPHERIC SCIENCE, COLORADO STATE UNIVERSITY; AND PATRICK J. MICHAELS, PROFESSOR AND VIRGINIA STATE CLIMATOLOGIST, DEPARTMENT OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF VIRGINIA

Mr. JANETOS. Thank you, Mr. Chairman. I am pleased to have this opportunity to address this committee on the topic of "Do the Climate Models Project a Useful Picture of Climate Change?"

Mr. GREENWOOD. You might want to pull the microphone. It is fairly directional, if you could—Thank you.

Mr. JANETOS. Thanks. The US National Assessment, "Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change" was released in November of 2000, following an extensive series of peer reviews and public comment.

This first document, the overview, was followed about a month later by the release of the foundation, a much more extensive, fully documented background document that lays out all of the analytical detail and data that were used in the National Assessment. We believe that the National Assessment is an extensive synthesis of the best available scientific information on this important topic.

There are three questions about climate change that have dominated discussions. How much climate change is going to occur? What will happen as a result? What can countries do about it? There are obviously heated opinions about each of these, but the issues are real, and it is critical to understand the underlying scientific knowledge about each if sound decisions are to be made. The national assessment report focuses on the second of these questions: What will happen as a result?

A national assessment of the potential impacts of climate change was called for in the 1990 legislation that established the U.S. Global Change Research Program. For several years, that program focused on developing the basic scientific knowledge that the international scientific assessment process, overseen by the IPCC, depends on.

That scientific research provided increasing evidence that change in the climate system is, in fact, occurring. It has become increasingly clear that there is a need to understand what is at stake for natural resources and human well-being in the U.S.

In response to this need, in 1998 Dr. John Gibbons, then Science Advisor to the President, requested the USGCRP to undertake a national assessment originally called for in the legislation. He directed—asked the program to investigate a series of important questions:

What are the current environmental stresses and issues for the United States that form a backdrop for additional impacts of climate change?

How might climate change and variability exacerbate or ameliorate existing problems?

What are the priority research and information needs that can better prepare policymakers for making wise decisions related to climate change and variability? What information and answers to what key questions could help decisionmakers make better informed decisions about risk, priorities, and responses? What are the potential obstacles to information transfer?

What research is most important to complete over the short term and over the long term?

What coping options exist that can build resilience to current environmental stresses, and also possibly lessen the impacts of climate change? How can we simultaneously build resilience and flexibility for the various sectors considering both the short and long term implications?

What natural resource planning and management options make most sense in the face of future uncertainty?

What choices are available for improving our ability to adapt to climate change and variability, and what are the consequences of those choices?

A variety of efforts emerged in response to Dr. Gibbons' quite daunting charge. Over 20 workshops were held around the country, involving academics, business people representing a range of industries including manufacturing, power generation and tourism, and people who work closely on the land and in the water, including resource managers, ranchers, farmers, foresters and fishermen.

Each workshop identified a range of issues of concern to stakeholders in those regions, many of them quite unrelated to climate change per se. Most were followed by the initiation of scientific, university led regional studies.

In addition to these kinds of bottom-up efforts, it was decided that it was also necessary to create a national level synthesis of what is known about the potential for climate impacts for the U.S. as a whole, addressing the issues identified in the regional workshops and national studies.

This synthesis, obviously, needed to build on the work that had begun to emerge from the subsequent regional and national studies, but also to draw on the existing scientific literature and analyses done with the most up to date ecological and hydrological models and data that could be obtained.

The National Assessment Synthesis Team, the NAST, was established by the NSF as an independent committee under the Federal Advisory Committee Act specifically in order to carry out this second step. It was made up of experts from academia, industry, government laboratories, and non-governmental organizations, and in order to ensure its openness and independence, all meetings of the NAST were open to the public, all documents discussed in its meetings are available through the NSF, as are all the review comments received and the responses to them.

This is perhaps out of the ordinary for a scientific study, but most scientific studies do not focus on issues of such broad and deep implications for the country, and about which there is such heated debate.

Our first action was to publish a plan for the conduct of the national synthesis. In addition, five issues, agriculture, water, forests, human health, and coastal and marine systems, were selected to be topics for national studies. Carrying out this plan was, obviously, a major undertaking, with the two reports that I mentioned earlier as the two primary national outputs.

Both of those national outputs have been through extensive review. At the end of 1999 two rounds of technical peer review were undertaken, and during the spring of 2000 an additional review by about 20 experts who had been outside of the assessment process was undertaken. Over 300 sets of comments were received from scientists in universities, industry, NGO's, and government labs. The responses to external comments have been described in comprehensive review memorandums.

The final stage of that process, a 60-day public comment period specifically requested by Congress, after which final revisions were then completed. The report was submitted to the President so that it could be transmitted to Congress, as called for in the original legislation. Hundreds of additional comments were received during the public comment period, each of which was responded to.

In order to ensure that we did our job well, an oversight panel was also established through the offices of the President's Council of Advisors on Science and Technology. That oversight panel was chaired by Dr. Peter Raven, Director of the Missouri Botanical Garden and former Home Secretary of the National Academy of Sciences, and Dr. Mario Molina, Professor of Atmospheric Chemistry at MIT and recent Nobel prize winner for his research on stratospheric ozone depletion. Its membership, like the NAST's, was also drawn from academia, industry, and the NGO's. It reviewed and approved the plans for the assessment. It reviewed each draft of the report, and reviewed the response of our synthesis team to all comments.

It is important to realize that the national assessment does not attempt to predict exactly what the future will hold for the U.S. It examined the potential implications of two primary climate scenarios, each based on the same assumptions about future global emissions of greenhouse gases, the same assumptions that has been used as one of many emission scenarios examined by the IPCC.

The two climate scenarios were based on output from two different global climate models used in the IPCC assessments, and we believe they were clearly within the range of global—The results were clearly within the range of the global annual average temperature changes shown by many such models, one of them near the low end of this range and one near the high end. Both also exhibit warming trends for the U.S. that are larger than the global average, but this is not surprising.

In addition to the two primary models from the Canadian Climate Centre and the Hadley Centre, in different parts of the national process results from climate models developed at the National Center for Atmospheric Research, NOAA's Geophysical Fluid Dynamics Laboratory, NASA's Goddard Institute for Space Studies, and the Max Planck Institute were also used in various aspects of the assessment.

The NAST was aware of the scientific issues surrounding the use of regional results form any general circulation models. In the analyses done with the climate models' regional outputs, simulations from the models were used to adjust historically observed data using methods that had already been peer reviewed in other studies, in order to depict scenarios that had sufficient regional richness for analysis. So, in fact, we did not use, for the most part, the raw data from the GCMs, but used that to adjust historical data.

In addition to models, the National Assessment used two other ways to think about potential future climate. Many groups involved in our process used historical climate records to evaluate sensitivities of regions, sectors and natural resources, the climate variability and extremes that have in fact occurred during the 20th Century.

Looking at real historical climate events, their impacts, and how people have adapted, gives valuable insights into potential future impacts that complement those provided by model projects. In addition, the assessment used sensitivity analyses, some of which ask how and by how much the climate would have to change to result in impacts on particular regions and sectors.

These climate scenarios describe significantly different futures that are scientifically plausible, given our current understanding of how the climate system operates. That understanding will, no doubt, continue to improve. As importantly, they describe separate baselines for analysis of how natural ecosystems, agriculture, water supplies, etcetera, might change as a result.

In order to investigate such changes, the potential impacts of changes in the physical climate system, the report relies on up to date ecological and natural resource models, on empirical observations from the literature, on investigations of how those systems have responded to climate variability that has been observed over the past century, and on the accumulated scientific knowledge that is available about the sensitivity of natural resources to climate, and about how the regions of the U.S. have and potentially could respond.

The U.S. National Assessment presents the results for each scenario clearly, and then takes the important additional step of explicitly describing the NAST's scientific judgment about the uncertainty inherent in each result. Those results that are viewed to be robust are described in more certain terms. Those viewed to be the result of poorly understood or unreconciled differences between models are described in substantially more circumspect language.

The lexicon of terms used to denote the NAST's greater or lesser confidence is explicitly described in the beginning of the Overview report. This helps ensure that the report does not mask important results by thoughtlessly merging models or overstating the scientific capability for assessing potential impacts.

Finally, the report begins to identify possible options for adaptation to this changing world. It does not do a complete analysis of the costs, benefits or feasibility of these options, however, which would be a necessary next step for developing policies to address those issues.

Future assessments will need to consider climate change in the context of the suite of environmental stresses that we all face. Perhaps most importantly, our report acknowledges very clearly that scientific uncertainties remain and that we can expect surprises as this uncontrolled experiment with the earth's geochemistry plays out over the coming decades.

Thank you very much.

[The prepared statement of Anthony C. Janetos follows:]

PREPARED STATEMENT OF ANTHONY C. JANETOS, SR. FELLOW, H. JOHN HEINZ III CENTER FOR SCIENCE, ECONOMICS, AND THE ENVIRONMENT

I am pleased to have the opportunity to address the US House of Representatives Committee on Energy and Commerce, Subcommittee on Oversight and Investigations on the topic of "The US National Climate Change Assessment: Do the Climate Models Project a Useful Picture of Climate Change?"

The US National Assessment, *Climate Change Impacts on the United States: the Potential Consequences of Climate Variability and Change* was released in November of 2000, following an extensive series of peer reviews and public comment. This first document, the Overview, was followed about a month later by the release of the Foundation, a much more extensive, fully documented background document that lays out all of the analytical detail and data that were used in the National Assessment. The National Assessment is an extensive synthesis of the best available scientific information on this important topic.

There are three questions about climate change that dominate discussions of this important topic. How much climate change is going to occur? What will happen as a result? What can countries do about it? There are obviously heated political opinions about each of these, but the issues are real, and it is critical to understand the underlying scientific knowledge about each if sound decisions are to be made. The assessment report focuses on the second of these questions.

A national assessment of the potential impacts of climate change was called for in the 1990 legislation that established the US Global Change Research Program (USGCRP). For several years, the research program focused on developing the basic scientific knowledge that the international scientific assessment process overseen by the Intergovernmental Panel on Climate Change (IPCC) depends on. The IPCC was jointly established by the World Meteorological Organization and the United Nations Environmental Programme in 1988. As scientific research has provided compelling evidence that climate change is in fact occurring, it has become increasingly clear that there is a need to understand what is at stake for natural resources and human well-being in the US. In response to this need, in 1998, Dr. John H. Gibbons, then Science Advisor to the President, requested the USGCRP to undertake a the national assessment originally called for in the legislation. Dr. Gibbons asked the USGCRP to investigate a series of important questions:

- What are the current environmental stresses and issues for the United States that form a backdrop for additional impacts of climate change?
- How might climate change and variability exacerbate or ameliorate existing problems?
- What are the priority research and information needs that can better prepare policy makers for making wise decisions related to climate change and variability? What information and answers to what key questions could help decision-makers make better-informed decisions about risk, priorities, and responses? What are the potential obstacles to information transfer?
- What research is most important to complete over the short term? Over the long term?
- What coping options exist that can build resilience to current environmental stresses, and also possibly lessen the impacts of climate change? How can we

simultaneously build resilience and flexibility for the various sectors considering both the short and long-term implications?
- What natural resource planning and management options make most sense in the face of future uncertainty?
- What choices are available for improving our ability to adapt to climate change and variability and what are the consequences of those choices? How can we improve contingency planning? How can we improve criteria for land acquisition?

A variety of efforts emerged in response to Dr. Gibbons' charge.

Over twenty workshops were held around the country, involving academics, business-people representing a range of industries including manufacturing, power generation and tourism, and people who work closely with land and water ecosystems including resource managers, ranchers, farmers, foresters and fishermen. Each workshop identified a range of issues of concern to stakeholders in those regions, many of them quite unrelated to climate change, *per se.* Most workshops were followed by the initiation of scientific, university-led regional studies.

In addition to these kind of "bottom-up" efforts, it was decided that it was also necessary to create a national-level synthesis of what is known about the potential for climate impacts for the US as a whole, addressing the issues identified in the regional workshops and national studies. This synthesis obviously needed to build on the work that had begun to emerge from the subsequent regional and national studies, but also to draw on the existing scientific literature and analyses done with the most up-to-date ecological and hydrological models and data that could be obtained. The National Assessment Synthesis Team (NAST) was established by the National Science Foundation as an independent committee under the Federal Advisory Committee Act (FACA) specifically in order to carry out this second step. This committee was made up of experts from academia, industry, government laboratories, and non-governmental organizations (NGO's) (membership list is Attachment 1). In order to ensure openness and independence, all meetings of the NAST were open to the public, all documents discussed in its meetings are available through the National Science Foundation, as are all the review comments already received and responses to them. This is perhaps out of the ordinary for a scientific study; but most scientific studies do not focus on issues of such broad and deep implications for American society, and about which there is such heated rhetoric.

The NAST's first action was to publish a plan for the conduct of the national synthesis. In addition, five issues (agriculture, water, forests, health, and coastal and marine systems), out of the many identified, were selected to be topics for national studies. Carrying out this plan was a major undertaking. The end result has been the production of a comprehensive two-volume national assessment report. The "Foundation" volume is more than 600 pages long, with more than 200 figures and tables, with analyses of the five national sectors, and 9 regions that together cover the entire US. It is extensively referenced, and a commitment was made that all sources used in its preparation were to be open and publicly available. The "Overview" volume is about 150 pages long, written in a style that is more accessible to the lay public, and summarizes the Foundation in a way that is understandable and informative, and which we are confident is scientifically sound. Both documents have already been through extensive review. At the end of 1999, two rounds of technical peer review were undertaken, and during the spring of 2000, an additional review by about 20 experts outside the assessment process was undertaken. Over 300 sets of comments have been received from scientists in universities, industry, NGO's, and government laboratories. The responses to all external comments have been described in comprehensive review memorandums. The final stage of the process, a 60 day public comment period specifically requested by Congress, after which final revisions was then completed, and the report was submitted to the President so that it could be transmitted to Congress, as called for in the original legislation. Hundreds of additional comments were received during the public comment period, each of which was responded to.

In order to ensure that the NAST carried out its charge well, an oversight panel was also established through the offices of the President's Council of Advisors on Science and Technology (membership list is Attachment 2). The oversight panel was chaired by Dr. Peter Raven, Director of the Missouri Botanical Garden and former Home Secretary of the National Academy of Sciences, and Dr. Mario Molina, Professor of Atmospheric Chemistry at MIT, and recent Nobel-prize winner for his research on stratospheric ozone depletion. Its membership, like the NAST's, was also drawn from academia, industry, and NGO's. It reviewed and approved the plans for the assessment, reviewed each draft of the report, and reviewed the response of the NAST to all comments.

What have been the results of this extraordinarily open process? What assumptions drive the analysis? What conclusions have been reached?

It is important to realize that the national assessment does not attempt to predict exactly what the future will hold for the US. It examined the potential implications of two primary climate scenarios, each based on the same assumptions about future "business as usual" global emissions of greenhouse gases that the IPCC has used for many of its analyses. The two climate scenarios were based on output from two different global climate models used in the IPCC assessment. They are clearly within the range of global annual average temperature changes shown by many such models, one near the low and one near the high end of the range. Both exhibit warming trends for the US that are larger than the global average. This is not surprising. For many years, one of the most robust results of global climate models has been that greater warming is expected in more northerly latitudes, and that land surfaces are expected to warm more than the global average. We have used assumptions that are entirely consistent with those used by the IPCC. In addition to the two primary models from the Canadian Climate Centre and the Hadley Centre, results from climate models developed at the National Center for Atmospheric Research, NOAA's Geophysical Fluid Dynamics Laboratory, NASA's Goddard Institute for Space Studies, and the Max Planck Institute were also used in various aspects of the Assessment.

The NAST was aware of the scientific issues surrounding the use of regional results from any general circulation models. In the analyses done with the climate models' regional outputs, simulations from the models were used to adjust historically observed data in order using methods that had already been peer-reviewed in other studies, in order to depict scenarios that had sufficient regional richness for analysis.

In addition to models, the Assessment used two other ways to think about potential future climate. First, it used historical climate records to evaluate sensitivities of regions and sectors to climate variability and extremes that have occurred in the 20th century. Looking at real historical climate events, their impacts, and how people have adapted, gives valuable insights into potential future impacts that complement those provided by model projections. In addition, the Assessment used sensitivity analyses, which ask how, and how much, the climate would have to change to bring major impacts on particular regions and sectors.

These climate scenarios describe significantly different futures that are scientifically plausible, given our current understanding of how the climate system operates. As importantly, they describe separate baselines for analysis of how natural ecosystems, agriculture, water supplies, etc. might change as a result. In order to investigate such changes, i.e. the potential impacts of climate changes, the report relies on up-to-date models, on empirical observations from the literature, on investigations of how these systems have responded to climate variability that has been observed over the past century in the US, and on the accumulated scientific knowledge that is available about the sensitivities of resources to climate, and about how the regions of the US have and potentially could respond.

One additional important point about the scenarios should be mentioned. The report does not average the results of models that disagree; it explicitly avoids doing so. The best example of this is in the analysis of potential changes in precipitation, where the two models used to create the scenarios give quite different results for some areas of the US. We have chosen to highlight these differences and explain that regional-scale precipitation projections are much more uncertain compared with temperature, rather than attempting to merge the results or guess which is more likely. The knowledge that the direction of precipitation change in some areas is quite uncertain is valuable for planning purposes, and clearly represents and important research challenge. There is however, consistency among models and observations on other aspects of precipitation changes. For example, both models and observations show an increase in the proportion of precipitation derived from heavy and extreme events as the climate warms. So, both types of information are pertinent to help with the identification of potential coping actions. In this respect, the report follows the procedure that the IPCC itself uses for its global impacts reports, each of which examines the potential impacts for entire continents.

The US national assessment presents the results for each scenario clearly, and then takes the important additional step of explicitly describing the NAST's scientific judgment about the uncertainty inherent in each result. Those results that are viewed to be robust are described in more certain terms; those viewed to be the result of poorly understood or unreconciled differences between models are described in more circumspect language. The lexicon of terms used to denote the NAST's greater or lesser confidence is explicitly described in the beginning of the Overview report. This helps ensure that the report does not mask important results by thoughtlessly merging models, or overstating the scientific capability for assessing potential impacts. Finally, the report begins to identify possible options for adaptation to this changing world. It does not do a complete analysis of the costs, benefits, or feasibility of these options however, which is a necessary next step for developing policies to address these issues.

The report's key findings present important observations for all Americans:

1. *Increased warming.* Assuming continued growth in world greenhouse gas emissions, the climate models used in this Assessment project that temperatures in the US will rise 5-10°F (3-5°C) on average in the next 100 years.

2. *Differing regional impacts.* Climate change will vary widely across the US. Temperature increases will vary somewhat from one region to the next. Heavy and extreme precipitation events are likely to become more frequent, yet some regions will get drier. The potential impacts of climate change will also vary widely across the nation.

3. *Vulnerable ecosystems.* Many ecosystems are highly vulnerable to the projected rate and magnitude of climate change. A few, such as alpine meadows in the Rocky Mountains and some barrier islands, are likely to disappear entirely in some areas. Others, such as forests of the Southeast, are likely to experience major species shifts or break up. The goods and services lost through the disappearance or fragmentation of certain ecosystems are likely to be costly or impossible to replace.

4. *Widespread water concerns.* Water is an issue in every region, but the nature of the vulnerabilities varies, with different nuances in each. Drought is an important concern in every region. Floods and water quality are concerns in many regions. Snow-pack changes are especially important in the West, Pacific Northwest, and Alaska.

5. *Secure food supply.* At the national level, the agriculture sector is likely to be able to adapt to climate change. Overall, US crop productivity is very likely to increase over the next few decades, but the gains will not be uniform across the nation. Falling prices and competitive pressures are very likely to stress some farmers, while benefiting consumers.

6. *Near-term increase in forest growth.* Forest productivity is likely to increase over the next several decades in some areas as trees respond to higher carbon dioxide levels. Over the longer term, changes in larger-scale processes such as fire, insects, droughts, and disease will possibly decrease forest productivity. In addition, climate change is likely to cause long-term shifts in forest species, such as sugar maples moving north out of the US.

7. *Increased damage in coastal and permafrost areas.* Climate change and the resulting rise in sea level are likely to exacerbate threats to buildings, roads, power lines, and other infrastructure in climatically sensitive places. For example, infrastructure damage is related to permafrost melting in Alaska, and to sea-level rise and storm surge in low-lying coastal areas.

8. *Adaptation determines health outcomes.* A range of negative health impacts is possible from climate change, but adaptation is likely to help protect much of the US population. Maintaining our nation's public health and community infrastructure, from water treatment systems to emergency shelters, will be important for minimizing the impacts of water-borne diseases, heat stress, air pollution, extreme weather events, and diseases transmitted by insects, ticks, and rodents.

9. *Other stresses magnified by climate change.* Climate change will very likely magnify the cumulative impacts of other stresses, such as air and water pollution and habitat destruction due to human development patterns. For some systems, such as coral reefs, the combined effects of climate change and other stresses are very likely to exceed a critical threshold, bringing large, possibly irreversible impacts.

10. *Uncertainties remain and surprises are expected.* Significant uncertainties remain in the science underlying regional climate changes and their impacts. Further research would improve understanding and our ability to project societal and ecosystem impacts, and provide the public with additional useful information about options for adaptation. However, it is likely that some aspects and impacts of climate change will be totally unanticipated as complex systems respond to ongoing climate change in unforeseeable ways.

Given these findings it is clear that climate impacts will vary widely across the Nation, as one would expect for a country as large and ecologically diverse as the US. Natural ecosystems appear to be highly vulnerable to climate changes of the magnitude and rate which appear to be likely; some ecosystems surprisingly so. The potential impacts on water resources are an important issue in every region examined, although the nature of the concern is very different for the mountainous West than for the East. The potential for drought is a concern across the country. The nation's food supply appears secure, but there are very likely to be regional gains and losses for farmers, leading to a more complex picture on a region-by-region basis. Forests are likely to grow more rapidly for a few decades because of increasing carbon dioxide concentrations in the atmosphere, but it is unclear whether those trends will be maintained as the climate system itself changes, leading to other disturbances such as fire and pest outbreaks. However, the climate change itself will, over time, lead to shifts in the tree species in each region of the country, some of them potentially quite profound. Coastal areas in many parts of the US and the permafrost regions of Alaska are already experiencing disruptions from sea-level rise and recent regional warming; these trends are likely to accelerate. Climate change will very likely magnify the cumulative impacts of other environmental stresses about which people are already concerned, such as air and water pollution, and habitat destruction due to development patterns. There are clearly links between human health, current climate, and air pollution. The future vulnerability of the US population to the health impacts of climate change depends on our capacity to adapt to potential adverse changes. Many of these adaptive responses are desirable from a public health perspective irrespective of climate change. Future assessments need to consider climate change in the context of the suite of environmental stresses that we all face. Perhaps most importantly, the report acknowledges very clearly that scientific uncertainties remain, and that we can expect surprises as this uncontrolled experiment with the Earth's geochemistry plays out over the coming decades.

ATTACHMENT 1

NATIONAL ASSESSMENT SYNTHESIS TEAM MEMBERS

Jerry M. Melillo, Co-chair, Ecosystems Center, Marine Biological Laboratory; Anthony Janetos, Co-chair, World Resources Institute; Thomas R. Karl, Co-chair, NOAA, National Climatic Data Center; Robert Corell (from January 2000), American Meteorological Society and Harvard University; Eric J. Barron, Pennsylvania State University; Virginia Burkett, USGS, National Wetlands Research Center; Thomas F. Cecich, Glaxo Wellcome, Inc.; Katharine Jacobs, Arizona Department of Water Resources; Linda Joyce USDA Forest Service; Barbara Miller, World Bank; M. Granger Morgan, Carnegie Mellon University; Edward A. Parson (until January 2000), Harvard University; Richard G. Richels, EPRI; and David S. Schimel, National Center for Atmospheric Research. *Additional Lead Authors;* David Easterling (NOAA National Climatic Data Center); Lynne Carter (National Assessment Coordination Office); Benjamin Felzer (National Center for Atmospheric Research); John Field (University of Washington); Paul Grabhorn (Grabhorn Studio); Susan J. Hassol (Aspen Global Change Institute); Michael MacCracken (National Assessment Coordination Office); Joel Smith (Stratus Consulting); and Melissa Taylor (National Assessment Coordination Office).

ATTACHMENT 2

INDEPENDENT REVIEW BOARD OF THE PRESIDENT'S COMMITTEE OF ADVISERS ON SCIENCE AND TECHNOLOGY (PCAST)

Peter Raven, Co-chair, Missouri Botanical Garden and PCAST; Mario Molina, Co-chair, MIT and PCAST; Burton Richter, Stanford University; Linda Fisher, Monsanto; Kathryn Fuller, World Wildlife Fund; John Gibbons, National Academy of Engineering; Marcia McNutt, Monterey Bay Aquarium Research Institute; Sally Ride, University of California San Diego and PCAST; William Schlesinger, Duke University; James Gustave Speth, Yale University; and Robert White, University Corporation for Atmospheric Research, and Washington, Advisory Group.

Mr. GREENWOOD. Thank you, Dr. Janetos. Thank you very much for your testimony.

Dr. Karl.

TESTIMONY OF THOMAS R. KARL

Mr. KARL. Good morning, Chairman Greenwood and members of the subcommittee. I was one of the three co-chairs of the report of the National Assessment Team. As Dr. Janetos has indicated, the synthesis team was comprised of scientists and other specialists from universities, industries, governments and non-governmental organizations.

The National Assessment reports are not policy positions or official statements of the U.S. Government. Rather, they were produced by a selected set of members of the scientific community and offered to the government for its consideration. I am very pleased to have this opportunity to present the testimony regarding the basis for the scenarios of the 21st century climate used in the National Assessment.

The purpose of the National Assessment was to synthesize, evaluate, and report on what we knew about the consequences of climate variability and change for the United States in the 21st Century.

The National Assessment was our first attempt to generate climate scenarios for various regions and sectors across the United States. It relied on a number of techniques to develop climate scenarios for the 21st Century, including historical data to examine the continuation of trends, the recurrence of past climate extremes, climate model simulations in attempt to provide plausible scenarios for how the future climate may change, and sensitivity analysis to explore the resilience of societal and ecology systems to climate fluctuations and change.

Numerous climate models were used in the National Assessment, but the two primary models were selected on the basis of a set of objective criteria that I have described in some detail in my written testimony. Today, if the assessment were repeated with similar criteria, results of several other models would be included.

As I described in some detail in my written testimony, in a comparison of the models used in the National Assessment with observations and other models indicates that the two primary model used in the National Assessment reflected the state of scientific understanding when the National Assessment was conducted between 1997 and 2000.

This had important consequences. For example, the amount of summertime precipitation expected over much of the contiguous USA as the climate warmed was quite uncertain and required the use of several what-if analyses to assess potential impacts. Other projected changes were less uncertain, like increased temperatures everywhere during all seasons. So the impact analysis could focus on the magnitude of the warming as opposed to the sign of the projected changes.

Interestingly, despite the fact that global models do not agree well in the sign of summer precipitation changes, in general climate models indicate that as greenhouse gases increase, on average more intense precipitation will occur. Indeed, observations in the USA and elsewhere reflect this today. That is, a greater proportion of the total precipitation occurs in heavy and very heavy precipitation events.

This attribute of precipitation change was another scenario considered by the sectorial and regional impact and adaptation assessments. Given the many differences among models, wherever feasible the National Assessment relied on model simulations to assess impacts to the greatest extent possible. A particularly noteworthy example comes from the Great Lakes region. Results from 10 models were used to assess changes in Great Lake levels during the 21st Century.

In conclusion, the National Assessment we conducted on the impact of climate change had significant limitations, but was an important first step. Quite clearly, more needs to be done, and such efforts can provide more effective decision support tools, help frame adaptation mitigation measures to avoid the potential risk and harm of climate change, and maximize the potential benefits.

I want to thank the chairman for allowing me the opportunity to describe the rationale used in the National Assessment to develop the climate scenarios for the 21st Century. I would be happy to answer any questions later. Thank you.

[The prepared statement of Thomas R. Karl follows:]

PREPARED STATEMENT OF THOMAS R. KARL, DIRECTOR, NATIONAL CLIMATIC DATA CENTER, NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICES, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

INTRODUCTION

Good morning, Chairman Greenwood and members of the Subcommittee. I am Thomas R. Karl, Director of NOAA's National Climatic Data Center. I was invited to appear today because I was one of the three Co-Chairs of the Report of the National Assessment Synthesis Team (NAST).

I would like to begin by emphasizing that the reports of the National Assessment Synthesis Team are not a product of the U.S. Government, and they do not represent government policy. In fact, they have sometimes been quite controversial. The National Assessment Synthesis Team is an advisory committee chartered under the Federal Advisory Committee Act. The NAST reports are not policy positions or official statements of the U.S. government. Rather, they were produced by selected members of the scientific community and offered to the government for its consideration.

The Synthesis Team was comprised of individuals drawn from governments, universities, industry, and non-governmental organizations that had responsibility for broad oversight of the National Assessment entitled "Climate Change Impacts on the United States—The Potential Consequences of Climate Variability and Change." The purpose of the Assessment was to synthesize, evaluate, and report on what we presently know—and don't know—about the potential consequences of climate variability and change for the United States in the 21st century. It attempted to review climate vulnerabilities of particular regions of the nation and of particular sectors, and sought to provide a number of adaptation measures to reduce the risk, and maximize the potential benefits and opportunities of climate change, whatever its cause. The National Assessment was conducted from 1997 to 2000 and was our first attempt to generate climate scenarios for various regions and sectors across the United States, which turned out to be a very challenging task. I am very pleased to have this opportunity to present testimony regarding the basis for the scenarios of 21st century climate used in the National Assessment.

As a basis for the National Assessment, and in the context of the uncertainties inherent in looking forward 100 years, the NAST pursued a three-pronged approach to considering how much the climate may change. The three approaches involved use of: (1) historical data to examine the continuation of trends or recurrence of past climatic extremes; (2) comprehensive, state-of-the-science (though still with significant limitations), model simulations to provide plausible scenarios for how the future climate may change; and (3) sensitivity analyses that can be used to explore the resilience of societal and ecological systems to climatic fluctuations and change. Of particular interest for this hearing is the second of these approaches, and that is where I will focus my remarks. As a pretext however, I note that the National Assessment rests on a combination of these approaches.

DEVELOPING MODEL-BASED SCENARIOS FOR THE 21ST CENTURY

Projecting changes in factors that influence climate

Because future trends in fossil fuel use and other human activities are uncertain, the Intergovernmental Panel on Climate Change (IPCC) has developed a set of scenarios for how the 21st century may evolve. These scenarios consider a wide range of possibilities for changes in population, economic growth, technological development, improvements in energy efficiency and the like. The two primary climate scenarios used in the National Assessment were based on a mid-range emission scenario used in the second IPCC report. This scenario assumes no major changes in policies to limit greenhouse gas emissions. Other important assumptions in the scenario are that by the year 2100:

- world population is projected to nearly double to about 11 billion people;
- the global economy is projected to continue to grow at about the average rate it has been growing, reaching more than ten times its present size;
- increased use of fossil fuels are projected to triple CO_2 emissions and raise sulfur dioxide emissions, resulting in atmospheric CO_2 concentrations of just over 700 parts per million; and
- total energy produced each year from non-fossil sources such as wind, solar, biomass, hydroelectric, and nuclear are projected to increase to more than ten times its current amount, providing more than 40% of the world's energy, rather than the current 10%.

There are a number of other important factors besides fossil fuel emissions that cause climate to change and vary. These were not part of the scenario used to drive climate change in the two primary models used in the National Assessment, because at the time of the National Assessment these simulations were not available. Figure 1 depicts the magnitude of these other climate forcings that were omitted from the emission scenario. Clearly, the two largest forcings are those related to increases in greenhouse gases and aerosols, both included in the two primary models used in the National Assessment. The addition of other forcings are an important consideration for improvement of future assessments, for example the

role of black carbon aerosols, and a more thorough treatment of land vegetative feedback effects which become quite important on local and regional space scales compared to global scales, e.g., the urban heat island.

Which models to use?

The NAST developed a set of guidelines to aid in narrowing the set of primary model simulations to be considered for use by the Assessment teams. This helped ensure a degree of consistency across the broad number of research teams participating in the Assessment. These guidelines included various aspects related to the structure of the model itself, the character of the simulations, and the availability of the needed results. Specifically this meant that the models must, to the greatest extent possible:

- be coupled atmosphere-ocean general circulation models that include comprehensive representations of the atmosphere, oceans, and land surface, and the key feedbacks affecting the simulation of climate and climate change;
- simulate the evolution of the climate through time from at least as early as the start of the detailed historical record in 1900 to at least as far as into the future as the year 2100 based on a well-understood scenario for changes in atmospheric composition that takes into account time-dependent changes in greenhouse gas and aerosol concentrations;
- provide the highest practicable spatial and temporal resolution (roughly 200 miles [about 300 km] in longitude and 175 to 300 miles [about 275 to 425 km] in latitude over the central US);
- include the diurnal cycle of solar radiation in order to provide estimates of changes in minimum and maximum temperature and to be able to represent the development of summertime convective rainfall;
- be capable, to the extent possible, of representing significant aspects of climate variations such as the El Niño-Southern Oscillation cycle;
- have completed their simulations in time to be processed for use in impact models and to be used in analyses by groups participating in the National Assessment;
- be models that are well-understood by the modeling groups who participated in the development of the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in order to ensure comparability between the US efforts and those of the international community;
- provide a capability for interfacing their results with higher-resolution regional modeling studies (e.g., mesoscale modeling studies using resolutions finer by a factor of 5 to 10); and
- allow for a comprehensive array of their results to be provided openly over the World Wide Web.

Including at least the 20th century in the simulation adds the value of comparisons between the model results and the historical record and can be used to help initialize the deep ocean to the correct values for the present-day period. Having results from models with specific features, such as simulation of the daily cycle of temperature, which is essential for use in cutting edge ecosystem models, was important for a number of applications that the various Assessment teams were planning.

At the time of the National Assessment only two models, the Canadian Climate Centre Model and the United Kingdom's Hadley Centre model, were able to satisfactorily meet these criteria. Today however, if the Assessment were repeated with the same criteria, several more models would meet these criteria, including modeling efforts in the USA. Let me emphasize the importance of this, which represents another limitation of the National Assessment. In 1998 the Climate Research Council (which I chaired) of the National Research Council issued a report, *Capacity of U.S. Climate Modeling to Support Climate Change Assessment Activities.* While improvements in model capability have occurred during the past four years, key findings from the CRC report are worthy of note:

> The CRC finds that the United States lags behind other countries in its ability to model long-term climate change. Those deficiencies limit the ability of the United States to predict future climate states . . . Although collaboration and free and open information and data exchange with foreign modeling centers are critical, it is inappropriate for the United States to rely heavily upon foreign centers to provide high-end capabilities. There are a number of reasons for this, including the following: (1) U.S. scientists do not necessarily have full, open and timely access to output from European models . . . (2) Decisions that might substantially affect the U.S. economy might be made based upon considerations of simulations (e.g. nested-grid runs) produced by countries with different priorities than those of the United States.

Furthermore, the report noted, "While leading climate models are global in scale, their ability to represent small-scale, regionally dependent processes . . . can currently only be depicted in them using high-resolution, nested grids. It is reasonable to assume that foreign modeling centers will implement such nested grids to most realistically simulate processes on domains over their respective countries which may not focus on or even include the United States."

The use of observations

Observations were an essential part of developing climate scenarios for the 21st century in the National Assessment. Reliance on model simulations provides only a limited opportunity to investigate the consequences of climate variability and change. To minimize this limitation, in the National Assessment the historical record was used to help determine regional and sector specific sensitivities to climate changes and variations of differing, but contextual realistic changes.

The observations were also used to understand how the models simulated present and past climate (see Figure 2), and to correct a number of model biases. While climate models have shown significant improvement over recent decades, and the models used in the National Assessment were among the world's best, there were a number of shortcomings in applying the models to study potential regional-scale consequences of climate change. This is a fundamental limitation to the results of the National Assessment, and should be kept in mind. In the National Assessment, several methods were used in an attempt to address these problems. Most importantly, the output from the primary models (the Hadley and Canadian) for temperature and precipitation were passed through a set of standardization processing algorithms to re-calibrate the model simulations with the observations. This is especially important in areas of complex terrain such as mountainous regions of the West were model resolution was insufficient to adequately resolve detailed small-scale climate characteristics. The processing procedure accounted for at least some of the shortcomings and biases in the models. So, the model scenario results used in the impact assessments were often adjusted to remove the systematic differences with observations that were present in the model simulations. Such a procedure is similar to what is now being implemented in daily weather forecasting, where actual model projections are not used, but rather the historical statistical and dynamical relationships between the weather model forecasts and actual observations are used to generate local weather forecasts. This adjustment process is fully described in the foundation report of the National Assessment.

In addition, some of the regional teams applied other types of "down-scaling" techniques to the climate model results in order to derive estimates of changes occurring at a finer spatial resolution. One such technique has been to use the global climate model results as boundary conditions for mesoscale models that cover some particular region (e.g., the West Coast with its Sierra Nevada and Cascade Mountains). These models are able to represent important processes and mountain ranges on finer scales than do global climate models. These small-scale simulations however, have not been as well tested as global models and are very computer intensive. It has not yet been possible to apply the techniques nationally or for the entire 20th or 21st centuries. With the rapid advances in computing power expected in the future, this approach should become more feasible for future assessments. To over-come the computational limitations of mesoscale models, some of the Assessment Teams developed and tested empirically based statistical techniques to estimate changes at finer scales than the global climate models, and these efforts are discussed in the various regional assessment reports. These techniques have the important advantage of being based on observed weather and climate relationships, but have the shortcoming of assuming that the relationships prevailing today will not change in the future.

Another type of tool developed for use in the sensitivity analyses were statistical models and weather generators used to calculate probabilities of unusual weather and climate events. These models enabled impact analysts to compose "what if" questions for strings of weather and climate events that could be important to their specific sector or region. Other approaches focused on using a variety of other types of observational data.

EVALUATION OF THE MODELS

Among the tests that have been used to evaluate the skill of climate models have been evaluations of climate model output to simulate present weather and climate, the cycle of the seasons, climatic variations over the past 20 years (the time period when the most complete data sets are available), climatic changes over the past 100 to 150 years during which the world has warmed, and climatic conditions for periods in the geological past when the climate was quite different than at present.

There are so many kinds of evaluations that can be made it is not possible to provide one test to ascertain the appropriateness of any model for climate impact assessments. For example, models may be expected to reproduce the past climate for hemispheric and global averages on century time-scales because much of the climate noise due to seasonal to inter-annual climate variability tends to be less important. This includes many of the important climate oscillations such as the El Nino, the North Atlantic Oscillation, the Pacific Decadal Oscillation, and others. Because models generally replicate the chaotic behavior of the natural climate, the climate models simulate their own year-by-year climates and they will not produce the precise timing of these events to match the observations. On the other hand, the climate models may be expected to reproduce the statistical distribution of these events. So, to compare models to observations it is important to be able to average out these natural variations that can have very large impacts for given regions in specific years. For this reason in the National Assessment comparisons of the model simulations with observations on regional and subregional levels were made by averaging over multiple decades or longer.

In conducting climate model evaluations it is tempting to prefer those models where the simulations most closely match the observations, but several complications must be accounted for in such intercomparisons. First, there are inherent errors and biases in our observational data. Models, even if they are provided perfect forcing scenarios and had perfect chemistry, physics and biology, should not be expected to perfectly match imperfect observations. By cross comparing observations from differing data sets and observing systems we can roughly estimate some of the observational errors and biases. Second, because of the chaotic nature of the climate, we cannot expect to match the year-by-year or decade-by-decade fluctuations in temperature that have been observed during the 20th century. Third, the particular model simulations used in the National Assessment did not include consideration of all of the effects of human-induced and naturally-induced changes that are likely to have influenced the climate, including changes in stratospheric and tropospheric ozone, volcanic eruptions, solar variability, and changes in land cover (and associated changes relating to biomass burning, dust generation, etc.). Finally, while it is desirable for model simulations not to have significant biases in representing the present climate, having a model that more accurately reproduces the present and past climate does not necessarily mean that projections of changes in climate developed using such a model would provide more accurate projections of climate change than models that do not give as accurate simulations. This can be the case for at least two reasons. First, what matters most for simulation of changes in future climate is proper treatment of the feedbacks that contribute to amplifying or limiting the changes, and accurate representation of the 20th century does not guarantee this will be the case. Second, because projected changes are calculated by taking differences between perturbed and unperturbed cases, the effects of at least some of the systematic biases present in a model simulation of the present climate can be eliminated. While potential nonlinearities and thresholds make it unlikely that all biases can be removed in this manner, it is also possible that the projected changes calculated by such a model could turn out to be more accurate than simulations with a model that provided a better match to the 20th century climate.

Recognizing these many limitations, evaluation of the simulations from the Canadian and Hadley models are briefly summarized here to give an indication of the kinds of tests climate scientists have completed to assess the general adequacy of the models for use in assessing the impacts of climate change and variability. As depicted in Figure 2 both primary models capture the rise in global temperature since the late 1970s, but do not do as well in reproducing decadal variations. The question of how these two models compare to other climate models, several of which were not available at the time of the National Assessment, is addressed in Figure 3. Note that the scaling factor required to match in the increase in temperature during the 20th century for all models is close to one, except for the Canadian Climate Model which is somewhat less than one, reflecting the relatively high sensitivity of this model to increases in greenhouse gases, although the scaling factor in a later version of the model (CGCM2 in Figure 3) is closer to one. It is also noteworthy that the later version of the Hadley Centre Model very closely reproduces the rate of 20th century warming when a more complete set of forcings, indirect sulfate forcing and tropospheric ozone, is added to the model. Another test of a model's ability to reproduce 20th Century global temperatures is to compare the annual temperatures generated by the models with the observations. To assess relative skill, errors can be compared to projections based on temperature persistence. That is, always predicting the annual mean temperature to be equal to the longer-term mean over the length of the averaging period centered on either side of the prediction year. Figure 4 shows some results of such a test for averaging periods from 10 to 50 years. This is a difficult test for a model to show skill because the persistence forecast actually includes information about the annual mean temperature both before and after the "prediction year." In all cases the model simulations have smaller errors than the persistence based projection, indicating significant skill.

So, analyses at the global scale for the two primary models used in the National Assessment indicate that there is general agreement with the observed long-term trend in temperature over the 20th century, but the Canadian Climate Model is significantly more sensitive to greenhouse gases compared to the Hadley Centre Model, and may be thought of as the "hotter" of the two models. This higher climate sensitivity of the Canadian model may be due to projection an earlier melting of the Arctic sea ice than the Hadley model. It is not yet clear how rapidly this melting may take place.

The question as to whether the Canadian Climate Model is an outlier can be addressed in Figure 5 where the global warming rate has been plotted for various models with similar forcings of greenhouse gases and sulfate aerosols. The Canadian Climate Model is seen to have a relatively high sensitivity to increases in greenhouse gases compared to other models, but its sensitivity is quite comparable to a model not used in the National Assessment, NOAA's Geophysical Fluid Dynamics Laboratory R15 model. So, although the Canadian model does appear to be one of the more sensitive models to increases in greenhouse gases, it is not an outlier. By comparison the Hadley Centre model appears to have moderate sensitivity to increases in greenhouse gases.

The National Assessment was not performed on global space scales, so it is important to understand the differences between model simulations and observations on regional scales. As part of a long-term Climate Model Intercomparison Project (CMIP2), Dr. Benjamin Santer of the Lawrence Livermore National Laboratory has recently compared results from a number of climate models related to their ability to reproduce the annual mean precipitation and the annual cycle of precipitation across North America. The results of this study, which included the two primary models used in the National Assessment, are depicted in Figures 6 and 7. The figure shows the correlation between the patterns of the model output and the observations (the y-axis) along with a measure of the differences in actual precipitation (the x-axis). If there were no errors in our observing capability, a perfect model would reproduce the observations exactly and have perfect correlation with the observations, the difference between any observed model grid point and observational grid point would be zero, and it would appear as a point in the far upper left corner of the plot. By comparing two different observational data sets we can get an estimate of the errors in the observations and this has been done in Figures 6 and 7 by comparing two different 20-year climatologies over North America by two different research groups. So, no model should be expected to be in the quadrant of the diagram to the upper left of the less than perfect observational data sets. It is clear in Figures 6 and 7 that the Hadley Centre model used in the National Assessment reproduces the observations better than all other models, while the Canadian Climate Centre Model does not do as well, but is by no means an outlier.

Although the changes in global scale features and the regional simulations of precipitation of the two primary models are seen to be rather typical of other models, there are important issues on regional scales that suggest that significant uncertainties remain in our ability to effectively use these models for impact assessments. For example, problems with the way these climate models simulate ENSO variability suggest that the projected pattern of changes may not be definitive. Also, as illustrated by the different projections of changes in summer precipitation used in the National Assessment in the Southeast, there are often several processes that can contribute to the pattern of change. The same process can lead to different projections of changes when imposed on a slightly different base state of the climate. For example, the proportion of the oceans that are frozen versus liquid, the amount of snow cover extent, the dryness of the ground surface, the strength of North Atlantic deep water circulation, etc., all can play important roles. In addition, the different representations of land surface processes, clouds, sea-ice dynamics, horizontal and vertical resolution, as well as many other factors included in different climate models, can have an important impact on projections of changes in regional precipitation. This dependence occurs because precipitation, unlike atmospheric dynamics, is a highly regionalized feature of the climate, depending on the interaction of many processes, many of which require a set of model parameterizations. Given these many limitations, in the National Assessment the model simulations were viewed as projections not as predictions. The significance of this distinction can be seen in the following quote from the recently-released Climate Action Report 2002: "Use of these model results is not meant to imply that they provide accurate *predictions* of the specific changes in climate that will occur over the next hundred years. Rather, the models are considered to provide plausible *projections* of potential changes for the 21st century. For some aspects of climate, the model results differ. For example, some models, including the Canadian model [used in this Assessment] project more extensive and frequent drought in the United States, while others, including the Hadley model [the other model used in the Assessment] do not. As a result, the Canadian model suggests a hotter and drier Southeast during the 21st century, while the Hadley model suggests warmer and wetter conditions. Where such differences arise, the primary model scenarios provide two plausible, but different alternatives."

HOW WERE THE MODEL PROJECTIONS USED?

They model projections were used as indications of the types of consequences that might result. For example, as evident in Figure 2, although the emissions scenarios are the same for the Canadian and Hadley simulations, the Canadian model scenario projects more rapid global warming than does the Hadley model scenario. This greater warming in the Canadian model scenario occurs in part because the Hadley model scenario projects a wetter climate at both the national and global scales, and in part because the Canadian model scenario projects a more rapid melting of Arctic sea ice than the Hadley model scenario.

Recognizing that all model results are plausible projections rather than specific quantitative predictions, the consistency of the temperature projections of the primary models used for the National Assessment were assessed in a broader context. Figure 8 illustrates how this strategy was used. It is apparent that virtually all models consistently show a much greater than the global average warming over the US during winter and a greater than average warming during summer, except for Alaska. So, in the National Assessment all the scenarios of temperature change related to increased temperatures and the increases were often as larger or larger than the global mean temperature increase.

Although there are many similarities in the projected changes of temperature amongst the many climate models considered by the IPCC (Figure 8), this is not true of precipitation changes. In the National Assessment the Hadley Centre model often projected significantly wetter conditions compared to the Canadian model, but this variation is typical of our present state of understanding as depicted in Figure 9. Only during winter is there a consistent pattern of a small increase of precipitation among most of the climate models; by contrast during summer there is not much agreement about the sign or magnitude of the precipitation change, except for a general tendency for more precipitation in the high latitudes of North America. The inconsistencies among all the models with respect to summertime mid-latitude North American precipitation (Figure 9) were reflected in the two scenarios used in the National Assessment, ensuring consideration of a range of possible outcomes. To address this range of possible outcomes a number of "what if" scenarios were developed and used in the National Assessment. For example, in the West, although both models in the National Assessment projected precipitation increases, a "what-if" scenario of less precipitation was used to broaden the assessment of possible climate impacts, vulnerabilities, and adaptation measures.

Interestingly, despite the fact that the global climate models do not agree well on the sign of summer precipitation changes, virtually all climate models indicate that as greenhouse gases increase more intense precipitation events will occur over many areas. Indeed, observations reflect this today in many mid and high latitude land areas where data are available for such an assessment. For these reasons and the fact an increase in precipitation intensity can effectively be argued from simple thermodynamic considerations, this attribute of precipitation change was an important scenario considered by the sectoral and regional impact and adaptation assessments.

It should also be noted in the National Assessment, due to the nature of the differences among various models, wherever feasible other model simulations were used to assess possible impacts. A particularly noteworthy example comes from the Great Lakes Region. Results from ten models were used to simulate changes in Great Lake levels during the 21st century. All but one of the models suggested lower Lake levels. So a combination of the primary models, other climate models, and observations were instrumental in identifying key climate impacts and vulnerabilities for the 21st Century.

FUTURE ASSESSMENTS

To build confidence in the projections used for future climate assessments, much remains to be done. Further improvements in climate models are needed, especially in the representations of clouds, aerosols (and their interactions with clouds), sea ice, hydrology, ocean currents, regional orography, and land surface characteristics. Improving projections of the potential changes in atmospheric concentrations of greenhouse gases, aerosols and land use is important. Climate model simulations based on these revised emissions forecasts should provide improved sets of information for assessing climate impacts. In addition to having results from more models available, ensembles of simulations from several model runs are needed so that the statistical significance of the projections can be more fully examined. As part of these efforts, it is important to develop greater understanding of how the climate system works (e.g., of the role of atmosphere-ocean interactions and cloud feedbacks), to refine model resolution, to more completely incorporate existing understanding of particular processes into climate models, to more thoroughly test model improvements, and to augment computational and personnel resources in order to conduct and more fully analyze a wider variety of model simulations, including mesoscale modeling studies.

While much remains to be done that will take time, much can also be done in the next few years that can substantially improve the set of products and tools available to assess climate impacts. For example, an intensified analysis program is needed to provide greater understanding of the changes and the reasons why they occur. New efforts to incorporate the interactive effects of changes in land use and vegetation in meso-scale and global models will help in understanding local and regional climate change and variability. A better understanding of the changes in weather patterns and extremes in relation to global changes is important. Improved efforts that combine analysis of the model results with the insights available from analysis of historical climatology and past weather patterns needs to be a priority. Regional climate scenarios can also be developed using a combination of climate model output and dynamical reasoning. More use of mesoscale models is important because they can provide higher resolution of spatial conditions.

In the National Assessment, we were able to consider only one set of emission scenarios rather than a range of emission scenarios. For the future, the actual emissions of greenhouse gases and aerosols could be different than the baseline used. Changing the emissions scenario would give increasingly divergent climate scenarios as the time horizon expanded. This would likely become important beyond the next few decades as different emission scenarios are not likely to significantly affect climate scenarios because of the relatively slow response of the global climate and energy systems, and because a large portion of the change will be due to past emissions.

As recently stated by the Assistant Secretary for Oceans and Atmosphere, Dr. Mahoney, the *highest and best use* of the scientific information developed in the combined United States Global Climate Research Program (USGCRP) and the President's Climate Change Research Initiative (CCRI) could be the development of *comparative information* that will assist decision makers, stakeholders and the general public in debating and selecting optimal strategies for mitigating global change, while maintaining sound economic and energy security conditions in the United States and throughout the world. Significant progress in developing and applying science-based decision tools during the next 1 to 3 years must be a key goal of the combined USGCRP and CCRI program. Examples of analyses expected to be completed during this time period that would improve our nations ability to conduct a subsequent National Assessment include:

- Long-term global climate model projections (*e.g.,* up to the year 2100) for a wide selection of potential mitigation strategies, to evaluate the expected range of outcomes for the different strategies.
- Detailed analyses of variations from defined "base" strategies, to investigate the importance of specific factors, and to search for strategies with optimum effectiveness.
- Linked climate change and ecosystem change analyses for several suggested strategies, to search for optimum benefits.
- Detailed analyses of the outcomes that would be expected from application of the wide selection of energy conservation technologies, and carbon sequestration strategies, currently being investigated by the National Climate Change Technology Initiative

SUMMARY

The National Assessment conducted from 1997-2000 was a first step. It relied on a number of techniques to develop climate scenarios for the 21st century including: historical data to examine the continuation of trends or recurrence of past climatic extremes; climate model simulations in an attempt to provide plausible scenarios for how the future climate may change; and sensitivity analyses to explore the resilience of societal and ecological systems to climatic fluctuations and change. Numerous climate models were used in the National Assessment, but the two primary models were selected on the basis of a set of objective criteria. Today, if the Assessment were repeated with the similar criteria, results of several other models would be included.

Intercomparison of the models used in the National Assessment with observations and other models indicates that the two primary models used in the National Assessment reflects the state of scientific understanding approximately 2-3 years ago. This had important consequences. For example, the amount of summertime precipitation expected over much of the contiguous USA as the climate warmed was quite uncertain and required use of several "what if" analyses to assess potential impacts. Other projected changes were more certain, like increased temperatures everywhere, during all seasons, and impact analyses could focus on the magnitude as opposed to the sign of projected change.

In conclusion, the National Assessment we conducted on the impact of climate variability and change had significant limitations, but was a first step. Quite clearly, more needs to be done and such efforts will provide more effective decision support tools to help frame adaptation and mitigation measures to avoid the risk and harm of climate change and maximize its potential benefits.

It is important to note a major recommendation in the National Research Council's recent analysis (2001) of some key questions related to Climate Change Science. Specifically, that report states that "the details of the regional and local climate change consequent to an overall level of global climate change" requires further understanding. The uncertainties that surfaced in generating scenarios for the National Assessment was clearly in our minds when we made this recommendation.

Resolving these uncertainties will be essential to understanding the scope of any climate change impact. Quite clearly, more needs to be done and such efforts will provide more effective decision support tools to help frame adaptation and mitigation measures to avoid the potential risk and harm of climate change and maximize its potential benefits.

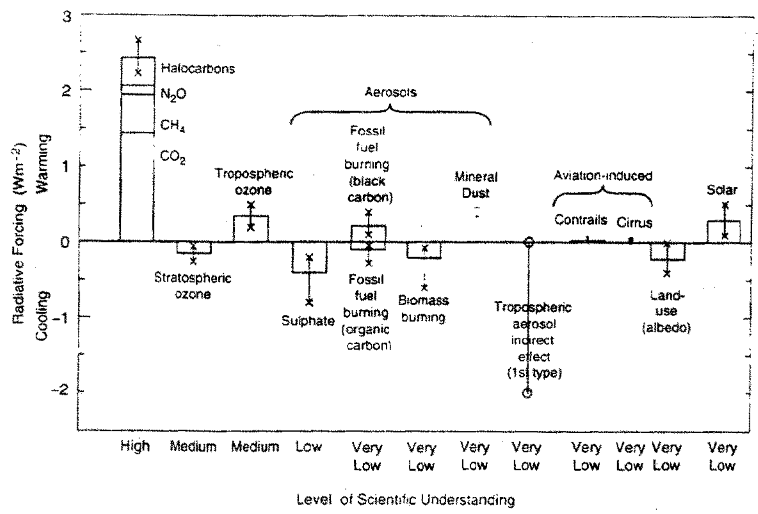

Figure 1 Global, annual-mean radiative forcings (Wm^{-2}) due to a number of agents for the period from pre-industrial (1750) to present (about 2000). In the National Assessment forcings due to greenhouse gases (the first column) and sulfate (the fourth column) were the only forcings used in the emission scenario. The height of the vertical bars represent the best estimate value, while its absence denotes no best estimate is possible. The vertical line about the rectangular bar with "x" provides an estimate of the uncertainty range. (From IPCC, 2001)

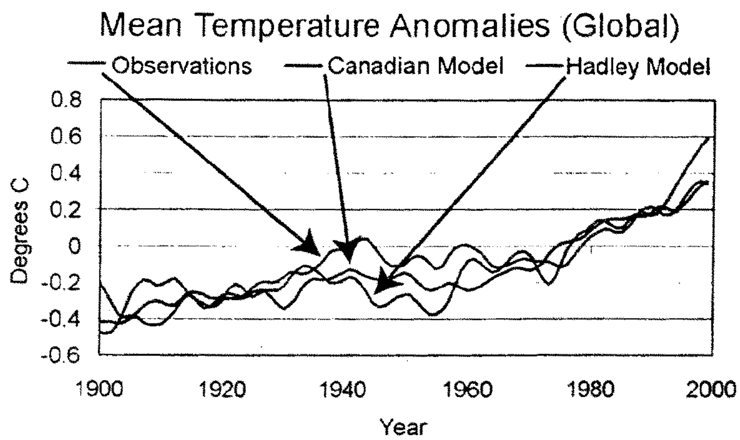

Figure 2 Trends of global temperature from observations, the United Kingdom's Hadley Center Global Climate Model, and the Canadian Climate Center's Global Climate Model. Trends have been smoothed to remove year-to-year high frequency variations.

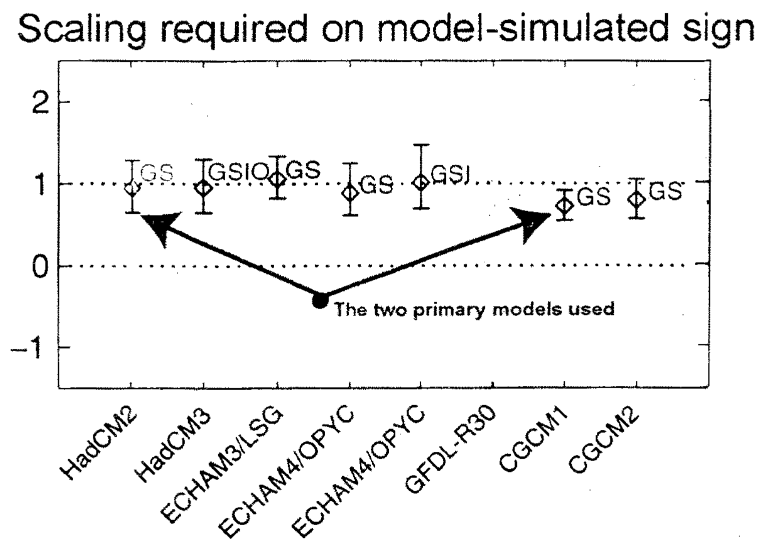

Figure 3 Estimates of the "scaling factors" by which the amplitude of several model-simulated signals must be multiplied to reproduce the corresponding change in the observed record. The vertical lines represent the 5-95% confidence interval due to internal natural variability. The models used in the National Assessment were the HadCM2 with greenhouse gases and sulfur (GS) and the CGCM1 with greenhouse gases and sulfur (GS). Abbreviations: GS includes greenhouse and sulfate forcing and GSIO includes also includes the indirect effect of sulfate aerosol forcing plus tropospheric ozone forcing. See IPCC(2001) for details.

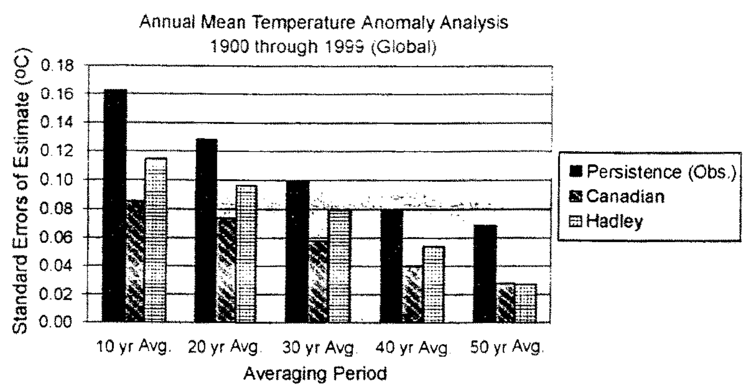

Figure 4 A comparison of the ability of the Hadley Center and Canadian Climate Center coupled global climate models used in the National Assessment to simulate the 20th century global climate compared with using the mean temperature over various time segments to predict year-to-year variations of global temperatures (persistence). Standard errors less than persistence based on observations reflect skillful simulations.

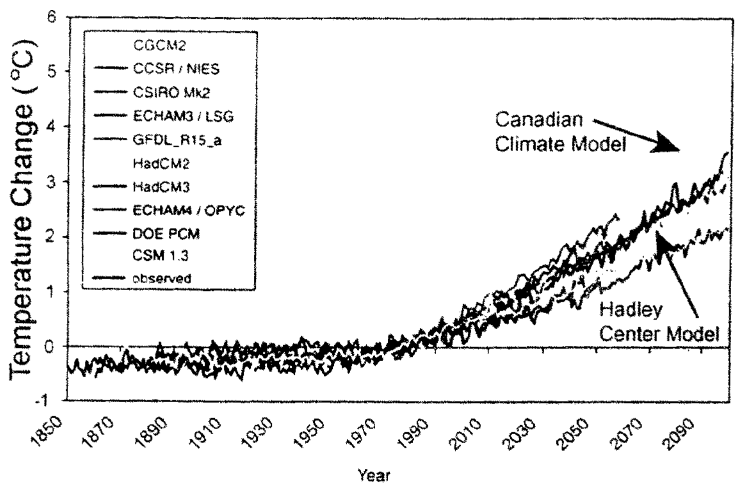

Figure 5 The time evolution of the globally averaged temperature change (relative to 1961-90 mean temperature) for various climate models forced with the emission scenarios used in the National Assessment (see IPCC 2001 for details)

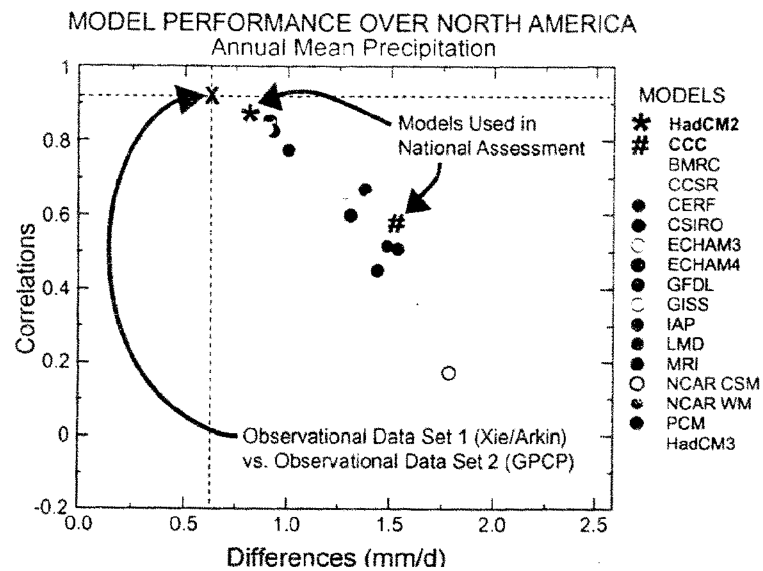

Figure 6 Results of a coupled ocean-atmosphere global Climate Model Intercomparison Project (CMIP) being conducted by the Lawrence Livermore National Laboratory. This comparison relates to the spatial distribution of annual precipitation across North America. All models are compared to the "Xie/Arkin" observational data set. The difference between two differing observation-based data sets reflect observational uncertainties, so we would not expect any model to skillfully exceed these differences. All models are evaluated on the basis of pattern correlations with the observations and the relative differences of annual precipitation integrated across all model grid points in North America. The Hadley Center climate model used in the National Assessment is shown with an "*" and the Canadian Climate Center is shown with a "#" symbol.

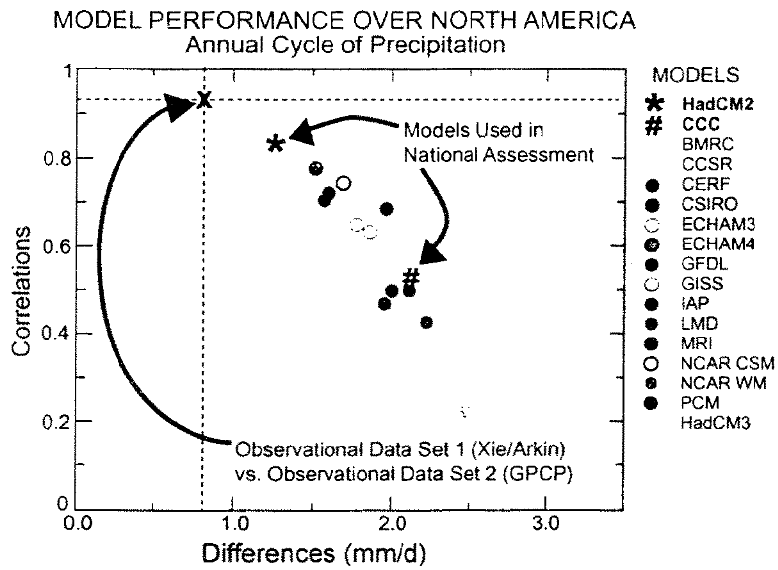

Figure 7 Similar to Figure 6 except the results relate to the ability of the models to reproduce the annual cycle of precipitation.

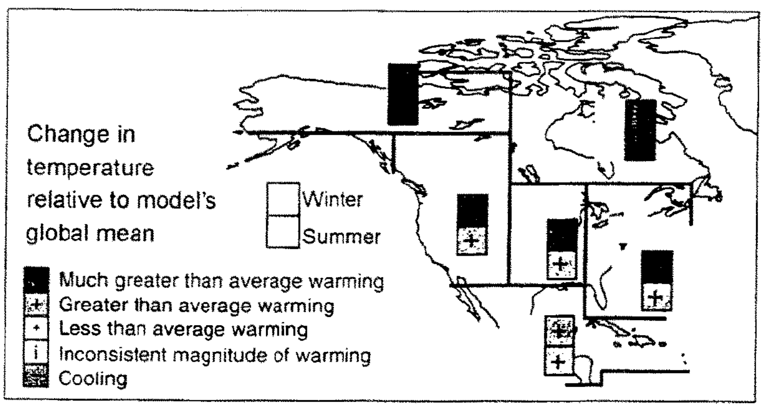

Figure 8 Analysis of coupled ocean-atmosphere inter-model consistency in regional temperature change based on much greater (40%) than average global warming, greater than average warming, less than average warming, inconsistent rates of warming, or cooling for the 21st century based on five model simulations (the Hadley and Canadian models used in the National Assessment and three other models used in the IPCC (2001) assessment) with 21st century increases in both greenhouse gases and sulfates (see IPCC 2001 for details).

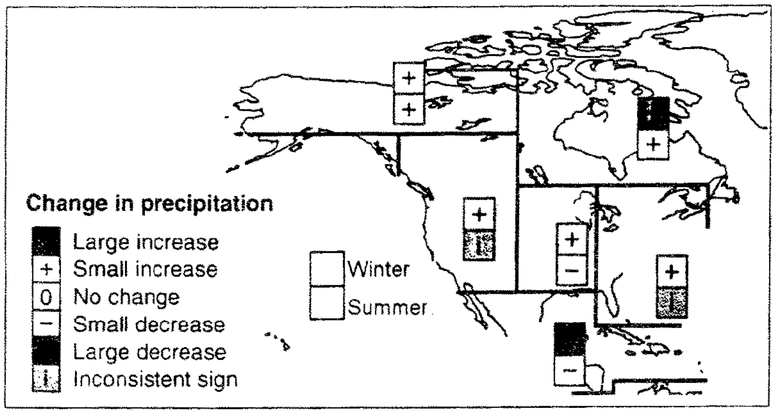

Figure 9 Similar to Figure 8 except for precipitation and a large change represents a change in excess of 20% and a small change is between 5 and 20% (see IPCC, 2001 for more details).

Mr. GREENWOOD. We thank you, Dr. Karl. Thank you so much. Dr. Lashof.

TESTIMONY OF DANIEL A. LASHOF

Mr. LASHOF. Thank you, Mr. Chairman. In summarizing my written statement I want to try to make three points.

The first is on the general value of climate models in looking into the future and trying to understand what is going on.

The second is the fact that the National Assessment and the models that underlie it were accepted not just by the Clinton administration. They were reviewed more recently by the Bush administration, showing very broad partisan acceptance of those results.

Third, I want to present an example of the use of climate models to one particular study that we conducted on the effects of global warming on trout and salmon expected in the United States.

So why climate models? Why do we use climate models to examine the effects of global warming. The fact, Mr. Chairman, is that we only have one earth, and it is, therefore, impossible to conduct a standard controlled experiment where you take one plot and apply an experimental drug or chemical to it and another plot which is the control, which you leave undisturbed.

We are, in fact, conducting an experiment on the earth by adding heat trapping carbon dioxide and other greenhouse gases to the atmosphere, but we have no control.

So the only way we can examine what the effects of the experiment that we are already engaged in would be is to have climate models which represent the earth based on the best available data we have from the atmosphere of the oceans, the land surface, and mathematical descriptions of the fundamental laws of physics. Those are run in a simulation on a computer, and that is what we call climate modeling.

Of course, this type of simulation model is not unique to climates. It is used to simulate everything from—We test crash cars in computers. We test fly airplanes in computers. We test detonate nuclear weapons in computers. In fact, it is no accident that Lawrence Livermore National Laboratory does both climate modeling and nuclear weapons simulations using some of the most advanced computers in the world. So the basic idea is we are running this experiment on the climate, and we want to know what is going to happen, because if we wait to see everything that happens and we don't like the results, it is too late to change it, because these carbon dioxide and other greenhouse gases last in the atmosphere for a very long period of time.

So that basic approach was taken. The models were selected, as we have heard. They are representative of what is in the inter- national community. I just want to emphasize that, as Tony Janetos explained, extensive peer review process, comments by Pat Michaels and others were submitted both on the National Assessment and the subsequent climate action report. They were fully considered. Responses are fully documented in the public record.

You can find those responses on the website of the Global Change Research Program. I believe he is going to repeat many of those comments today, and it is going to be difficult to sort out all of that in this particular forum. I think it is important to recognize that those comments were considered, and detailed responses to them are available in the public record.

So just to make the point that the administration—the current administration also accepted these conclusions, it is worth noting that in 2001 the Intergovernmental Panel on Climate Change's Synthesis Report of its Third Assessment Report was adopted. The State Department submitted detailed comments on the draft of this document under this administration, and the administration fully participated in a plenary session in September 2001 where the summary of policymakers was adopted.

I quote extensively—or I quote not extensively, but I quote from that report in my written testimony a few examples of the conclusions from that report, which basically show that global warming is happening, that we expect to see more heat waves, heavy precipitation events, fewer cold days. These findings were embraced by the administration.

Let me focus a little bit more on the U.S. Climate Action Report of 2002. This report was based upon conclusions of the National Academy of Sciences, the IPCC climate change report that I just mentioned, and the National Assessment that we have been discussing today. It was thoroughly vetted by this administration and approved before its official release and transmittal to the United Nations Framework Convention on Climate Change.

Among the key findings of the Climate Action Report are that, for example, rather than, "Rather than simply considering the potential influences of arbitrary changes in temperature, precipitation, and other variables, the use of climate models scenarios ensured that the set of climate conditions considered was internally consistent and physically plausible." That is the basic reason for using the models.

Natural ecosystems appear to be the most vulnerable to climate change, because generally little can be done to help them adapt to the projected rate and amount of change. Sea level rise at midrange rates is projected to cause additional loss of coastal wetlands, particularly in areas where there are obstructions to landward migration, and put coastal communities at greater risk of storm surges, especially in the southeastern United States.

Further, it found that reduced snow pack is very likely—and this term "very likely," as Dr. Janetos explained, is a specific term used to represent that this is a robust finding—to alter the timing and amount of water supplies, potentially exacerbating water shortages, particularly throughout the western United States. Current water management practices cannot be successfully altered or modified.

So I think the clear conclusion from these findings is that global warming does pose a very severe threat to public health and welfare in the United States Let me just finish by summarizing the example of a recent study that NRDC and Defenders of Wildlife released in May that used some of the climate models, updated versions of two of the models used in the National Assessment plus a third model to project the likely effects of global warming on a particularly valued sport fish, trout and salmon, in the United States.

We found, based on this analysis in this report, which I would ask to be included in the record, that at the regional level the loss of trout habitat in the northeast and southwest could be particularly severe, although losses are also expected in the southeast and Rocky Mountain regions.

For example, in Pennsylvania we found that losses of trout habitat are projected to be 6 to 11 percent by 2030, 22 to 28 percent by 2060, and 33 to 44 percent by 2090, assuming continued emission increases of heat trapping gases. At the national level the results are loss of 5 to 17 percent by 2030, 14 to 34 percent by 2060.

This range of results are based on using a variety of climate models to look at the effects that are possible. Providing that range is very helpful, because it gives us a sense not of a precise pre- diction but of the likely outcomes and the probability of those outcomes, and gives us a way to really anticipate the types of effects we will look at if we don't take action.

So I believe that climate models are very useful to give a picture of what will happen. They are not precise predictions, but they do very usefully inform us when we make decisions about whether to control emissions of carbon dioxide and other heat trapping gases. Though I know it is not the subject of this hearing, I conclude from that that it is time to take action, and it is time for mandatory limits on emissions of greenhouse gases.

Thank you very much, Mr. Chairman.

[The prepared statement of Daniel A. Lashof follows:]

PREPARED STATEMENT OF DANIEL A. LASHOF, SCIENCE DIRECTOR, CLIMATE CENTER, NATURAL RESOURCES DEFENSE COUNCIL

INTRODUCTION

Thank you Mr. Chairman and members of the committee. My name is Daniel Lashof, and I am the Science Director of the Natural Resources Defense Council's Climate Center. I appreciate the opportunity to appear before you today.

I have been engaged in research and assessment related to global climate change for more than 15 years. I was a reviewer of the National Assessment Synthesis Report. I have also served as a Lead Author of the Intergovernmental Panel on Climate Change Special Report *Land Use, Land-Use Change, and Forestry* and as a reviewer of several reports by the panel. I have also served on the National Research Council's Committee on Atmospheric Chemistry and on the Energy Research and Development Panel of the Presidents' Committee of Advisers on Science and Technology. Previously I served on the Federal Advisory Committee on Options for Reducing Greenhouse Gas Emissions from Personal Motor Vehicles. I hold a bachelor's degree in physics and mathematics from Harvard University and a doctorate in Energy and Resources from the University of California at Berkeley.

The Natural Resources Defense Council (NRDC) is a national, non-profit organization of scientists, lawyers, and environmental specialists, dedicated to protecting public health and the environment. Founded in 1970, NRDC serves more than 500,000 members from offices in New York, Washington, Los Angeles, and San Francisco.

In my statement today I will address the value of using climate models to assess the potential effects of global warming on the Untied States and illustrate this by reviewing the results of a recent study published by NRDC and Defenders of Wildlife on the threat posed by global warming to trout and salmon.

EXPERIMENTING ON THE EARTH'S CLIMATE

Mr. Chairman, there is only one earth. It is therefore impossible to conduct a controlled physical experiment that compares an "experimental" earth with elevated concentrations of carbon dioxide (CO_2) and other heat-trapping gases to a "control" earth with an unpolluted atmosphere. Instead we are currently conducting an uncontrolled experiment in which emissions from power plants, automobiles and other sources are adding to a thickening layer of carbon pollution in the only atmosphere we have. The problem is that if we don't like the consequences of this experiment it will be too late to reverse them.

Given our one-earth experimental design, which I don't think even Congress has the power to change, the best approach available to us is to simulate the earth's climate system using all available data on the composition of the atmosphere, the properties of the earth's surface, and the conditions of the earth's oceans combined with mathematical equations that describe the fundamental physical laws of motion and conservation of mass and energy. This is called climate modeling. Climate models allow us to conduct non-destructive controlled experiments: An "experimental" simulation with rising concentrations of heat-trapping gases can be compared to a "control" simulation with constant concentrations.

The idea of using computers to simulate physical systems with mathematical models is not unique to climate modeling. Simulation models are used to test-crash cars, test-fly airplanes, and test-detonate nuclear weapons. All without the need to sweep up afterward. If computer models were inherently useless, Boeing 777's would be falling out of the skies. In fact, it's no accident that the Lawrence Livermore National Laboratory does both climate sim- ulations and nuclear weapon simulations. And for the same reason. It is safer to run these tests on computer models than on the real thing.

Climate models are in fact a remarkable achievement of modern science. Despite the incredible complexity of the earth's climate system, these models are able to simulate with high fidelity the major processes that determine the variations in the earth's climate over space and time: from the polar vortex to tropical monsoons and from the depths of winter to the heat of summer and everything in between. Are the models perfect? Of course not. Someone looking selectively for discrepancies will always be able to find something to point to and there will always be room for refinements. Nevertheless, overall the models have achieved a level of realism and accuracy that makes them very useful tools. Indeed, they are the only tool we have for safely performing experiments to investigate the effects of large-scale pollution of the atmosphere with heat-trapping gases.

THE BUSH ADMINISTRATION RECOGNIZES THE THREAT POSED BY GLOBAL WARMING

The current Bush Administration has recognized the value of using simulation models to test the potential consequences of global warming on the United States in two recent reports that underwent extensive interagency review. These are the 2001 Intergovernmental Panel on Climate Change's (IPCC) *Synthesis Report* of the Third Assessment Report and the *U.S. Climate Action Report 2002,* formally known as the Third National Communication of the United States of America Under the United Nations Framework Convention on Climate Change (UNFCCC).

First, in August 2001, the State Department submitted detailed comments on the draft of the IPCC's *Synthesis Report* of the Third Assessment Report. The administration carefully reviewed this report and, while suggesting some changes and clarifications, agreed with all the key findings. Furthermore, they participated fully in the IPCC Plenary meeting in September 2001, where the final IPCC TAR *Synthesis Report* Summary for Policymakers (SPM) was approved in detail. Among other things, this report concludes that:

- "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities." (*Climate Change 2001: Synthesis Report,* SPM, p. 5)
- "Projections using the SRES emissions scenarios in a range of climate models result in an increase in globally averaged surface temperature of 1.4 to 5.8 C over the period 1990 to 2100. This is about two to ten times larger than the central value of observed warming over the 20th century and the projected rate of warming is very likely to be without precedent during at least the last 10,000 years, based on paleoclimate data." (SPM, p. 8)
- "Models project that increasing atmospheric concentrations of greenhouse gases result in changes in frequency, intensity, and duration of extreme events, such as more hot days, heat waves, heavy precipitation events, and fewer cold days. Many of these projected changes would lead to increased risks of floods and droughts in many regions, and predominantly adverse impacts on ecological systems, socio-economic sectors, and human health." (SPM, p. 14)

Then, in May 2002, the administration released the *U.S. Climate Action Report 2002* and submitted it to the Secretariat of the UNFCCC. This report is based upon conclusions by the National Academy of Sciences, the IPCC climate change reports, and the U.S. Global Change Research Program's U.S. National Assessment of the Potential Consequences of Climate Variability and Change. It was thoroughly vetted by this administration and approved before its official release. Among the key finding of the Climate Action Report are:

- "To provide an objective and quantitative basis for an assessment of the potential consequences of climate change, the U.S. National Assessment was organized around the use of climate model scenarios that specified changes in the climate that might be experienced across the United States (NAST 2001). Rather than simply considering the potential influences of arbitrary changes in temperature, precipitation, and other variables, the use of climate model scenarios ensured that the set of climate conditions considered was internally consistent and physically plausible." (p.84)
- "Use of these model results is not meant to imply that they provide accurate predictions of the specific changes in climate that will occur over the next 100 years. Rather, the models are considered to provide plausible projections of potential changes for the 21st century. For some aspects of climate, all models, as well as other lines of evidence, are in agreement on the types of changes to be expected. For example, compared to changes during the 20th century, all climate model results suggest that warming during the 21st century across the country is very likely to be greater, that sea level and the heat index are going to rise more, and that precipitation is more likely to come in the heavier categories experienced in each region." (p.84)
- "The model scenarios used in the National Assessment project that the continuing growth in greenhouse gas emissions is likely to lead to annual-average warming over the United States that could be as much as several degrees Celsius (roughly 3-9°F) during the 21st century. In addition, both precipitation and evaporation are projected to increase, and occurrences of unusual warmth and extreme wet and dry conditions are expectedto become more frequent." (p.84)
- "Natural ecosystems appear to be the most vulnerable to climate change because generally little can be done to help them adapt to the projected rate and amount of change.
- "Sea level rise at mid-range rates is projected to cause additional loss of coastal wetlands, particularly in areas where there are obstructions to landward migration, and put coastal communities at greater risk of storm surges, especially in the southeastern United States.
- "Reduced snow-pack is very likely to alter the timing and amount of water supplies, potentially exacerbating water shortages, particularly throughout the western United States, if current water management practices cannot be successfully altered or modified.
- "Increases in the heat index (which combines temperature and humidity) and in the frequency of heat waves are very likely." (p.82).

The clear conclusion from these findings is that global warming poses a severe threat to public health and the environment in the United States.

TROUT AND SALMON IN HOT WATER

A study published by NRDC and Defenders of Wildlife in May on the threat posed by global warming to trout and salmon in the United States provides one example of the kind of analysis that can be usefully performed using the regional results of global climate models. Because trout and salmon are known to be intolerant of warm water, their abundance could be threatened if future climate change warms the streams they inhabit. I ask that this report be included in the hearing record.

Trout and salmon are highly valued for their contribution to the economy and culture of the United States. They thrive in the cold, clear streams found in many mountainous and northern regions of the country. About 10 million Americans spend an average of ten days per year angling in streams or lakes for these fish. Dams, water diversions, pollution, and development threaten trout and salmon, which have already disappeared from many of the streams where they were formerly found. Global warming poses a less visible but no less severe threat to their survival.

To assess the magnitude of this threat we contracted with Abt Associates to perform a new simulation study of how climate change might affect existing habitat for four species of trout (brook, cutthroat, rainbow, and brown) and four species of salmon (chum, pink, coho and chinook) in streams throughout the contiguous United States. The simulation uses the results of three different climate models, including updated versions of the Canadian model (CGCM2) and the Hadley Center model (HadCm3) used in the National Assessment, as well as an Australian model (CSIRO-Mk2). The changes in air temperatures projected by these global climate models are used to project the impact of global warming on U.S. stream temperatures, using a new, more accurate method to estimate the relationship between air and stream temperatures.

Interestingly, the version of the Hadley Center model used for this study projects warming rates for the United States that are quite similar to Canadian Model results used in the National Assessment. Trout and salmon are particularly sensitive to increases in summer temperature and the Hadley Model (HadCm3) projects an increase in average July temperatures for the contiguous United States of as much as 10 degrees Fahrenheit by 2090, assuming that emissions of heat-trapping gases are not curtailed.

The study found that trout and salmon habitat is indeed vulnerable to the effects of global warming. At the national level we estimate that individual species of trout and salmon could lose 5-17 percent of their existing habitat by the year 2030, 14-34 percent by 2060, and 21-42 percent by 2090, based on emissions scenarios A1 and A2 from the Intergovernmental Panel on Climate Change (IPCC), depending on the species considered and model used. Projected effects on trout and salmon are lower for IPCC scenarios B1 and B2, which assume that global CO_2 emissions are reduced for reasons not directly related to global warming. For these scenarios, we estimate habitat losses of 4-20 percent by 2030, 7-31 percent by 2060, and 14-36 percent by 2090, depending on fish species and model. Of particular concern is the number of stream locations that become unsuitable for all modeled species (Exhibit 1).

At the regional level, loss of trout habitat in the Northeast and the Southwest could be particularly severe, although losses are also expected in the Southeast and Rocky Mountain regions. For example, in Pennsylvania losses of trout habitat are projected to be 6-11 percent by 2030, 22-28 percent by 2060, and 33-44 percent by 2090, based on the A1 and A2 emission scenarios. Significant losses of salmon habitat are projected throughout their current range. The number of locations expected to become unsuitable for both trout and salmon expands steadily over time, assuming emissions of heat-trapping gases continue to increase (Exhibit 2).

These results are robust with respect to key model specifications and assumptions. For a given emissions scenario, the greatest uncertainty is due to differences among the global climate models, yet the results provide a valuable indicator of the regions most vulnerable to loss of cold water fish habitat. Differences among the scenarios for future emissions of heat-trapping gases also significantly affect the results, even though none of the scenarios examined assumes that policies are adopted specifically to address global warming. For all emissions scenarios our results are likely to understate expected losses of habitat because of the several dimensions of climate change and potential effects on habitat that were beyond the scope of the study. These include potential effects on stream flows, changes to the temperature of groundwater discharge, changes in ocean conditions, and other considerations. In addition, these results must be viewed within the context of other present and future threats to fish habitat, which are likely to add to the temperature-related losses estimated in the report.

This analysis demonstrates that it is possible to draw robust conclusions about the vulnerability of key resources to the effects of global warming, despite variations in climate model projections. The results show that future strategies to protect trout and salmon will need to address the potential effects of global warming.

RESPONDING TO THE THREAT OF GLOBAL WARMING

The administration has recognized the threat posed to the United States by global warming and has reaffirmed the United States' commitment to the objective of the Framework Convention on Climate Change, which is to stabilize greenhouse gas concentrations in the atmosphere at safe levels. Nonetheless, the administration has refused to consider any mandatory limits on emissions of heat-trapping gases. This position is both illogical and irresponsible.

The administration has argued, in essence, that mandatory limits on emissions of CO_2 and other heat-trapping gases would harm the economy, and that therefore we should rely on voluntary measures and adapt to changes in climate. The administration has not advanced any analysis, however, to suggest that voluntary action has any chance of stabilizing greenhouse gas concentrations in the atmosphere. Indeed, the United States has now relied on voluntary measures for more than a decade and emissions have continued to increase.

The administration's claim that setting mandatory limits on emissions now would harm the economy is equally unsupported by analysis. While it is possible to construct straw-man proposals that would be costly, surely there must be some level and timetable for a CO_2 emission limit that would be affordable. Yet the administration has rejected any mandatory limit out of hand. In fact, failure to set limits now will lead to stranded investments in new highly emitting power plants and other equipment that will become obsolete when limits are established in the future.

Further delay in establishing mandatory limits on heat-trapping gas emissions is irresponsible because our window for taking action in time to stabilize greenhouse gas concentrations at safe levels is rapidly closing. The IPCC Synthesis Report cited earlier, which was adopted with the full participation of the administration, makes this quite clear:

- "The severity of the adverse impacts will be larger for greater cumulative emissions of greenhouse gases and associated changes in climate." (SPM p.9)
- "Inertia is a widespread inherent characteristic of the interacting climate, ecological, and socieconomic systems. Thus some impacts of anthropogenic climate change may be slow to become apparent, and some could be irreversible if climate change is not limited in both rate and magnitude before associated thresholds, whose positions may be poorly known, are crossed." (SPM p. 16)
- "The pervasiveness of inertia and the possibility of irreversibility in the interacting climate, ecological, and socio-economic systems are major reasons why anticipatory adaptation and mitigation actions are beneficial. A number of opportunities to exercise adaptation and mitigation options may be lost if action is delayed." (SPM p. 18)

Mr. Chairman, global warming poses a clear threat to the United States. The good news is that this is a threat that we know how to stop. Now is the time to set mandatory limits on emissions of heat-trapping gases.

Thank you.

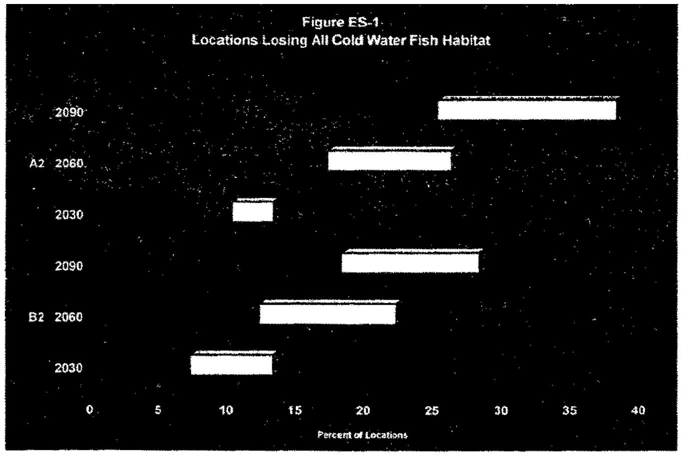

Exhibit 1. Locations Losing All Cold Water Fish Habitat

Mr. GREENWOOD. Thank you, Dr. Lashof. The last two times at my trout fishing in Pennsylvania I caught nothing. Now I know why.

Dr. O'Brien.

TESTIMONY OF JAMES J. O'BRIEN

Mr. O'BRIEN. Mr. Chairman, thank you very much for inviting me today. I have been a physical scientist in oceanography/meteorology for 40 years. I will tell you that in the early part of my career primarily I was an ocean modeler, and my students and I are recognized for that internationally. Then in the Seventies, late Seventies and Eighties, we contributed to understanding of El Nino and how it can be forecast, and then in the Nineties, while most scientists were studying what was happening in tropical countries, my students and I concentrated on impacts in the United States, and I have listed in my paper many of the things we have done.

In 1990 I accepted the pro bono job as the State Climatologist in Florida. Mr. Deutsch, I am your State Climatologist. So if you have any constituents who need to know about climate variability or climate data, please refer them to my office in Tallahassee.

The reason I took it was very simple. Based on the climate variability studies, which is part of my theme, the mitigatable impact in the State of Florida is at least $500 million a year, primarily in forestry and agriculture, tourism and fisheries. I want to see that we accelerate this information for the people of Florida.

Recently, we have actually developed—which is now being used by the wildfire management people in Florida—a way to predict up to 6 months in advance which county is more vulnerable for forest fires. You know we have had quite a time with 3 years of drought in the State of Florida.

So we provide climate advice to the citizens of Florida for all sectors, but particularly agricultural, forestry, tourism and power generation, and I am funded by NOAA in this area also to do the research that goes along with providing the information. We work closely with Tom Karl and he provides us lots of the old data which is very useful.

Now, turning to the National Regional Assessment of Climate Change, I was the co-chair for the Southeast Regional Assessment. Unfortunately, my co-chair, Dr. Ron Ritschard, died at an early year. We were funded by NASA.

Today I want to focus on the question, and in my scientific opinion, the Hadley model is a state-of-the-art model, but it has poor horizontal resolution, inadequate physics, particularly in the ocean component. And since we deal primarily with—when we worry about whether it is going to be a cold winter in Chicago, you know, or too much rain in San Diego, these are related to what the ocean is doing, the memory that the ocean has, and it is very important if you are going to do a 100 year run that you have an adequate ocean model.

A very prominent French physical oceanographer told me recently—fortunately, he is quite young—that he hopes that before he dies, the ocean models used by these global climate models represents something that he knows that's in the real ocean.

Anyway, my opinion is that to Canadian model is very flawed and should never have been used. Even when it was first distributed to the team across the United States, the data was represented incorrectly geographically, and the attitude was, well, maybe that is not real important. I have no knowledge whether they actually ever fixed it up.

You know, I enjoy learning about climate variability over the United States, such as floods, droughts, freezes, and hurricanes. I don't have time to go into what our studies have shown us, but for the average citizen, you know, they are wondering about the variability in climate. Okay? Is it different than, you know, my grandfather told me about? Is my experience different?

They are not really interested in whether the average temperature is going to rise 3 to 5 degrees Fahrenheit in 100 years. They are interested in is winter going to be colder than normal and many other things.

For example, one of the things I discovered early on the Canadian model is they didn't have El Ninos in it. Now I was told it is in there, but I have looked at the data. I am an expert in that, and I couldn't find any sign of it, and I cannot imagine any climate model that we are going to run for 100 years that doesn't have some robust signal of the way that our climate variability is changing on year to year and decadals.

In the Hadley model, you see that, but you don't see that in the Canadian model. We are three State climatologists here today, and another one from the State of Alabama, Dr. John Christie, says that he believes that the Canadian model was modeling another planet than this one.

Okay. Can we do better? I think we can really do better, and I actually have some very good news. Yesterday when I came, someone delivered to me a testimony of James Mahoney, who is now the Assistant Secretary of Commerce for Ocean Atmospheres, and he on July 11 this year before the Committee on Commerce, Science and Transportation of the U.S. Senate had delivered this paper which I can add into the record.

In just part of it he says that uncertainties in climate models address exactly what we are talking about. It says the poor regional performance of current general circular models severely restricts the examination of potential global climate influence on key regional systems. I am so delighted that at very high level in government that that is now understood.

I am going to conclude now and just say that I believe global climate change would occur. I am not convinced that we are going to see it in terms of surface temperature increase or sea level increase. It will change. We need to address what to do.

In my outline I have indicated that we need a new Manhattan type project. We need an institute outside the government, labs in the government, where we hire the best managers,the best scientists, and give them finally decent computers so they can do the job correctly and make adequate American models.

There is a model like this, sir. The model is the European Centre model for medium range weather prediction where the European nations got together and formed a center which is physically in Britain but has members all over. I think nobody will disagree in this room that they give the best week-long weather forecasts of anyplace. The reason they do is because of a unique way it is managed—good managers that don't stay there for lifetimes, good scientists that stay 5 to 10 years and then go to their home countries, and the best computers in the world for doing the problem right.

The technical director of the Center for European Centre for Medium Weather Prediction, a good Irishman like me, recently said to General Kelly, the head of the Weather Service—He says, General Kelly, we are two decades ahead of you now; why don't you just buy our results and shut down the operation.

Thank you very much.

[The prepared statement of James J. O'Brien follows:]

PREPARED STATEMENT OF JAMES J. O'BRIEN, ROBERT O. LAWTON DISTINGUISHED PROFESSOR, METEOROLOGY AND OCEANOGRAPHY, THE FLORIDA STATE UNIVERSITY

INTRODUCTION

I have been a physical scientist in oceanography and meteorology for 40 years. In my early years, my graduate students and postdocs concentrated primarily on modeling time dependent ocean motions. In the late 1970's and 1980's, we contributed to the physical understanding of El Nino. Namely, how it works and how it can be forecast.

In the 1990's, while most other scientists were applying ENSO forecasts to tropical countries, my students and I have concentrated on impacts in the United States. We have written papers on: ENSO and Atlantic Hurricanes; ENSO and Tornadoes; ENSO and Precipitation; ENSO and Temperature; ENSO and Wild Fires (In Florida); ENSO and Snowfall; ENSO and Excessive Wind Events; ENSO and Great Lakes Snow Events; and ENSO and Freezes in Central Florida.

In 1999, I accepted the pro bono job as official State of Florida Climatologist. We have been advising the Florida Commissioner of Agriculture on wild fire forecasts, droughts, hurricanes, etc. We provide climate advice to the citizens of Florida for all sectors, but, particularly agriculture, forestry, fisheries, tourism and power generation.

In some local circles, I am labeled, Dr. El Nino for my research.

Turning now to the National Regional Assessment of Climate Change, I was the Co-Chair for the Southeast Regional Assessment. (My Co-Chair, Dr. Ron Ritschard, recently died at a young age). Our work was funded by NASA, Huntsville, Alabama.

In the early beginnings of the National Regional Assessment, the entire U.S. team met and we agreed there would be "ONE" Global CO_2 doubling model so everyone referring to future projections would be on the same page. There were two choices: (1) The Hadley, (British model), or (2) The Max Planck (German model). The Hadley model was selected. Subsequently, I attended a meeting of the U.S. National Resource Board Committee on Climate. Many senior scientists were shocked that there was no American models. In due time, a very new recent model, the Canadian Model was added for our use. It was recently computed so no documentation or response of this model was available to the assessment teams.

In my opinion, the Hadley model is a state-of-the-art model with poor resolution, inadequate physics—particularly, the ocean component. The Hadley Model gives reasonable projections, but it is still flawed and I am sure that, in due time, will be improved. As better ocean models are improved in climate models, the future changes are greatly reduced.

The Canadian's model is flawed, and, in my opinion, should never have been used. My effort to capture the attention of the leaders to recognize this were rejected outright. My team discovered that, initially, the data provided to the team had been incorrectly registered with respect to the geography of the U.S. Since the model has horizontal grid boxes around 500 km on a side, being set off by one grid, really confuses geographic identification. (As an aside, I do not know if this was fixed, but I was told it can't make any difference).

I really enjoy learning about climate variability over the United States, such as droughts, floods, freezes, hurricanes, etc. For the citizen for whom climate is important, it is the variability which matters! It is not whether the average temperature will rise 3-5 °F in 100 years. The citizen wants to know "Is this winter going to be colder than normal?" and other simple questions. I discovered that we could not find ENSO variability in the ocean model of the Canadian model. I was told it was there, but it makes no difference if it is too small.

Mr. Chairman, the variability of climate over most of the United States is primarily controlled by ENSO and other ocean-related phenomena (North Atlantic Oscillation, and the Pacific Decadal Oscillation) and land use changes. I cannot accept a 100 year climate run as useful if it doesn't also include the observed variability in the climate system.

What is the climate system? It is the entire atmosphere, ocean, land, ice systems which are heated by the sun. The chemistry of global climate change is completely correct. We have an excellent scientific understanding of how radiatively-active gases such as carbon dioxide, methane and water vapor can delay heat in the climate system. There is an assumption that this extra heat will manifest itself in raising the temperature of the biosphere—that portion of the climate system in which we humans live. The data measured from the actual climate system seems to indicate other processes are dominate, such as stronger mid-latitude storms which are important for distributing the extra heat. In my opinion, even the current models are not capable in calculating the climate system well enough for policymakers to believe in any projection.

Can we do it better? I believe we can, but it will take a new effort and considerable investment. We know most of the physics of the climate system. In order to calculate the variability of the system, we need adequate computers. We need the kind of investment in computers that the Congress funds to DOD, NSF, NSA, etc.

I propose a "Manhattan Type Project" to estimate future climate variability for our National Security. Any future climate change will probably require trillions of dollars to adjust our culture or mitigate the consequences. My vision is a NEW Institute, outside the government with top management, the best scientists and adequate resources. My estimate is $50M/year for at least 10 years.

When I suggest this, OMB folks usually ask me, "Dr. O'Brien, where are we going to find that money?" My answer is, "Give us 2 attack helicopters" monies, and we will be happy for a few years. Give us a fighter jet monies, we will be very happy for a few years. Give us an aircraft carrier monies, and we will never ask for any more resources". The Congress has to decide on the priorities. Do we want to understand the future climate or not?

Returning to my belief, that we can do better in modeling climate, I am encouraged that each generation of climate change modeling gets better. The original CO_2-doubling model by NASS,GISS under the leadership of Dr. Jim Hansen, estimated around 10 °F surface temperature change by 2050. This was so dramatic because no ocean was included. I remember reading in the Tallahassee Democrat, a story that said, as a result of the GISS model, that sea-level would rise 3 meters or 7-10 feet by 2050. The current IPCC estimates a few degrees temperature rise by 2100 and a doubling of the current sea-level rise of around 8-10 inches to 20 inches as the worst case by 2100. Certainly, policymakers will react differently to plan for a two feet rise in 100 years vs. 10 feet rise in a generation.

Let me provide one more remark on sealevel rise. In order to double sealevel, one would expect to observe an increased rate of rise by 2002. Everyone agrees that the current average rise is about 7-10 inches a century, averaged over the globe. However, the experts who have tried to find any acceleration find none.

How about global warming in the United States? I will leave this subject to my fellow climatologist, Dr. Tom Karl. I am, however, the State Climatologist of Florida. In Florida, the cities are warming at the rate of about one degree in the entire 20th century. But the rural places are cooling at the rate of more than one degree per century. I have included some graphics in my presentation documenting this for minimum temperature over the entire 20th Century. What is happening? My fellow, State Climatologist, from Colorado, Dr. Roger Pielke, Sr., explains this by land use changes. Dr. Karl has published work showing the cooling in the Southeast United States, but unfortunately, the summary of average temperature in Florida in the last century, in the S.E. Assessment summary, shows Florida warmer than the rural data would dictate.

Finally, the ocean part of the global climate system models are very inadequate. The research community is aware that warm and cold ocean currents are very important in predicting the weather even for 10 days. It is critical to model the oceans correctly if a global climate model is expected to work at all. A young French ocean modeler said to me recently, "I hope that the ocean models used by global climate models look like the real ocean before I die!"

There are hundreds of scientists other than climate modelers that have been told the Hadley and Canadian models are good projections of the future. This is a shame. When I joined the U.S. National Assessment Team as Co-Chair of the Southeast Regional Assessment, a bright young EPA ecologist from Louisiana reported to me that the number of hurricanes in the Gulf of Mexico were increasing due to global warming. I was unaware of this. Consequently, my students and I did a study. We found, that, in fact, the number of hurricanes have decreased significantly in the Gulf of Mexico. This is a published paper. 1998: Are Gulf Hurricanes Getting Stronger? Bull. Amer. Meteorol. Soc., 79(7), pp. 1327-1328 (with Bove, M.C., and D. F. Zierden).

CONCLUSION

Global climate changes will occur. Whether surface temperatures will increase due to radiatively-active emissions is not clear. The Global Climate System must change. In order to address what the nation needs to do, I recommend a large investment in improving the basic understanding by investing in very good global climate system calculations.

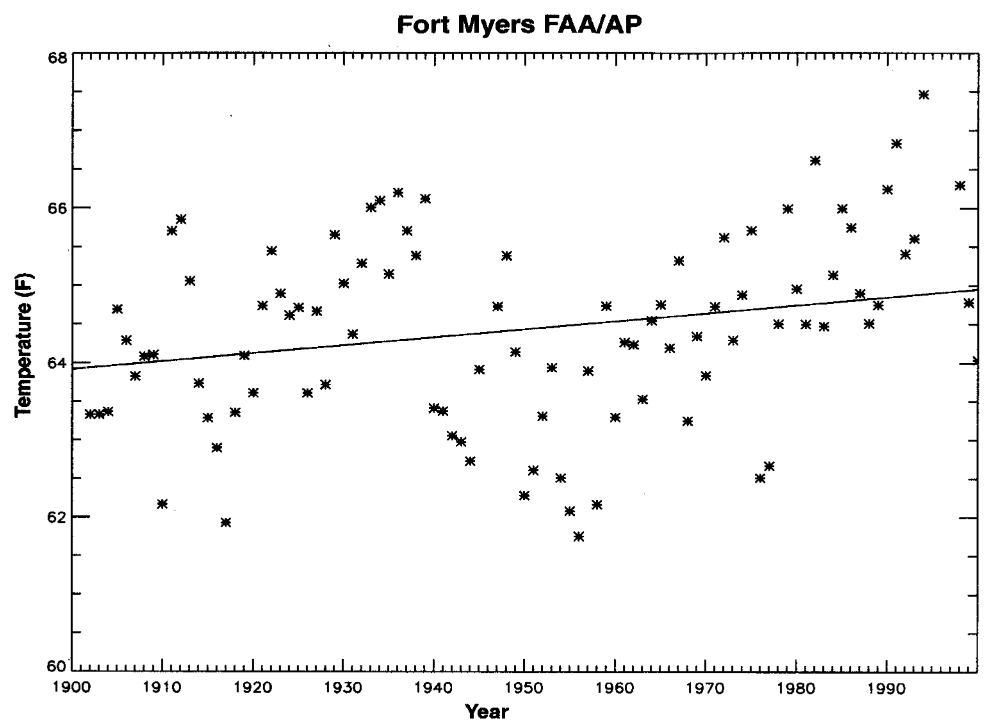

Figure 1: Annual Minimum Temperatures in Fort Myers, FL show a 1.0°F increase.

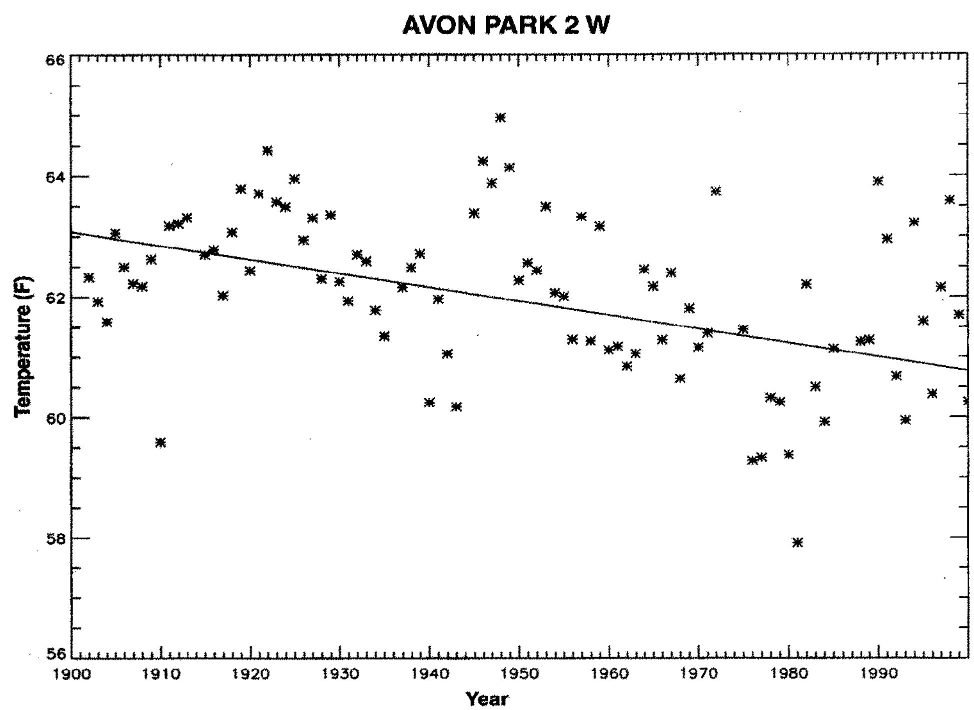

Figure 2: Annual Minimum Temperatures in Avon Park, FL show a 1.25˚F decrease.

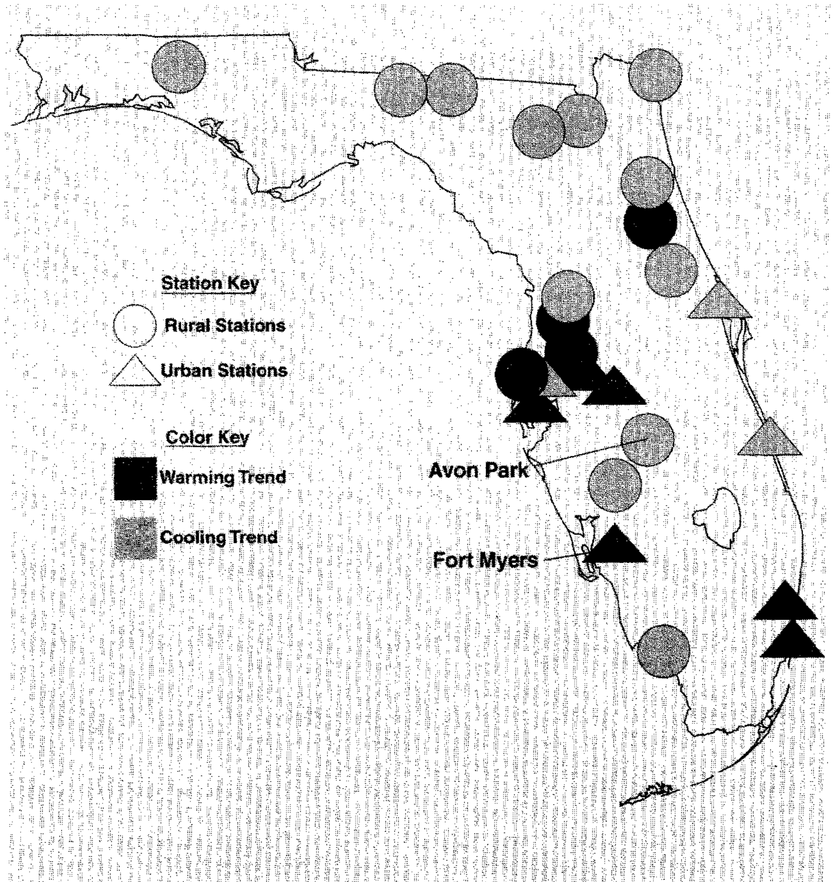

Figure 3: 20th Century Minimum Temperature Changes.
Circles represent rural area; triangles represent urban areas.

Mr. GREENWOOD. Thank you. My staff said it sounds like a field hearing. We will have to go over to Europe and take a look at that.

Dr. Pielke.

TESTIMONY OF ROGER A. PIELKE, SR.

Mr. PIELKE. Yes, Mr. Chairman, members of the committee, thank you for the opportunity to present testimony. I received my PhD and Master's degree from Penn State in the Department of Meteorology, and since the 1960's my research has focused on weather and climate studies using both models and observations.

In my testimony I would like to convey two main points: First, that the perspective I am presenting today does not easily fit into the conventional two-sided debate over climate change. This third perspective, as I have written elsewhere, suggests that humans have an even greater impact on climate than is suggested by the international and national assessments.

The human influence on climate is significant and multi-faceted. However, any attempt to accurately predict future climate is fundamentally constrained by the significant and multi-faceted characteristics of the human influence on climate. By focusing on vulnerabilities rather than prediction as a focus of research, I believe that the scientific community can provide more comprehensive and likely more useful information to decisionmakers.

These points are consistent with the American Association of State Climatologists Policy Statement on Climate Variability and Change which was approved on October 25, 2001, and I will read part of that statement:

"Our statement provides the perspective of our Society on issues of climate variability and change. Since the Society members work directly with users of climate information at the local, State and regional levels, it is uniquely able to put global climate issues into the local perspective which are needed by users of climate information. Our main conclusions are as follows:

"First, past climate is a useful guide to the future. Assessing past climate conditions provides a very effective analysis tool to assess societal and environmental vulnerability to future climate, regardless of the extent the future climate is altered by human activity. Our current and future vulnerability, however, will be different than in the past, even if the climate were not to change, because society and the environment change as well. Decision makers need assessments of how climate vulnerability has changed.

"Two, climate prediction is complex with many uncertainties. The AASC recognizes climate prediction is an extremely difficult undertaking. For time scales of a decade or more, understanding the empirical accuracy of such predictions, called verification, is simply impossible, since we have to wait a decade or longer to assess the accuracy of the forecasts."

In the remainder of my 5 minutes I will discuss one example of the scientific basis that underlie the statement. Greater detail is available in the peer reviewed scientific publications that are listed at the end of my written testimony.

A fundamental basis of the U.S. National Assessment is the use of the Canadian and Hadley Centre General Circulation Models to project the future state of the climate as the basis for discussion of climate impacts and ultimately alternative courses of action by decisionmakers. The perspective I offer here suggests that in relying on GCMs to, in effect, bound the future state of the climate, the U.S. National Assessment may have had the effect of underestimating the potential for change and overestimating our ability to accurately characterize such changes with computer models.

The hypothesis for using these models is that including human caused increases of carbon dioxide and other greenhouse gases and aerosols in the models are sufficient to predict long term effects on the climate of the United States. The position presented here is that such forcings are important, but a subset of those needed to develop plausible projections, and even if all the forcings were included, accurate long term prediction would remain challenging, if not impossible.

To test the hypothesis that GCMs can accurately project climate, it is possible to compare model performances with observed data for the period 1979-2000. One test is the ability of the model to predict the averaged temperatures of the earth's atmosphere over this 20-year period. Such a test is a necessary condition for regional projection skill, since if globally averaged long term changes cannot be skillfully projected, there will necessarily be no regional skill.

During this period, for example, at around 18,000 feet above sea level, the Canadian GCM projects a 0.7 degree C warming of the global averaged temperature. The Hadley Centre model also has atmosphere warming for this time period. The observations, in contrast, have no statistically significant change in these averaged atmospheric temperatures.

Thus, either the models or the observations must be incorrect. Both cannot be correct. Since, for the 1979-2000 time period, satellite, radiosonde and National Center for Environmental Prediction model reanalyses each agree closely with respect to global averages, the observations should be interpreted as our best estimate of reality.

The scientific evidence, therefore, is that the models have failed to replicate the actual evolution of atmospheric temperatures over the time period 1979-2000. Thus using the results of these models as the basis for assessments, much less for particular decisions, for the next several decades is not justified. Such models clearly have usefulness as scientific tools with which to conduct sensitivity experiments, but it is important to not overstate their capabilities as predictive tools.

One major reason for this difficulty is the absence and/or inadequate representation of significant human caused forcing of the climate. These include land use changes over time, the effect of aerosols on clouds and precipitation, and the biogeochemical effect of carbon dioxide. The Intergovernmental Panel on Climate itself concludes that there is a very low level of scientific understanding of these forcings.

The importance of one of these effects can be illustrated by a just published paper of the influence of human caused land use change on the global climate. Even with a conservative estimate of land use change, the global redistribution of heat and the effects on regional climate is at least as large as simulated by the existing GCM simulations. However, even when these forcings are included, the complex interactions among the components of the climate system will likely limit our ability to skillfully predict the future. Indeed, we cannot even predict with any skill beyond a season in advance, and then only under special situations such as an evolving El Nino.

As a result, we have—There is a new book that is coming out by the International Geosphere-Biosphere Programme titled "Vegetation, Water, Humans and the Climate," and there is a chapter in there which talks about how to evaluate the vulnerability in changing environmental conditions.

This chapter basically proposes that we start first from an assessment of vulnerability. Only at that point do we bring in these other tools, such as GCM models, historical record, and so forth.

Even the IPCC, I am told by some colleagues, is starting to embrace a greater focus on vulnerability, and several U.S. programs, most notably the Regional Integrated Science and Assessments program of NOAA, have also acknowledge the importance of vulnerability as a scientific organizing theme.

Let me conclude by saying I wish to underscore that the inability of the U.S. National Assessment models to skillfully predict climate change does not mean that the radiative effect of anthropogenic greenhouse gases on climate is not important, nor does it suggest which policy responses to the issues of climate change make the most sense.

Such matters of policy go well beyond any discussion of the issues of science and well beyond the information presented in my testimony today.

Effective mitigation and adaptation policies in the context of climate variability and change do not depend on accurate prediction of the future and, consequently, a lack of ability to generate accurate predictions should not be used as a justification to ignore the policy challenges presented by climate. Too often, debate over climate substitutes for debate over policy.

Thank you.

[The prepared statement of Roger A. Pielke, Sr. follows:]

STATEMENT OF PROFESSOR ROGER A. PIELKE, SR.

Mr. Chairman, Members of the Committee, thank you for the opportunity to present testimony on "The U.S. National Climate Change Assessment: Do the Climate Models Project a Useful Picture of Regional Climate?"

I am a Professor of Atmospheric Science at Colorado State University. I am also State Climatologist for Colorado and President-Elect of the American Association of State Climatologists. I received my M.S. and Ph.D. from Pennsylvania State University in the Department of Meteorology. Since the 1960s, my research focuses on weather and climate studies using models and observations.

In my testimony I'd like to convey the following two points:

1. The perspective I am presenting today does not easily fit into the conventional two-sided debate over climate change. This third perspective, as I have written elsewhere, "suggest[s] that humans have an even greater impact on climate than is suggested by [international and national assessments]. The human influence on climate is significant and multi-faceted."[1]

[1] Pielke Sr., R.A., 2001: Comments on "IPCC report cautiously warns of potentially dramatic climate change impacts." EOS, 84, 394, 396.

2. Any attempt to accurately predict future climate is fundamentally constrained by the significant and multi-faceted characteristics of the human influence on climate. By focusing on *vulnerabilities* rather than *prediction* as a focus of research, I believe that the scientific community can provide more comprehensive and likely more useful, information to decision makers.

These points are consistent with the American Association of State Climatologists Policy Statement on Climate Variability and Change which was approved on October 25, 2001. The American Association of State Climatologists is a professional scientific organization composed of state climatologists (one per state), directors of the six Regional Climate Centers of the National Oceanic and Atmospheric Administration within the Department of Commerce, and associate members who are persons interested in the goals and activities of the Association. State Climatologists are individuals who have been identified by a state entity as the state's climatologist and who are also recognized by the Director of the National Climatic Data Center of the National Oceanic and Atmospheric Administration as the state climatologist of a particular state.

State Climatologists currently exist in 47 states and Puerto Rico. They are typically either employees of state agencies or are staff members of state-supported universities. Associate members may be assistant state climatologists or other climatologists under the employ of the state climatologist; representatives of federal climate agencies; retired state climatologists; or others interested in climate services. The total membership of the Association is approximately 150.

AASC Policy Statement on Climate Variability and Change

Our statement provides the perspective of the AASC on issues of climate variability and change. Since the AASC members work directly with users of climate information at the local, state and regional levels, it is uniquely able to put global climate issues into the local perspective needed by the users of climate information. Our conclusions are as follows:

1. **Past climate is a useful guide to the future – Assessing past climate conditions provides a very effective analysis tool to assess societal and environmental vulnerability to future climate, regardless of the extent the future climate is altered by human activity. Our current and future vulnerability, however, will be different than in the past, even if climate were not to change, because society and the environment change as well. Decision makers need assessments of how climate vulnerability has changed.**

2. **Climate prediction is complex with many uncertainties – The AASC recognizes climate prediction is an extremely difficult undertaking. For time scales of a decade or more, understanding the empirical accuracy of such predictions – called "verification" – is simply impossible, since we have to wait a decade or longer to assess the accuracy of the forecasts.**

Climate prediction is difficult because it involves complex, nonlinear interactions among all components of the earth's environmental system. These components include the oceans, land, lakes, and continental ice sheets, and involve physical, biological, and chemical processes. The complicated feedbacks and forcings within the climate system are the reasons for the difficulty in accurately predicting the future climate. The AASC recognizes that human activities have an influence on the climate system. Such activities, however, are not limited to greenhouse gas forcing and include changing land use and sulfate emissions, which further complicates the issue of climate prediction. Furthermore, climate predictions have not demonstrated skill in projecting future variability and changes in such important climate conditions as growing season, drought, flood-producing rainfall, heat waves, tropical cyclones and winter storms. These are the type of events that have a more significant impact on society than annual average global temperature trends.

1. **Policy responses to climate variability and change should be flexible and sensible – The difficulty of prediction and the impossibility of verification of predictions decades into the future are important factors that allow for competing views of the long-term climate future. Therefore, the AASC recommends that policies related to long-term climate not be based on particular predictions, but instead should focus on policy alternatives that make sense for a wide range of plausible climatic conditions regardless of future climate. Climate is always changing on a variety of time scales and being prepared for the consequences of this variability is a wise policy.**

2. **In their interactions with users of climate information, AASC members recognize that the nation's climate policies must involve much more than discussions of alternative energy policies – Climate has a profound effect on sectors such as energy supply and demand, agriculture, insurance, water supply and quality, ecosystem management and the impacts of natural disasters. Whatever policies are promulgated with respect to energy, it is imperative that policy makers recognize that climate – its variability and change – has a broad impact on society. The policy responses should also be broad.**

Thus, to address the issues of climate variability and change, modernizing and maintaining high quality long-term climate data must be a high priority in order to permit careful monitoring. With the rapid dissemination of these data, State Climate Offices, as well as the Regional Climate Centers, and the National Climatic Data Center can better monitor emerging climate threats to critical national resources, such as our water supply, agriculture, and energy needs. The climate data must include all-important components of the climate system (e.g., temperature, precipitation, humidity, and vegetation health and soil moisture). We also recommend that the nation strengthen its local, state, and regional climate services infrastructure in order to develop greater support capabilities for those decision makers who have to respond to climate variability and change.

Finally, ongoing political debate about global energy policy should not stand in the way of common sense action to reduce societal and environmental vulnerabilities to climate variability and change. Considerable potential exists to improve policies related to climate; the AASC is working to turn that potential into reality.

In the remainder of my testimony, I will provide several examples of the scientific basis that underlie the AASC Statement. Greater detail is available in the peer-reviewed scientific publications that are listed at the end of my testimony.

A fundamental basis of the U.S. National Assessment is the use of the Canadian and Hadley Centre General Circulation Models (GCMs) to project the future state of the climate as the basis for discussion of climate impacts and ultimately alternative courses of action by decision makers. The perspective I offer here suggests that in relying on GCMs to, in effect, bound the future state of the climate, the U.S. National Assessment may have had the effect of underestimating the potential for change and overestimating our ability to accurately characterize such changes with computer models.

The hypothesis for using these models is that including human caused increases of carbon dioxide and other greenhouse gases and aerosols in the models are sufficient to predict long-term effects on the climate of the United States. The position presented here is that such forcings are important, but a subset of those needed to develop plausible projections, and even if all forcings were included, accurate long term prediction would remain challenging, if not impossible.

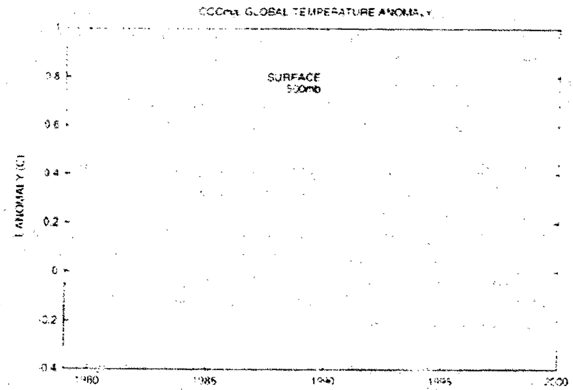

Figure 1

To test the hypothesis that GCMs can accurately project climate, it is possible to compare model performances with observed data for the period 1979-2000. One test is the ability of the model to predict the averaged temperatures of the Earth's atmosphere over this 20-year period. Such a test is a necessary condition for regional projection skill, since if globally averaged long term changes cannot be skillfully projected; there will necessarily be no regional skill. During this period, for example, at around 18,000 feet above sea level, the Canadian GCM projects a 0.7° C warming of the global averaged temperature.[2] The Hadley Centre model also has atmosphere warming for this time period. The observations, in contrast, have no statistically significant change in these averaged atmospheric temperatures.[3] Thus, either the models or the observations must be incorrect; both cannot be correct. Since, for the 1979-2000 time period, satellite, radiosonde and National Center for Environmental Prediction model reanalysis each agree closely with respect to global averages, the observations should be interpreted as our best estimate of reality.

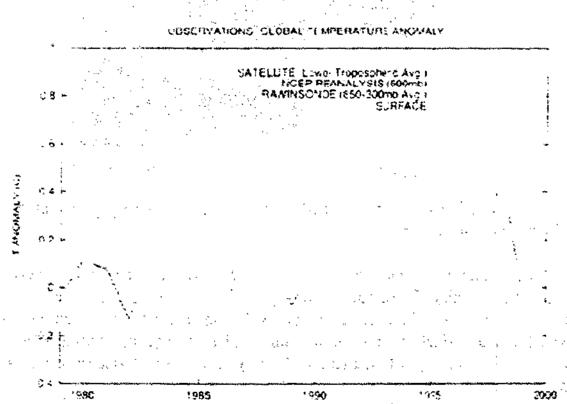

Figure 2

[2] The Canadian Climate Model results can be obtained from http://www.cccma.bc.ec.gc.ca/data/cgcm2/cgcm2.shtml .
[3] Figures 1 and 2 shown were plotted by Dr. Thomas Chase of the University of Colorado.

The scientific evidence, therefore, is that the models have failed to replicate the actual evolution of atmospheric temperatures over the time period 1979-2000. Thus using the results of these models as the basis for assessments, much less for particular decisions, for the next several decades is not justified. Such models clearly have usefulness as scientific tools with which to conduct sensitivity experiments, but it is important to not overstate their capabilities as predictive tools

Moreover, there are overlooked issues concerning the spatial representativeness of the surface land data. The National Climate Data Center (NCDC) under the leadership of Tom Karl has contributed significantly to develop representative data sets, but as yet there has been no attempt within the scientific community to incorporate regional and local land use change, except urbanization effects, into these data sets.[4] Even with urbanization, there is no adjustment for the different effect on temperatures depending on the geographic location. Denver, for instance has a distinct different effect on local temperature variations than Washington D.C.

The temperature measuring sites themselves have not been investigated to determine their exposure to the air, and whether local biases are affecting the temperature. In eastern Colorado, for example, several of the Historical Climate Reference sites[5] have exposure which would result in a non-spatially representative warming. As an example, Figure 3 shows that one of the sites is located adjacent to the south face of a brick building next to an air conditioner unit. Since this data is part of the U.S. Historical Climate Network it presumably has been used in the construction of the global surface analysis which is the basis for the claim of global averaged surface warming.

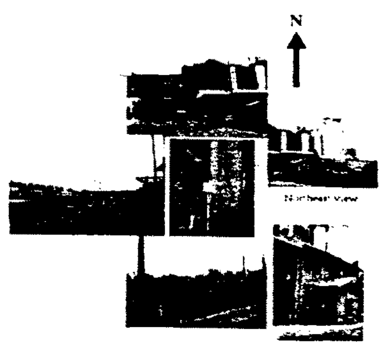

Figure 3

Close up of sensor location

The GCM projections clearly have difficulty capturing the actual evolution of the Earth's climate system.

One major reason for this difficulty is the absence and/or inadequate representation of significant human caused forcing of the climate. These include land use changes over time, the effect of aerosols on clouds and precipitation, and the biogeochemical effect of carbon dioxide. The Intergovernmental Panel on Climate (IPCC), itself, concludes that there is "a very low level of scientific understanding" of these forcings.[6]

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[4] See, for example, Pielke et al. (1999: The influence of anthropogenic landscape changes on weather in south Florida. Mon. Wea. Rev., 127, 1663-1673). Surface warming has been observed in south Florida in July and August since the early 1900s. The observed warming, however, could be explained by land use change alone. The land use change that occurred include the conversion of marshes and wetlands to agricultural, grazing and suburban landscapes.

[5] The U.S. Historical Climate Network sites are listed at the web site ftp://ftp.ncdc.noaa.gov/pub/data/ushcn/station.inventory.z

[6] See Figure 3 from IPCC 2001: Summary for Policymakers. A Report of Working Group 1of the Intergovernmental Panel on Climate Change (available at: http://www.ipcc.ch/)

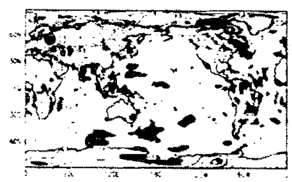

Figure 4

The importance of one of the effects can be illustrated by a just published study of the influence of human-caused landuse change on the global climate.[7] Even with a conservative estimate of land use change the global redistribution of heat is at least as large as simulated by the existing GCM model projections. As an example, Figure 4 illustrates the near surface 10-year averaged January temperatures that resulted from this simulation study.

A model comparison of the regional effect of landuse change on the thunderstorms in the central Great Plains is shown in Figure 5. In the top Figure the current landscape is applied in the model. In the bottom Figure, the natural short grass prairie is imposed. A major effect on weather clearly results.

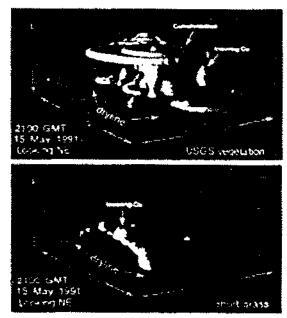

Figure 5

Even when these forcing are included, however, the complex interactions among the components of the climate system will likely limit our ability to skillfully predict the future. Indeed, we cannot even predict with any skill beyond a season in advance, and then only under special situations such as an evolving El Niño.

The inherent limitations on predicting future climate has lead the International Geosphere-Biosphere Programme to conclude their new book entitled "Vegetation, Water, Humans and the Climate: A New Perspective on an Interactive System. A Synthesis of the ICBP Core Project, Biospheric Aspects of the Hydrologic Cycle" with a chapter entitled "*How to evaluate the vulnerability in changing environmental conditions.*" That chapter proposes an approach to environmental assessment focused on *vulnerability* which first seeks to identify the exposure of human and environmental systems to human and environmental driven change and variability. After such vulnerabilities are assessed, all available tools should be used to create plausible scenarios for future societal and environmental outcomes, as a function of alternative courses of action. This include the historical record (e.g., what would happen today or in 10 years, if the weather of the dust bowl years of the 1930s reoccurred?), the paleo-record (e.g., what would occur if the megadrought of the 16^{th} Century happened again?), synthetic analysis (e.g., connecting the most serious drought years of the last 100 years into a consecutive ten year period), and plausible GCM simulation results in which all important feedbacks and forcings are included. In this vulnerability framework, GCMs play an important role in science and assessment but can not be depended on to accurately define the entire range of possible future conditions. The Intergovernmental Panel on Climate Change, I have been told by colleagues, is embracing a greater focus on vulnerability and several U.S. programs, most notably the Regional Integrated Science and Assessments (or RISA) program of NOAA, have also acknowledged the importance of vulnerability as a scientific organizing theme.

[7] Pielke Sr., R.A., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D. Niyogi, and S. Running, 2002: The influence of land-use change and landscape dynamics on the climate system- relevance to climate change policy beyond the radiative effect of greenhouse gases. Phil. Trans. A, Special Theme Issue, in press.

Finally, I wish to underscore that the inability of the U.S. National Assessment models to skillfully predict climate change does not mean that the radiative effect of anthropogenic greenhouse gases on climate is not important. Nor does it suggest which policy responses to the issue of climate change make the most sense. Such matters of policy go well beyond any discussion of the science of climate and well beyond the information presented in my testimony presented today.

Effective mitigation and adaptation policies in the context of climate variability and change do not depend on accurate prediction of the future, and consequently a lack of ability to generate accurate predictions should not be used a justification to ignore the policy challenges presented by climate. Too often debate over the science substitutes for debate over policy.

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Figure 1: Canadian GCM projection of surface and 500 mb temperature for the period 1979-2000. Plot prepared by Dr. Thomas Chase from data at http://www.cccma.bc.ec.gc.ca/data/cgcm2/cgcm2.shtml

Figure 2: Observations of global temperature anomalies from surface, satellite, rawindsonde and model reanalysis for the period 1979-2000. Plot prepared by Dr. Thomas Chase. Data are from http://www.cru.uea.ac.uk/ (surface; http://weather.msfc.nasa.gov/MSU/msusci.html (satellite); http://cdiac.esd.ornl.gov/ (rawindsones); http://dss.ucar.edu/pub (NCEP model reanalysis).

Figure 3: Fort Morgan Colorado climate observing site.

Figure 4: From Chase, T.N., R.A. Pielke Sr., T.G.F. Kittel, R.R. Nemani, and S.W. Running, 2000: Simulated impacts of historical land cover changes on global climate in northern winter. Climate Dynamics, 16, 93-105.

Figure 5: Model simulation of afternoon weather over the Texas-Oklahoma panhandle region for May 15, 1991 with the current landscape (top) and if the natural landscape existed instead (bottom). (From Pielke, R.A., T.J. Lee, J.H. Copeland, J.L. Eastman, C.L. Ziegler, and C.A. Finley, 1997: Use of USGS-provided data to improve weather and climate simulations. Ecological Applications, 7, 3-21.)

Mr. GREENWOOD. Thank you, Dr. Pielke.

Dr. Michaels.

TESTIMONY OF PATRICK J. MICHAELS

Mr. MICHAELS. Mr. Chairman, I am sitting over here. Dr. O'Brien is much more handsome.

I am a Professor of Environmental Sciences at the University of Virginia and past President of the American Association of State Climatologists, and I should say my colleague, Roger, is the future President.

I offer you a word of caution on the science about which we base our Nation's policy on global warming. Mr. Chairman, would you tell people what was going to happen to the United States temperature based upon a table of random numbers? I don't think so. But that is what happened in the assessment on climate change.

Effects have causes. Our society is currently confronting a potentially serious effect, the specter of climate change caused by human alteration of the atmosphere. We ask scientists to quantify these causes and effects. They pursue truth by making hypotheses and testing them against reality. In climate science, these hypotheses are computer models. If they are at odds with reality, they only inform bad policy.

It is absolutely logical to want a scientific assessment of the effect of human induced climate variability on the U.S. Coming from the University of Virginia, I am commanded, as you know, to refer to its founder, Thomas Jefferson. Had he been alive and seen changes in the greenhouse effect that we have observed today, he would ask scientists what will happen to America's climate?

So let's transport Mr. Jefferson's scientists in the 19th Century, newly minted in the environment, naive, not involved in the political process. What would they do? Well, they would probably learn about computer models such as we have today, and then they would use those computer models to drive impact of climate change on other aspects of our society, our farms, our forests, our water supply.

That is, in a sense, what was used for the methodology for the U.S. National Assessment on Climate Change. Now what models would they choose? I argue they would find a climate model that predicted large changes, one that predicted medium changes, and probably a third that predicted small changes.

In the very real case of the 20th Century National Assessment on Climate Change, two models were chosen. The first from the Canadian Climate Center, shown here in this Vu-Graph, predicts the largest changes of temperature of any of the models considered here in the report.

It is also different than the dozens of other climate models. It is against the consensus of climate models, as described by the United Nations, because it has an exponential increase in temperature, meaning an increase which gets larger and larger in terms of rate, as opposed to the average of models. This is from the United Nations' new summary on climate change, which you can see clearly is a straight line.

So not only have we chosen the most extreme temperature prediction, we have chosen one whose mathematical and functional form is at variance to the consensus of models.

The second model used in the Assessment, from Britain's Hadley Center, predicts the largest changes in rainfall. These are the precipitation forecasts from the models considered. You can see this is at major variance to any of the other consensus models that we have.

Consequently, the very real 20th Century scientists, as opposed to our 19th Century hypothetical scientists, chose the most extreme forecasts to guide our national assessment. I would bet our 19th Century scientists would ask another question: Do these models work? And they would test them, and they would discover that both the Hadley and the Canadian models chosen by the 20th Century counterparts were worse than a table of random numbers when applied to United States temperatures.

At this point, I believe the 19th Century scientists would have stopped and said we do not have the tools to forward project climate. They might have said, perhaps we should take a look at how U.S. climate has changed as the greenhouse effect has changed and as global temperatures have changed.

The very real 20th Century assessment teams was informed in the review process about this problem with the models. IN public comments, it was swept aside with a statement that United States temperatures are warming, model temperatures are warming and, therefore, everything is fine.

In fact, the Canadian model predicts recent years to be 2.7 degrees warmer than the years in which the Canadian model starts. The observed change in U.S. temperature is .9 degrees, a 300 percent error.

Random numbers are not plausible scenarios. It is no longer science when our results are worse than random numbers. It is mathematical philosophy. It is scenario building, but it is not science. Mr. Chairman, whatever is based upon models that do not better than random numbers is science fiction, glossy, colorful, meticulous, but fiction.

Unfortunately, the assessment serves as the basis for sweeping legislation on global warming at both the Federal and the State levels. Using computer models that demonstrably do not work can only inform bad policy.

The first time I testified on the subject of global warming was in February 1889—yes, it seems like 1889—1989 before this very Energy and Commerce committee. I stated then that warming was likely to be at the lowest end of projected ranges based on a comparison of then existing models and observed temperatures. I stated that "our policy should be commensurate with our science."

Thirteen years later I am compelled to tell you exactly the same. Thank you.

[The prepared statement of Patrick J. Michaels follows:]

PREPARED STATEMENT OF PATRICK J. MICHAELS, DEPARTMENT OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF VIRGINIA

This testimony makes no official representation for the University of Virginia or the Commonwealth of Virginia, and is tendered under the traditional protections of academic freedom.

Effects have causes. Confronting our society today is a potentially serious effect, climate change, caused by human influence on our global atmosphere.

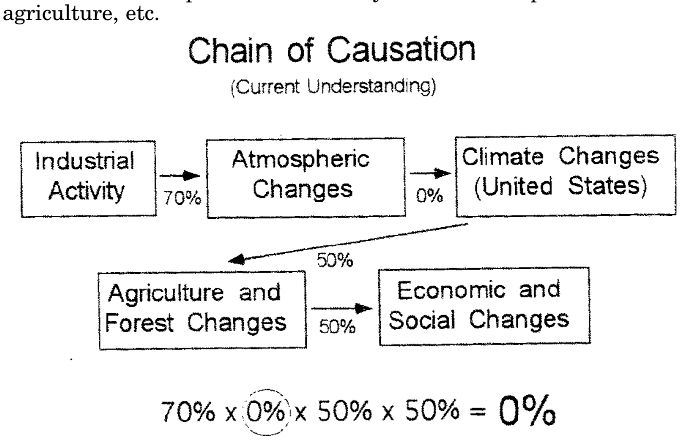
The quantitative tools of mathematics and science are what we use to inform rational analysis of cause and effect. Science, in particular, obeys a rigid standard: that the tools we use must be realistic and must conform to observed reality. If they do not, we modify or abandon them in search of other analytical methods. Whenever the federal government releases a comprehensive science report, the public naturally assumes that it has passed these tests. The documents we will discuss today failed those tests. This failure was ignored in the public review process.

There is no doubt that the issue of climate change rightly provokes private citizens and our government to ask what its potential effects might be on the United States. That was the purpose of the recent report Climate *Change Impacts on the United States: The Potential Consequences of Climate Variability and Change.* This document is often called the "U.S. National Assessment" (USNA) of climate change. This report forms much of the basis for Chapter 6 of the *U.S. Climate Action Report—2002*, a chapter on "Impacts and Adaptation" to climate change.

The USNA began with a communication from President Clinton's National Science and Technology Council (NSTC), which was established in 1993. According to the USNA, "This cabinet-level council is the principal means for the President to coordinate science, space and technology policies across the Federal Government." "Membership consists of the Vice President [Al Gore], the Assistant to the President for Science and Technology, Cabinet Secretaries and Agency heads . . ." The Council is clearly a political body ("coordinating . . . policies") rather than a scientific one.

This NSTC was, in turn, composed of several committees, including the Committee on Environment and Natural Resources, chaired in 1998 by two political appointees, D. James Baker and Rosina Bierbaum. Baker developed a further subcommittee of his committee, the Subcommittee on Global Change Research, to "provide for the development . . . of a comprehensive and integrated . . . program which will assist the Nation and the world to understand, assess, *predict* [emphasis added], and respond to human-induced and natural processes of global change." Ultimately, this resulted in the selection of the National Assessment Synthesis Team (NAST).

NAST was confronted with a daunting task, detailed in the schematic below. The chain of cause and effect begins with industrial activity and the combustion of compounds that alter the atmosphere's radiative balance. These are then distributed through the atmosphere. These affect the climate of the United States. Then, those changes in climate are input to a subsidiary series of computer models for forest growth, agriculture, etc.



An understanding of the effects of climate change on the United States requires that there be no substantially weak links in this catena. As an example of a relatively strong link, I would estimate that we understand about 70 percent of the changes in atmospheric carbon dioxide that result from human activity. The reason this number is not 100 percent largely stems from the fact that the current concentration of carbon dioxide seems low, given the amount emitted and assumptions about how it distributes through the atmosphere and the biosphere, and how it eventually returns to the soil and the ocean bottom.

There are two main ways to assess the most important of these linkages, which is between "Atmospheric Changes" and "Climate Changes in the United States." One involves the use of computer simulations, known as General Circulation Models (GCMs) to estimate how climate changes as a result of atmospheric alterations. An alternative method for assessment is described on page 10 of this Testimony.

There are literally dozens of GCMs currently available, and the USNA considered a subgroup of these models. Eventually, they selected two, the Canadian Climate Centre model, acronymed CGCM1, and another from the United Kingdom Meteorological Office, known as HadCM2[1]. The prime outputs of these models that are important for the assessment of climate change are temperature and precipitation.

In using GCMs to project future climate at regional scales, the USNA clearly placed itself squarely against the consensus of world climate science. In 2001, the United Nations' Intergovernmental Panel on Climate Change (IPCC) compendium on climate change, the *Third Assessment Report,* states:

> "Despite recent improvements and developments . . . a coherent picture of regional climate change . . . cannot yet be drawn. More co-ordinated efforts are

[1] In 1998, the National Research Council report *Capacity of U.S. Climate Modeling to Support Climate Change Assessment Activities* strongly remonstrated against the use of foreign models to assess U.S. climate. According to the NRC, ". . . it is inappropriate for the United States to rely heavily upon foreign centers to provide high-end modeling capabilities. There are a number of reasons for this including . . . [the fact that] decisions that might substantially affect the U.S. economy might be based upon considerations of simulations . . . produced by countries with different priorities than those of the United States."

> thus necessary to improve the integrated hierarchy of models . . . and apply these methods to climate change research in a comprehensive strategy."

In other words, even three years after the Assessment team began its report relying on GCMs, the consensus of world climate science was that they were inappropriate for regional estimates, such as those required for the United States.

CHOICE OF EXTREME MODELS

As shown in the IPCC's *Third Assessment Report* of climate change, the average behavior of GCMs is to produce a linear (constant) rate of warming over the projectable future. In other words, once warming begins from human influence, it takes place at a constant, rather than an exponentially increasing rate.

However, the CGCM1 is an outlier among the consensus of models, producing a warming that increases as a substantial exponent. This behavior can be seen in Figure 1a, taken directly from the USNA, in which the CGCM1 clearly projects more warming than the others illustrated in the USNA.

The USNA also illustrates a similarly disturbing behavior for precipitation. Figure 1b, again taken directly from the USNA, shows that the other model employed, HadCM2, predicts larger precipitation changes than the others that are illustrated in the USNA.

A close inspection of Figure 1a reveals that CGCM1 predicts that the temperatures in the United States at the end of the 20th century should be about 2.7 °F warmer than they were at the beginning, but the observed warming during this time, according to the most recent analysis from the National Climatic Data Center, is 0.9 °F. CGCM1 is making a 300 percent error in its estimation of U.S. temperature changes in the last 100 years.

My colleague Thomas Karl, Director of the National Climatic Data Center and co-chair of the USNA synthesis, explained that the reason CGCM1 was chosen was because it was one of only two models (the other was HadCM2) that produced daily temperature output, and that this was required to drive some of the subsidiary models, such as those for forest impacts.

Michael MacCracken, Executive Director of the National Assessment Coordination Office, told me otherwise. He said that the two models were selected because they gave extreme results, and that this was a useful exercise. How the explanations of the co-chair and the Executive Director could be so different is still troubling to me.

THE FAILURE OF THE MODELS

GCMs are nothing more than hypotheses about the behavior of the atmosphere. The basic rule of science is that hypotheses do not graduate into facts unless they can be tested and validated against real data.

As part of my review of the USNA in August 2000, I performed such a test. The results were very disappointing. Both CGCM1 and HadCM2 were incapable of simulating the evolution of ten-year averaged temperature changes (1991-2000, 1990-1999, 1989-1998, etc. . . . back to 1900-1909) over the United States better than a table of random numbers. In fact, the spurious 300 percent warming error in CGCM1 actually made it worse than random numbers, a dubious scientific achievement, to say the least.

I wrote in my review:

> "The essential problem with the USNA is that it is based largely on two climate models, neither one of which, when compared to the 10-year smoothed behavior of the lower 48 states reduces the residual variance below the raw variance of the data [this means that they did not perform any better than a model that simply assumed a constant temperature]. The one that generates the most lurid warming scenarios—the . . . CGCM1 Model—also has a clear warm bias . . . All implied effects, including the large temperature rise, are therefore based upon a multiple scientific failure [of both models]. The USNA's continued use of those models and that approach is a willful choice to disregard the most fundamental of scientific rules . . . For that reason alone, the USNA should be withdrawn from the public sphere until it becomes scientifically based."

The Synthesis Team was required to respond to such criticism. Publicly, they deflected this comment by stating that both U.S. temperatures and model temperatures rose in the 20th century, so use of the models was appropriate!

This was a wildly unscientific response in the face of a clear, quantitative analysis. The real reason for the models' failure can be found in the USNA itself (Figure 11 in Chapter 1 of the USNA Foundation document). It is reproduced here as our Figure 2. The discrepancies occur because:

1. U.S. temperatures rose rapidly, approximately 1.2°F, from about 1910 to 1930. The GCMs, which base their predictions largely on changes in atmospheric car-

bon dioxide, miss this warming, as by far the largest amounts of emissions were after 1930.

2. U.S. temperatures fell, about 1.0°F, from 1930 to 1975. This is the period in which the GCMs begin to ramp up their U.S. warming, and
3. U.S. temperatures rose again about 1.0°F from 1975 to 2000, recovering their decline between 1930 and 1975.

It is eminently clear that much of the warming in the U.S. record took place before most of the greenhouse gas changes, and that nearly one-half of the "greenhouse era," the 20th century, was accompanied by falling temperatures over the U.S. *These models were simply too immature to reproduce this behavior because of their crude inputs.*

Despite their remarkably unprofessional public dismissal of a rigorous test of the USNA's core models, the Synthesis Team indeed was gravely concerned about the criticism. So much so, in fact, that they replicated my test, not just at 10 year-intervals, but at scales ranging from 1 to 25 years.

At the larger time scales, they found the models applicable to global temperatures. But over the U.S., not surprisingly, they found exactly what I had. The models were worse than random numbers.

It is difficult for me to invoke any explanation other than political pressure that would be so compelling as to allow the USNA to continue largely unaltered in this environment. And so the USNA was rushed to publication, ten days before Election Day, 2000.

Given the failure of the models when directly applied to U.S. temperatures, there were other methods available to the USNA team. One would involve scaling various global GCMs to observed temperature changes, and then scaling the prospective global warming to U.S. temperatures. The first part of this exercise has been performed independently by many scientists in recent years, and published in many books and scientific journals. It yields a global warming in the next 100 years of around 2.9 °F, which is at the lowest limit of the range projected by the IPCC in its *Third Assessment Report.*

If applied to the United States this would similarly project a much more modest warming than appears in the USNA. Perhaps that is the reason such an obviously logical methodology was not employed after the failure of the models was discovered by a reviewer and then independently replicated by the USNA itself.

EFFECT OF THE USNA

This discussion would be largely academic if the USNA were an inconsequential document. But, as noted above, it served largely as the basis for Chapter 6 of the *U.S. Climate Action Report—2002.* Further, it served as the basis for legislative findings for S. 556, a comprehensive proposal with extensive global warming related provisions, and it was clearly part of the findings for legislation restricting carbon dioxide emissions recently passed by the California Legislature. Hardly a week goes by without some press reference to regional alterations cited by the USNA. Would the USNA have such credibility if it were generally known that the driver models had failed?

SOLVING THE STRUCTURAL PROBLEMS WITH THE USNA

The USNA synthesis team contains only two individuals who can logically claim, in my opinion, to be climatologists. Of the entire 14-member panel, there is not one person who has expressed considerable public skepticism about processes that were creating increasingly lurid scenarios for climate change with little basis in fact. As noted above, the administrative structure that selected the synthesis team was clearly directed by political appointees, which no doubt contributed to this imbalance.

In my August 2000 review, I wrote:

> "Finally, we come to the subject of bias in selection of USNA participants. There are plenty of knowledgeable climatologists, including or excluding this reviewer, who have scientific records that equal or exceed those of many of USNA's participants and managers. They would have picked up the model problem [that extreme versions were selected, and that they could not simulate U.S. temperatures] at an early point and would not have tried to sweep it under the rug. Where is Bob Balling? Where is Dick Lindzen? Where are [Roger] Pielke Sr., [a participant in this hearing], [Gerd] Weber or [Roy] Spencer?"

My review was tendered shortly after attending the annual meeting of the American Association of State Climatologists (AASC) in Logan, Utah, in August 2000. The AASC is the only professional organization in the U.S. devoted exclusively to climatology. Membership consists largely of senior scientists who are tasked by their states, usually through the state's major universities, to bring climate information and services to the public. Until 1972, the State Climatologists were employees of the U.S. Department of Commerce.

In my review of the USNA I further noted that:

> "Yesterday . . . I returned from the annual meeting of the American Association of State Climatologists (I am a past president of AASC). There were roughly 100 scientists present. I can honestly state that not one positive comment was tendered to me about the USNA, out of literally dozens made. If the report is published in anything like its current form, I predict it will provoke a public examination of how and why the federal science establishment [could have produced such a document]."

That prediction has come true. It is why we are here today.

Besides being research scientists, the State Climatologists are interpretive professionals who deal with the climate-related problems of their states on a day-to-day basis. It's hard to imagine a better-suited team of professionals to provide a significant leadership role in any new *Assessment.*

RECOMMENDATIONS

1. The current USNA should be redacted from the public record. 2. Another *Assessment* should be undertaken, this time with a much more diverse synthesis team selected by a more diverse political process. 3. Professional interpreters of climate information, who will be called upon to explain or defend any future *Assessment*, such as the State Climatologists, should provide strong input to any new report. 4. Any new *Assessment* must be based only upon hypotheses that can be verified by observed data.

CONCLUSION

The 2000 document, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change,* which served as the basis for an important chapter in the new *Climate Action Report—2002,* was based on two computer models which were extreme versions of the suite of available models. The two selected models themselves performed no better than a table of random numbers when applied to U.S. temperatures during the time when humans began to subtly change the composition of the earth's atmosphere. As a result, both reports are grounded in extremism and scientific failure. They must be removed from the public record.

This scientific debacle resulted largely from a blatant intrusion of a multifaceted political process into the selection process for those involved in producing the *U.S. National Assessment.* The clear lesson is that increased professional diversity, especially intermingling state-based scientists with the federal climatologists, would have likely prevented this tragedy from ever occurring.

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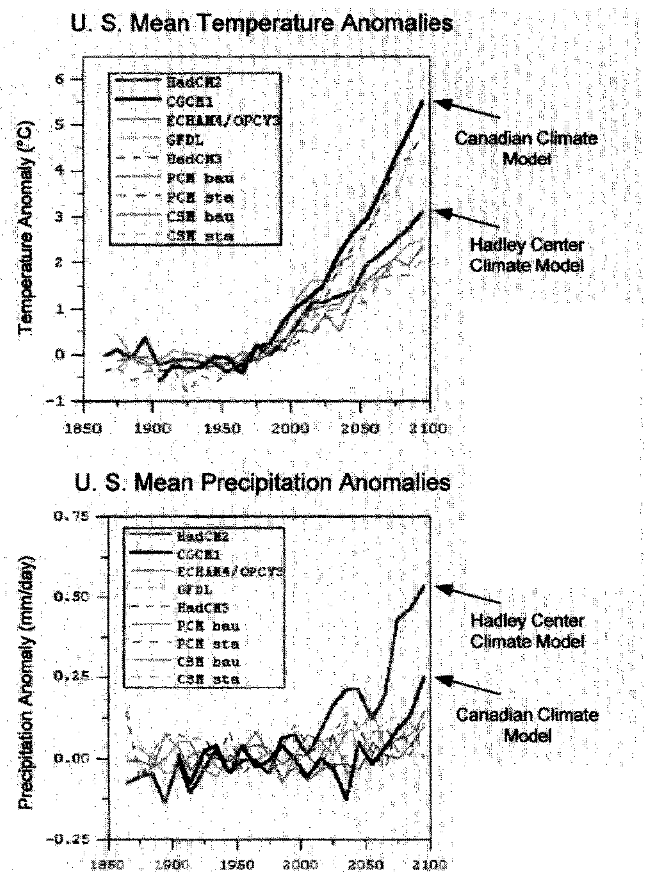
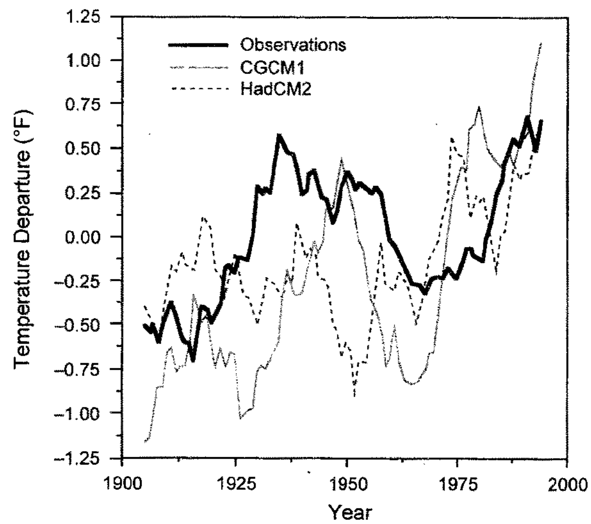
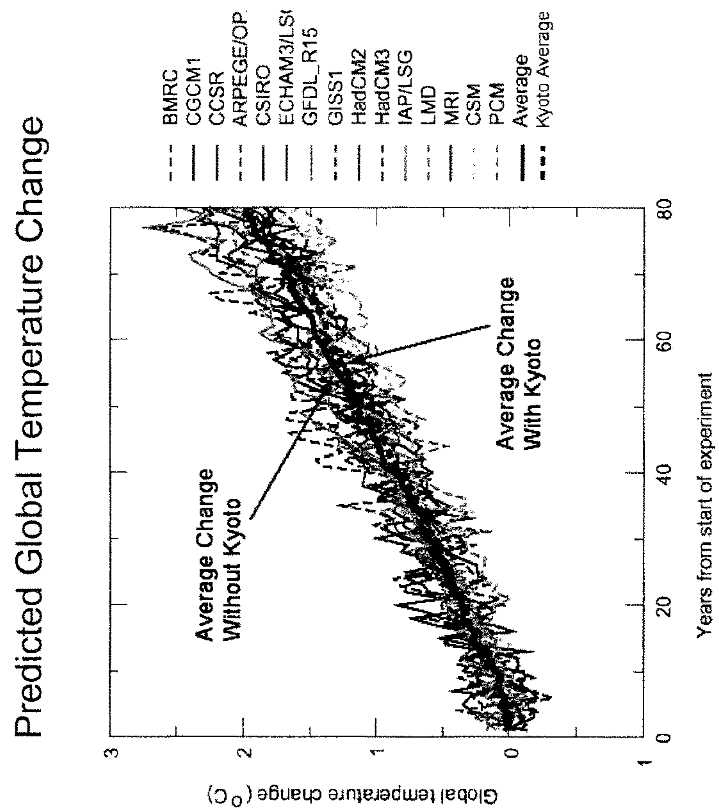


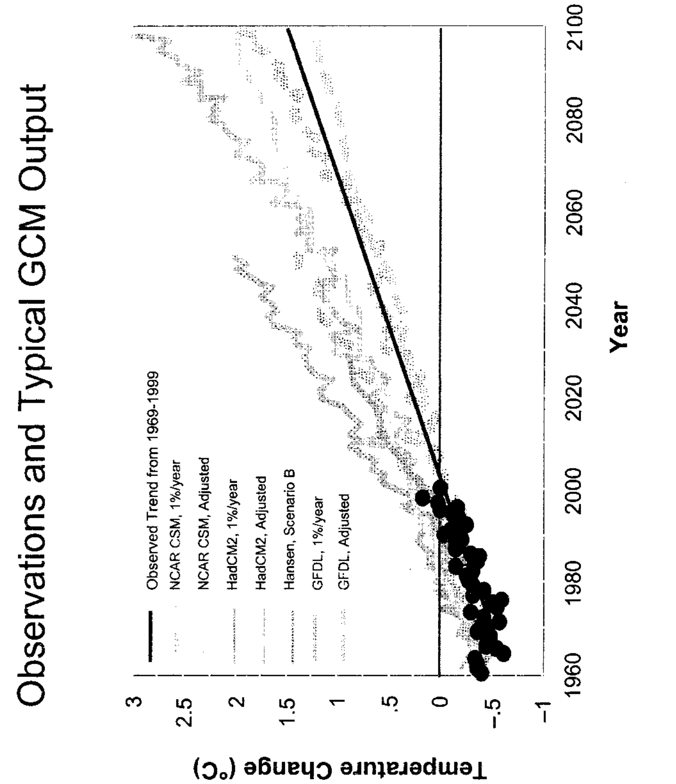
Figure 1a. (top) Future temperature changes for the United States projected by models considered for inclusion in the U.S. National Assessment . Figure 1b. (bottom) Future precipitation changes for the United States projected by models considered for inclusion in the U.S. National Assessment. (Source: U.S. National Assessment, Foundation Document)



'igure 2. Time histories of the changes in annual temperature for the United States uring the 20th century based on observations and on simulations from the Canadian nd Hadley models, calculated as 10-year running means from 1900 to 2000. (Source:].S. National Assessment, Foundation Document).



Predicted Global Temperature Change
Global temperature change (°C)
Years from start of experiment
Average Change Without Kyoto
Average Change With Kyoto
BMRC
CGCM1
CCSR
ARPEGE/OP.
CSIRO
ECHAM3/LS(
GFDL_R15
GISS1
HadCM2
HadCM3
IAP/LSG
LMD
MRI
CSM
PCM
Average
Kyoto Average



Observations and Typical GCM Output
Observed Trend from 1969-1999
NCAR CSM, 1%/year
NCAR CSM, Adjusted
HadCM2, 1%/year
HadCM2, Adjusted
Hansen, Scenario B
GFDL, 1%/year
GFDL, Adjusted
Temperature Change (°C)
3
2.5
2
1.5
1
.5
0
-.5
-1
1960
1980
2000
2020
2040
2060
2080
2100
Year

Mr. GREENWOOD. Thank you.

The Chair recognizes himself for 10 minutes for inquiry.

Dr. Karl, I want to start with you. In your written testimony, you note several factors that cause climate change and variability that were not included in assessment models. This is on page 2 and more extensively on page 10. You also note that foreign models were problematic for use in the United States, and cite a National Research Council report which you chaired—this is from page 4 of your testimony—that underscored these important limitations.

Can you explain why, given your own knowledge about the models' limitations, you went ahead with these models? Weren't they too limited for the public uses that would result from this report?

Mr. KARL. Sure. I would be happy to, Mr. Chairman.

The two models that were selected, by no means, were perfect models, and no model is perfect. I don't think anyone would argue that. I think the question that we all asked ourselves is whether they would be useful tools.

As I tried to indicate in my testimony, we believe they were quite effective as useful tools, along with the observational data and "what if" scenarios. Maybe I can give you a little bit of an analogy.

In daily weather forecasting today, operational weather models cannot predict tornados or hailstones, but yet our weather forecasts do give an idea of when we would expect tornados and hailstorms and are largely based on those operational weather models, despite the fact that the operational weather models do not have the high resolution details to be able to predict those phenomena.

So in that sense, these models, we felt, were effective tools and, as I tried to indicate in my testimony, there was a number of issues that were neglected, those being changes in land use, as Dr. Pielke had described, changes in black soot and other aerosol, changes in stratospheric ozone depletion.

Those simulations weren't available at that time, but the intent of the assessment was to look into the 21st Century, and if you look at the IPCC results, those forcings, although are important and it is important to try and understand the regional details, the two most important factors, that being aerosols and increases in greenhouse gases, were included in the models.

So for that reason, we thought that it was a valuable tool to go ahead and use and, in fact, if we had not used them, I think we would have been negligent.

Mr. GREENWOOD. How do you respond to Dr. Michaels' suggestion that these models haven't produced more—anything different than a random set of numbers?

Mr. KARL. Random numbers? Yes, and I am glad you asked that question, because we have conducted those tests on those models similar to what Dr. Michaels has suggested. First, let me qualify. There's many tests you can do on models, and no one test should be used to say whether or not a model is effective.

There's been many types of tests applied to these models and other models, but I can say the same kind of tests that Dr. Michaels suggests was applied to precipitation data over the U.S., and the model showed significant skill. If you apply the same test to global temperatures, the models show significant skill.

There is a number of reasons why we think it is inappropriate, actually, to apply that test on the national temperature or precipitation over the course of the 20th Century. That is, as I indicated, the models do not have all those forcings. They did not have volcanic eruptions. We know the U.S. climate record was affected by volcanic eruptions in the 20th Century.

It did not have solar variability. Some of the changes were affected by solar variability. The timing of El Ninos and North Atlantic oscillations and other important oscillations are not in these models when they simulate climate. They are trying to produce the stoclastic behavior of climate, and they can't predict the timing.

So if you are looking at small regional scales where these effects are important in the historical record, it is going to be very difficult to evaluate a model. That is why most evaluations look at the global scale. They will aggregate regions, but they will aggregate it up globally to remove a lot of this noise and variability. When you do that, the models that we have used and many of the other models do show significant skill.

In fact, a recent test by Lawrence Livermore National Laboratory looking at the annual cycle of precipitation and the total precipitation for the last 20 years showed that the Hadley Center model 2 that was used in the assessment exceeds all other models, and they tested 24 models. This was part of a model inter-comparison project and has been going on for a number of years.

The Canadian climate model did not do as well. It wasn't an outlier. It was in, I would say, the lower third of the distribution of the models being used. So I think again it depends on what kind of tests you apply, and you have to look at the broad breadth of the scientific information that is out there, in my opinion.

Mr. GREENWOOD. Dr. Michaels, you wanted to respond. Yes.

Mr. MICHAELS. Yes. The standard test of whether——

Mr. GREENWOOD. What I need you to do is you see how this microphone points directly at my mouth. That's what you need to do. If it is pointing over my head, you can't hear.

Mr. MICHAELS. The standard test of whether a model performs, a model being a hypothesis, is a statistical test against random numbers. Tom very adequately answered the question, and I would like to point out what is kind of missing from his response, which was in fact that he did replicate my experiment and found, as I found, on 10-year averages that it was worse than random numbers.

He did it on 1 year averages, on 5 year averages, on 10 and on 25 and found the same thing. Now we are talking about warming of the surface of the planet created by changes in greenhouse gases. After that surface and mid-atmosphere warm, that creates a change in the temperature distribution. That creates changes in precipitation.

I think it is rather interesting to agree on this panel that we couldn't simulate the temperature of the United States and somehow be happy about the fact that the precipitation was right, because it is the temperature change that drives the precipitation change.

Here is the real problem, if you must know. We are going to have great difficulty simulating the temperature history of the United

States with these models for one main reason. There was a large warm-up in the United States' temperatures that occurred before the greenhouse effect changed very much, and then as the greenhouse gases began to ramp up into the atmosphere in the middle part of the century, the temperature dropped. In the latter part of the century, the temperature has returned to levels that are near the maxima that occurred after the large warm-up in the early 20th Century.

It is going to be very, very difficult to simulate that, because no one really understands why the first one occurred and why it was of such similar magnitude to the latter one, given the large changes in the atmospheric greenhouse effect. I am left to conclude that we could not use the models for even assessing the annual temperature of the United States, and the irony of this report is it then devolves into regional assessments after having admittedly failed now with United States temperature.

I think we need to rethink the validity of this entire process.

Mr. GREENWOOD. Let me ask a question that is a bit off the script here, but Dr. O'Brien talked about the need for a Manhattan project. I'd like the panelists, if you would, starting with Dr. Janetos and going right down the line, to offer up your sense as to whether there is a lack of resources here. Do we need to, in fact, apply governmental and/or private sector dollars in a very significant way to create resources, computer and intellectual, in order to get a better grip on this?

Mr. JANETOS. Mr. Chairman, I would answer your question very briefly. Yes, we do. We have been very clear both in the National Assessment and in subsequent publications about the need for substantial additional research into the topics of vulnerabilities, and then to understand what changes, in fact, are the most plausible in the physical climate system itself.

We have had a significant research program for sometime now, but this is one of the most challenging issues in both underlying biology, ecology, and the physics of the climate system that this country has had to address in environmental science, and I believe certainly deserves additional resources toward its investigation.

Mr. GREENWOOD. Dr. Karl?

Mr. KARL. Yes. I think one way to take a look at whether or not we need additional resources is to look back at some of the problems that we faced in the National Assessment, we attempted to do this. There were issues related to just understanding whether or not we had effective observations, not to simulate what the real climate is, but to look at the changes.

You heard Dr. Pielke talk about changes in the mid-troposphere. There are some new results coming out that suggest, well, the increases of temperature were a little more than we perhaps thought. It just reflects this issue of trying to understand what is happening in the climate itself is complex, requiring significant investment in time and resources.

Then the issue related to the models: We were severely constrained by the number of models that were able to simulate, for example, just a day/night temperature. Many of the ecosystem modelers said this was critical for them to be able to look at the impacts further down into the century.

So it is very clear that we need the details of climate from the observations. We need many more improvements in the models. My sense is that there is plenty of work out there to be done and plenty that could be very effective in helping to do another national assessment, if we so attempt it.

Mr. GREENWOOD. Dr. Lashof?

Mr. LASHOF. Well, I certainly agree with that. We are investing quite a bit in the global change research program now. Additional resources certainly would be useful, and particularly the kind of detailed modeling center that Dr. O'Brien suggests, I think, would be very helpful in the United States.

I would just add to that a caution, that the goal of furthering the research to get at many of the details that need to be addressed should not be posed as a substitute for the need to take action now to reduce emissions.

I would just like to quote from the Intergovernmental Panel on Climate Change report, synthesis report from 2001, that says that, "The pervasiveness of inertia and the possibility of irreversibilities in the interacting climate, ecological and socioeconomic systems are major reasons why anticipatory adaptation and mitigation actions are beneficial. A number of opportunities to exercise adaptation and mitigation options may be lost if action is delayed."

Mr. GREENWOOD. Dr. O'Brien, we know what your answer is, but perhaps you could elaborate on what you have in mind.

Mr. O'BRIEN. Well, I am going to brag now. I have used more computer time than you probably imagine that a scientist and his students can use all my life. I can say for the absolute first time in my life I personally have adequate access to computer time. It is through two ways.

One was when the Soviet Union surrendered, they finally changed procurement rules in the Department of Defense, and now in the Department of Defense they can buy computers. You know, in 1975 the poor guys inside Department of Defense had to guess what Kray and the other ones are going to have 8 years from now, because that is how long it took to buy a computer.

We, fortunately, have ONR support, and I can get access to those for some of our ocean modeling. Florida State has invested in a large system which, as I'll brag, has put us 3, 4 in the world, and the first in universities in the United States, and I am very happy.

We know, for example, that why didn't we have any U.S. models? Well, there are two institutions that historically we would look to. That is the Geophysical Dynamics Lab, NOAA's lab in Princeton, and the National Center for Atmospheric Research, and neither one had adequate computer things to do these kind of models that our international partners are doing.

You know, sir, in a word I want you to remember, computers are cheap. I find hundreds of young scientists, PhDs, working in these labs with absolutely inadequate computers, and you know, you figure out what the cost per manyear is for a PhD with all the support, and the computers these days with Moore's law operating are really, really inexpensive.

The other thing is that at NCAR I have been developing a new climate model, and I am putting their best scientists on it. But they want to go back to individual papers and things like that. I really believe, to advance this, this is a national emergency, the kind of cost that you mentioned yourself, that climate change is going to cost this country trillions of dollars and problems as we go down 10 to 20 years. We need to put it in a situation where it is outside the politics of whatever the history of that lab is, and something where, you know, young—bright, young scientists will take this as a challenge, that they can go there and work for a while.

You know, there is an example in our government. You know, they are having their 30th anniversary. It is ICASE. Under NASA, you know, they have this little think tank for numerical modelers in other areas besides weather and climate, and it is at Langley, and it is the NASA Administrator's budget, and it is an absolutely beautiful thing.

They take the brightest young mathematicians that come out of our university systems, and put them in an environment in which they an really advance the understanding in areas like, you know, simulating, as someone said, aircraft and simulating other things.

So I think it is really a priority, and I really think it is relatively cheap compared to the kind of money that we are spending on satellite systems, observing systems, that we really need to do this. I'm sorry to take so long.

Mr. GREENWOOD. That's quite all right. Dr. Pielke.

Mr. PIELKE. Yes. I think there is a need to have a redirection of this effort, but I would like to focus more on the vulnerability perspective. That is, you start from that, and we have to assess vulnerabilities to environmental risks, societal risks, all kinds of risks that we can think of, and where does climate fit within that umbrella, and then develop plausible projections from both models, from historical record, artificial creation of data.

This is, I think, a much more vibrant and inclusive approach than what the National Assessment did, because if we start from vulnerability and we find where our thresholds and our concerns are, that is where we can spend our resources.

I think, in terms of developing better models, I would agree with Dr. O'Brien that we actually have a lot of computer tools available today, and we can do a lot more with these models. I think that needs to be integrated more into the process, some of the work with respect to land use change on the climate system, the multiple effect that aerosols have on cloud and precipitation.

Climate is a very complicated problem. As I said in my testimony, I don't think that predictability may be the ultimate goal to understanding of the climate process itself. That is why I fall back to the vulnerability paradigm, because that permits us to make decisions even if we don't understand what exactly will happen in the future.

Mr. GREENWOOD. Dr. Michaels?

Mr. MICHAELS. Mr. Chairman, perhaps I spend too much time in Washington, but it would be hard for me to imagine a panel of scientists or agency heads saying that they didn't need the money, and you always have to be very careful.

Mr. GREENWOOD. We have a predictive model that predicted that you all would say this.

Mr. MICHAELS. Yes. Now having said that, let me offer somewhat of an alternative point of view, first of all, on the assessment. I think that it probably would have been appropriate had there been more involvement from the State climatologist community, because we are the people who have to respond to the press more than anybody else, and the public, when these reports come out. If we had had more input, I think we would have been happier with the report.

Having said that, I might be able to simplify the problem for you a little bit, and I am going to show you a picture. Mr. Chairman, in absence of a picture, I'll paint you a picture.

We have a number of computer models for the behavior of the atmosphere, and by and large, although there are a few outliers like the Canadian model, they predict straight line increases. They say once human warming starts from changes in the greenhouse effect, it takes place at a constant rate. I believe human warming has started from changes in the greenhouse effect, because I believe that human warming has started.

Mr. GREENWOOD. So you are defining human warming as——

Mr. MICHAELS. Greenhouse warming has started as a result of this.

Mr. GREENWOOD. All right.

Mr. MICHAELS. So perhaps what we ought to do is to adjudicate all these straight lines. You see some of them are going up like this. Some of them are going up like this, and some of them are going up like this, and some of them are going up like that. Now all the models say that once the warming starts, it takes place at a constant rate. So why don't we just plot the observed rate of human warming?

You know what you get when you do that? You get something around 1.6 degrees Celsius over the next 100 years. I would think that our research effort should be attempting to answer the question why is the warming rate proceeding at the low end of the range of expectations, and why has it been so constant?

I wish I could show you a chart right now to show you how constant it has been, and I think that that is the research question of the future.

Again, my other answer is the next time around, let's get more of the State people in these reports, because they are the ones who can take these reports to the public and explain them the best.

Mr. GREENWOOD. Feel free to find your picture and show it to us when you find it.

The Chair recognizes the gentleman from Florida, Mr. Deutsch, for 10 minutes.

Mr. DEUTSCH. Thank you. How much confidence do we have in the climate projects at this point in time, and then specifically related to that, we have—You know, there's different models and different scenarios. Can each of you comment on what is agreed to in these different models and scenarios? Maybe we could just go to Mr. Janetos.

Mr. JANETOS. Yes, sir. In the models that we used in the assessment itself, there was a single underlying emission scenario. This is, in fact, a limitation of the assessment. The scenario—The emissions scenario that we chose was one that had been thoroughly examined internationally.

So in one sense, one of the things that was agreed quite constant throughout the assessment was the underlying forcings of greenhouse gas accumulations and changes in sulfates and aerosols, for example. the models that were used——

Mr. GREENWOOD. Would you define forcings, because you have all been using that, and I am not sure that Mr. Deutsch and I understand.

Mr. JANETOS. The changes in the impacts on the atmosphere that actually cause climate to change and to vary, in an abbreviated way. The models—All of the models that were used in the assessment shows some warming. There was obviously—over the U.S. There is obviously disagreement in the actual magnitude of that warming.

They also show—They do show rather different changes in precipitation, which Dr. Karl has referred to in his testimony. In each case we actually—The analysis that we actually performed was to take the changes in the models and apply those to an interpolated dataset of the historical record of the United States.

So the actual variability that was analyzed was drawn from the historical record itself. We did this in order to attempt to be conservative in our analyses, in particular with respect to changes on intra-annual and decadal time scales. Thank you.

Mr. KARL. If I could address the question simply, there's a number of items that I think everyone would agree on. One it is going to get warmer, and again, as Dr. Michaels has mentioned, the issues are how much warmer. That is why you will see in the IPCC reports this uncertainty range, and that is why I think it is important in these scenarios to look at that full range.

So, clearly, being warmer is part of it, and then the implications of what happens when it is warmer, reduced snow pack, more rain versus snow, and you can imagine what some of those hydrological impacts might be.

The other aspect that I think most of us would agree on is that we can only state in very general terms what we would expect to see with precipitation: Increase in mid and high latitude precipitation, generally globally more precipitation, subtropics perhaps less precipitation, and that dividing line between the subtropics and mid and high latitudes comes very close to the United States. That is why you see that we are very uncertain about just the exact sign of precipitation.

One thing is also, I think, in general agreement. If it is not raining, with warmer temperatures, you generally have more evaporation, more evapotranspiration, depending—Here is where vegetation becomes important. So when you get down to local scales, if vegetation begins to change as temperatures increase, it could actually affect the amount of water that is being evaporated.

So in the general sense, there is agreement when it's not raining, more evaporation; but there is important regional and local scale differences that we probably would not all agree on.

Last, one item, that again in general all the models that we have looked at, all the models that are available in the literature—you can argue from thermal dynamic considerations from some of the equations that we use in physics that, as the globe warms, precipitation tends to fall in heavier events. This is what all the models are projecting.

We are beginning to see this in the observations. It doesn't occur everywhere, but more areas we are seeing than areas we are not seeing it, and that is also reported in the IPCC report.

So those are a number of the things, I think, that there's some consistency that I think we might all be able to agree upon.

Mr. DEUTSCH. Dr. Lashof.

Mr. LASHOF. Thank you. Let me start by saying what we can't do. Dr. Michaels has made this argument that the models are like a table of random numbers. But the test that he has applied is a very particular test, and it is a test that basically says can these models predict the weather in Philadelphia or Miami on July 25, 2010 better than a table of random numbers.

The answer to that is no. Why? Because 2010 is only 10 years from now, and over a 10-year period natural variability, El Ninos, volcanic eruptions that can't be predicted, the general oscillations in heat between the atmosphere and the ocean system are of the same magnitude as the expected overall warming trend that's a result of adding heat trapping gases to the atmosphere.

So over a 10-year period you don't expect to be able to do better than simply using roughly current conditions as your best predictor of the likely conditions then. Over a 30-year period or a 50-year period, then the effects of human alterations to the atmosphere dominate over these natural changes and, when you apply that test, the models do much better than a table of random numbers.

So that's the fundamental point. As a result of that kind of consideration, there is agreement, again accepted by this administration as well as the last administration, that warming during the 21st Century will be larger than warming during the 20th Century.

Again, Dr. Michaels said, well, why don't we just take the observed data and draw a straight line through it. That's okay. The problem is that, when you have data with some scatter and you take a relatively small period and you want to project out over a long, you can draw a lot of straight lines with different slopes, and it doesn't help you answer the question how steep that slope is going to be. Again, that is why the models are useful. They give us more insight into that.

Just a couple of other facts that are very robust to add to the ones Dr. Karl just mentioned. We expect sea level rise during the 21st Century will be significantly more rapid than sea level rise during the 20th Century. That has obvious implications for your State, Mr. Deutsch.

In addition, the effects on coral reefs are expected to be very severe. The reason for that is both the increase in temperature—where coral reefs are already threatened by high sealable temperature events that cause coral bleaching, that becomes much more common—plus the direct effect of increased CO_2 which, as the atmosphere accumulates more carbon dioxide, carbon dioxide increases the acidity of the ocean and literally erodes the corals.

So if we continue to add carbon dioxide to the atmosphere, with high confidence we can say, and the National Academy says, that coral reefs are extremely vulnerable to being wiped out in many areas. Those are just a couple of examples. Thank you.

Mr. O'BRIEN. One of the interesting things about the global models is that some of us near my age remember the first one by Jim Hanson from NASA GIS in which he told the Senate that we would increase 10 degrees Fahrenheit by 2020, but he had a very small computer. So he had no ocean in his model, and eventually the GCMs, which were putting oceans in—The trend that I mentioned in my report is that what I see in the models is that, as the models keep increasing, the magnitude of the impact out at 100 years is decreasing.

I think that Dr. Michaels' straight line—and I think there is probably only one—is a lower bound unless something else happens, because we might be going into an ice age, which has nothing to do with what man is doing to the planet. In fact, Mr. Deutsch, if you look in the back of my report, you will find out that where you live in south Florida is warming up, but most of Florida is actually cooling down. It is actually cooling down.

I remind the panel that around 1880 in Savannah, Georgia, and Jacksonville, Florida, two wonderful places, they harvested tens of thousands of boxes of very good oranges which they shipped to Europe and to Washington and those areas, and now if you want to grow oranges, you have to be south of Orlando.

So, clearly, part of the southeast has certainly not experienced this warming that some people are finding in the data. But I believe that the models will get better, and I believe that Dr. Pielke's ideas about vulnerability and other effects are extremely important in order to direct the modelers that are not in an ivory tower just doing these physical models, and we are already working in those areas.

You know, right now in the State of Florida, actually by using climate variability, we are actually now providing forest fire predictions, county by county, month by month. So there's a lot to do in applied work, and I am very pleased that we have the support of that.

So the models will get better as the resolution gets better. This is a known fact with weather prediction. You know, we went from, when I was in graduate school, about 250 kilometer on side grids until now, you know, the weather predictions are getting down to 10 kilometers on a side, particularly at this European center that I mentioned earlier, and their forecasts for weather are getting very, very nice, much better than we have had in the past.

So I really believe that we need these models. You know, also the Nation is investing a lot of new resources in the ocean. There is a large portion of the scientific community that believes that we also need to understand the ocean. The ocean is the flywheel in the climate system. It is the thing that will change, and I am sorry to tell you, Dr. Lashof, but the ocean's pH cannot incorporate—The ocean is a very buffered system.

Also the things about corals is somewhat a red herring. There's later research. Remember, about 10 years ago the corals south of Florida were dying. They blamed it all on the El Nino. That was the era when everything was due to El Nino. In fact, actual experiments and in the literature, published not by me, of course, shows that, you know, a lot of this is natural, and sometimes the bleaching is actually beneficial for the coral for when they take their next bloom.

It's sort of like in northern Florida and Georgia, you know, if we don't get any cooling in the winter, you don't get any peaches. Thank you.

Mr. PIELKE. Yes, sir. The fundamental hypothesis for these models is that we can predict the future change based on CO_2 and other greenhouse gases and aerosols, and not just CO_2 but the radiative effect of CO_2, how it affects the greenhouse effect. But carbon dioxide has other effects such as biogeochemical effects, and there's the land use change that we have already mentioned.

These make it—These haven't been included in the models. So we don't know if they have predictive ability, but it is a necessary condition to test. As I showed in my testimony, the current suite of models that were used in the U.S. National Assessment have failed to replicate the atmospheric change over the last 20 years.

The atmosphere has to warm in order to warm the surface, and as to why the surface has warmed and the atmosphere hasn't, that is the subject of some controversy. But some of our initial work suggests maybe some of the surface data is not spatially representative. We can talk about that more, if you would like.

For south Florida specifically, we have actually published papers on that subject, and we have shown, for example, the July, August warming that has occurred in south Florida over the past 80 years or so can be explained entirely by land use change, the fact of the draining of the marshes, the draining of the wetlands. Doesn't mean that is the only reason that it has occurred, but we can explain it. That has not been included in the National Assessment.

Finally, I would like to conclude this answer with just going back to the statement of my Society of the American Association of State Climatologists. We specifically concluded that climate projects have not demonstrated skill in projecting future variability in change in such important climate conditions as growing season drought, flood producing rainfall, heat waves, tropical cyclones, and winter storms, and these types of events have a much more significant effect on society than average annual global temperature trends, even if we could predict them correctly.

Mr. MICHAELS. Thank you. I think, I'm sure inadvertently, Dan misrepresented my analysis. We weren't just using 10-year decadal averages. We were looking at 10-year running means, 1991 to 2000, 1990-1999, etcetera, on back through the historical record.

He said that, if we had looked at 30-year averages, that would have been important. Well, I didn't, but Tom Karl was so interested in our analysis that he did, and he found that the models over the U.S. for temperature, in fact, were no better than random numbers on 25-year averages.

I would like to get back to this notion of what we know and what we don't know. Both the House and Senate have considered—thrown considerable resources at us, probably about $10 billion over the years, to study this issue of climate change, and much of it has gone toward the modeling of climate change.

Now I am going to believe that for that $10 billion we at least got the mathematical form of those models correct. This is the grab bag of models. I could get you a whole bunch of others. What you see is they are straight lines in general. The Canadian model is an outlier.

Now the reason for this is simple. It is because we are adding carbon dioxide in the atmosphere at a slightly exponential rate, if I could draw your attention to my hand, slightly greater than a straight line, but the response of the atmospheric temperature to carbon dioxide is what we call a logarithm. It begins to damp off. If you add up an exponent and a logarithm, you get a straight line. That is what we have here.

As the greenhouse era began, and we can, I think, see that when we see the cold air masses in Siberia start to warm up—that's a real strong signal of a greenhouse.

Mr. GREENWOOD. When was that?

Mr. MICHAELS. That's about around 1970 or so this begins to take place. We could plot the temperatures against this. I want to show you something. Now let me finish with an analogy.

We have different weather forecasting models, and I teach weather forecasting at University of Virginia every once in a while, and some days the models will differ. We have the ADA model. We have the NGM model which stands for "no good model." We have the ECMWF. We have all these models. What do you think we tell students, for all their tuition money, when we have all these different models forecasting slightly different weather for the next 3 days?

We tell them to look out the window. We tell them look at what is happening around the country, and see which model corresponds best to reality. That is what we do for the weather forecasting problem, and that is what this graph does for the climate forecasting problem.

I draw your attention to the blue dots, once they start to go up, how remarkably little they depart from the straight lines. It's just that the computers predict different straight lines. What has happened here—what explains this curve is not only the addition of the logarithmic and the exponential response, but a remarkable constant has emerged in our study of human influence on the atmosphere, which is the amount of carbon dioxide emitted per person is constant as population increases.

Now we believe population is not going to increase as much as it was. This curve is a true indicator of what is happening, and I see absolutely no reason to believe that those constances are going to begin to suddenly depart from reality.

Mr. GREENWOOD. I am going to recognize myself for an additional 10 minutes.

Mr. DEUTSCH. Mr. Chairman, if I might, I have gotten a request, a unanimous consent request, that other members be allowed to submit statements and questions for the record.

Mr. GREENWOOD. Without objection, they certainly will be.

Dr. Pielke, in your testimony you described a policy statement of the American Association of State Climatologists which recommends that, "Policies related to long term climate not be based on particular predictions, but instead should focus on policy alternatives that make sense for a wide range of plausible scenarios."

Does this mean State climatologists, by and large, do not consider the National Assessment a useful tool for policymaking?

Mr. PIELKE. Well, we didn't specifically talk about the National Assessment. We talked about the climate change issue in general. I would think we would fall back on our comment No. 2 in our policy statement that recognizes that the models are—or that climate prediction itself was a very complicated problem, and that verification is also difficult, if not impossible, because you have to wait a long period of time in order to come up with the predictions.

I think we also recognize as State climatologists that climate is much more complex than is implied by the U.S. National Assessment, since they didn't, for example, include all the human forcings; and because of that, as I said a few minutes ago, we have concluded that there is no skill in any of these models, the IPCC or the U.S. National Assessment, for predicting these regional impacts of growing season, drought, flood producing rainfall and so forth.

So even if the models did show global skill, which I don't think they have, they certainly have not shown regional skill as voted on by nearly a unanimous vote of our Society.

Mr. GREENWOOD. Thank you. Dr. Janetos, let me return to you. You note in your testimony that the report explicitly describes the synthesis team's scientific judgment about the uncertainty inherent in each result. (a) Can you explain why this effect was sufficient, given the complexities of the undertaking, the public mindset, and the context in which the report would be taken?

Mr. JANETOS. It was certainly our hope and our intent to signal to our readership, however wide or narrow it might have ended up being, our judgment about the robustness and confidence that we had in our major findings. To give you a particular example, results that were only found in one model run from one GCM and one ecological model, as extreme as they might have been, were judged to be of substantial—We had substantially less confidence in those results than findings that were consistent amongst either climate models or ecosystem models.

It was certainly not our intent, nor the design of this report, to have it serve as the sole basis for national policymaking, and it obviously is not being used as such, as a sole basis for policymaking, which I think is wise.

Many of us have subsequently collaborated on a publication in which we lay out our views of the scientific uncertainties and recommend programs for addressing those, which is currently in press in the peer reviewed literature.

Mr. GREENWOOD. Thank you. Mr. Karl, do you believe the caveats about uncertainty were sufficient?

Mr. KARL. Yes, I believe that we went to great pains to develop a lexicon, as Dr. Janetos had indicated, to try and convey where it was clear in our minds that there was considerably higher probability, given all the assumptions of the scenarios that were generated, of the outcomes. Then there were some where we tried to convey the information in the sense that we just didn't know, and there was equal chances.

So I thought that, in fact, the assessment followed a protocol that was begun in the first IPCC report in 1990 that tried to give asterisks, asterisks meaning one, two, three or four-star asterisks to try and convey some sense of confidence that the scientists had in the outcomes that they were expecting in the future.

It was very clear when we were writing this report, words can be very deceiving. One individual may say likely, and it causes a whole different set of ideas to come to mind that, you know, maybe this is 95 percent certain. So we tried, and it is shown in the report—tried to use those words and link them with probabilities, not fixed probabilities but likely didn't mean 95 percent. It was somewhere between 65 and 85, 90 percent. So we thought that this was a quite important thing to do.

Mr. GREENWOOD. Any of the other panelists want to comment on the adequacy of the caveats?

Mr. MICHAELS. Yes, I would, if you don't mind. It has clearly been established here that both Tom and I agree that there was the problem of the two driver models doing no better than the table of random numbers, and on temperature, not on precipitation, temperature being a very important variable for agriculture and many of what we call the subsequent impact models.

To use a colloquialism, that's garbage, garbage in, and there is a transitive property of refuse when you apply it to subsequent computer models, and that's what comes out. I have yet to understand, I have yet to hear a justification for proceeding along this road when the leadership knew that there was this problem with the models.

I think they should have stopped and said, wait a minute, we need to report back to you that we really can't go down this road, even though we were commanded to, because we don't have the tools. They could have come to you and said, listen—I mean, they could have disagreed with me, that's fine—we need a lot more money. We need a lot more support to study this problem and to give you what is an assessment that is based upon real numbers, not random numbers. That is my problem with the competence in this report.

Mr. GREENWOOD. Thank you. Mr. Karl, can you elaborate on the timing of model improvements in your testimony? Can models ever provide a level of certainty needed to convince policymakers or even the State climatologists?

Mr. KARL. First off, I would preface my comment that I think I will try and limit my comments to how the improvements in the models—how long it will take to narrow the uncertainties as opposed to when State climatologists or policymakers may choose to use them.

I think that, if you take a look at history, you can get a good sense of how quickly we might be able to converge. If you look at this issue that really began to become a focus of the scientific community in the 1980's, the first models that were generated—in fact, if you even look before that, the first National Research Council report talked about the sensitivity of models to doubling of carbon dioxide on the global average temperature, and they gave an uncertainty range that stands to this day today.

That first report done by the NRC now is over 30 years old, and you will see that we still have the same range of uncertainty, you know, doubling of CO_2, 1.5 to 4 degrees Celsius increase in temperature globally, and then the issues come down to, well, what is going to happen in the specific regions.

I do see some significant improvements in the next number of years with the use of not only global models but coupling with regional climate models, putting in more of the regional details, as we have discussed. So there will be some improvements, but I would not expect that that range is going to change substantially in the next 5 or 10 years.

If I may make one other comment with respect to some of Dr. Michaels' statements regarding whether or not these models are better than a table of random numbers—and again, I don't want to turn this into a scientific debate, but the way you apply tests to models is very important to know the framework. What's the level playing ground?

These models that were run had one simulation. We know that you need many simulations to adequately capture important climate fluctuations, and we don't have that, and only if you have many, many different ensembles, orders of hundreds of climate model runs using the same forcings, can you hope to see what the scope of variability might be.

These models did not include volcanic eruptions at the time they erupted, like Mount Pinatubo, El Chechon. So again there are—As I said in my testimony, my oral statement, there's many different tests out there, and it's very tenuous to put too much information on any single test.

One other issue that's come up related to the tropospheric temperatures, mid-troposphere, that Dr. Pielke has argued show less warming than models projected. I just wanted to point out, if you go back to the early Sixties, we have radiosonde data that go the early Sixties. The warming produced by the observations and the models on a global basis are quite consistent.

Mr. GREENWOOD. Dr. Michaels, you wanted to respond?

Mr. MICHAELS. That is true, Tom, except you know and I know that the warming that occurred in the radiosondes—these are the weather balloons—is a peculiar warming that shows a step function somewhere around 1975, 1976.

In fact, if you take this weather balloon record and go from its beginning, which depending on the record you are using is 1956 or—or 1957 or 1948—Take the 1956 to 1975, and it is constant—or 1976. There is no warming. Then you take the 1977 to now or to the late 20th Century, and it is constant.

There is this jump that occurred in the mid-1970's. Some people call it the great climate shift. We have no idea what it was. We also have no computer model. O'Brien will explain it all. We have also no computer model that I know of for change in greenhouse gases that says all of a sudden the tropospheric temperature jumps.

So it is a little misleading to say, yeah, those records match up, because the computer models are predicting a smooth change—you saw that—in the free troposphere, and the atmosphere isn't obeying the law as specified by the computer.

I think Tom and I are in agreement, by the way, largely. If I were to deconstruct, and as a college professor I am forced to do this—If I could deconstruct your answer about, well, Michaels' test, you know, really was a little bit harsh, because he didn't include volcanoes or something like that, isn't Tom Saying that the models were inadequate for this report?

Mr. GREENWOOD. I will let him answer that himself. Actually, we have a pending vote. So I am going to ask the last question of the hearing, and it is kind of a wide open question.

That is this. The Congress and the Executive commanded that this study be done, but I want to ask each of you to respond to this question. If you had the power to command the Congress and the President with regard to the policies that we should enact and employ with regard to this entire range of global warming, everything from resources needed to study, the policy decisions with regard to emissions, how would you command us? Dr. Janetos?

Mr. JANETOS. Mr. Chairman, a daunting question indeed. I think my command would be twofold. One would be to take those actions which make sense now, not to imagine that the uncertainty in the science acts as a break to inhibit mitigation activities that make sense——

Mr. GREENWOOD. Could you give us an example of those actions that you think we should take?

Mr. JANETOS. I believe that some measure of mitigation for greenhouse gas emissions is in order, mitigation actions that are achievable with current technology and at reasonable cost.

I also believe quite strongly that resources and a focused program on vulnerabilities and the sensitivities of natural resources to changes not only in climate but to other environmental stresses is in order. We face a changing planet. That is very clear. Ultimately, our well-being depends on our ability to manage those resources well.

Mr. GREENWOOD. Dr. Karl.

Mr. KARL. Well, one of the things that I think is most important to consider to try and move forward on this issue is the difficulty that we face when we try to go from discipline to discipline to understand the important impacts and the adaptations, the mitigation measures we might take.

There is a tremendous amount of collegial interaction that must occur between physicists, climate scientists, ecologists, specialists in hydrology. One of the things we found in the National Assessment, I think, that was so valuable was, for the first time, these communities were actually talking together. Outputs from one model were looked to see how they might be able to run another model. Observations from one group were looked at how they might apply to another area.

That activity is really critical, and it is dependent on individuals trying to forge these interactions, these discussions. So I think one of the important messages from the National Assessment, one area that really is important if we expect further progress in this area, is to continue and encourage anything we can do to encourage that dialog across disciplines.

Most scientists get much more pats on the back by being specialists in their own field. So without a push in that direction, it is going to be very hard, I think, to expect individual scientists to—although I'm not speaking for everybody, but I think letting the system go and expecting that to happen on its own will be difficult.

Mr. GREENWOOD. Dr. Lashof.

Mr. LASHOF. Mr. Chairman, we know that we are adding a thickening blanket of heat trapping pollution to the atmosphere in CO_2 emissions from automobiles and power plants. We know that that is going to cause the climate to change, and indeed the climate has already begun the changes. I think everybody on this panel has recognized.

The National Assessment shows that the United States is very vulnerable in many respects. We can't predict what the weather will be on July 25, 2030, but we can say that there are very severe risks to the United States if we continue to add carbon dioxide to the atmosphere at the increasing rates that we have been.

We also know that for the last 10 years we have had a voluntary approach to trying to limit the emissions of greenhouse gases, and it's failed. Our emissions are going up. So I think that the basic conclusion is pretty straightforward. It's time for mandatory limits on emissions of carbon dioxide and other heat trapping gases.

The House has before it the Clean Smokestack Act sponsored by Congressmen Boehlert and Waxman that would take a big start on that, focusing on an integrated approach to cleaning up emissions from power plants. I think we need an energy policy that is designed to limit carbon dioxide emissions. Unfortunately, I believe that the policy that was passed by the House earlier in the year moves us in the wrong direction, and instead of, for example, strengthening efficiency standards for automobiles that would have the result of reducing emissions of CO_2 and making us less vulnerable to dependence on foreign oil, it actually moves us in the wrong direction. It weakens currently law.

So I think there are some very clear steps. You know, the good news is that this is a very daunting problem, but unlike some other problems like terrorism and poverty, I think we know how to solve this problem, and we just really need to get to work on it. So that would be my answer. Thank you.

Mr. GREENWOOD. Dr. O'Brien.

Mr. O'BRIEN. Mr. Chairman, I have two points here. One point is that, besides my colleague, Dr. Pielke's, very good points about looking to see where the vulnerabilities are so you know where to put the emphasis on your studies, I believe that more—that Congress should direct the scientific community to start looking at understanding climate variability, and I mean how we vary on the scales of annual, multi-years and multi-decades, because these are the way that we finally get to this straight line. I think that just looking at what is going to happen 100 years from now is the wrong approach.

I also believe—The second point is I believe that this changing climate variability and its understanding should be made a national security issue and not just a domestic issue. I feel sad to hear that we continue to focus today too much on just what is happening in the United States, but unfortunately with our standing in the world, you know, we are taking on responsibility for lots and lots of parts of the world, you know.

You see lots of efforts both in the military and the civilian side, and I do believe that we need to think about other places in the world. You know, if climate variability destabilizes countries which are on the edge—and I'm not going to mention any now—you know, that is going to cause a great problem for our economy and our citizens. So I really believe that we should return to the idea that the changing climate in the future and its variability is really an important national security issue for the United States.

Mr. GREENWOOD. Thank you, sir. Dr. Pielke.

Mr. PIELKE. Well, first I would like to mention, I think we should move beyond the term global warming to the more inclusive term, which is human induced climate change; because I think it is multi-dimensional and multi-faceted, as our policy statement says.

In the specific policy statement of my association, there are two bullets in there that I think address your question specifically. The first one is that policy responses to climate variability and change should be flexible and sensible. The difficulty of prediction and the impossibility of verification of predictions decades into the future are important factors that allow for competing views of a long term climate future. Therefore, the American Association of State Climatologists recommends that policies related to long term climate not be based on particular predictions but instead should focus on policy alternatives that make sense for a wide range of plausible climatic conditions, regardless of future climate.

Climate is always changing on a variety of time scales, and being prepared for the consequences of this variability is a wise policy.

Second, in our interactions with users of climate information AASC members recognize that the Nation's climate policies must involve much more than the discussions of alternate energy policies. Climate has a profound effect on sectors such as energy supply and demand, agriculture, insurance, water supply and quality, ecosystem management, and the impacts of national disasters.

Whatever policies are promulgated with respect to energy, it is imperative that policymakers recognize that climate variability and change has a broad impact on society. The policy responses should also be broad. Thank you.

Mr. GREENWOOD. Dr. Michaels.

Mr. MICHAELS. Mr. Chairman, as a CATO scholar, I guess I am going to have to be rational. The fact of the matter is that I believe what we should do now is not mandate technological programs and technologies that will not do very much about warming.

When Mr. Gore came back from Kyoto in 1997, he asked the government scientists to project how much warming the Kyoto Protocol would save. The Protocol would require us to reduce our emissions 7 percent below 1990 levels, etcetera. Let me show you the calculation.

The solid black line is the average temperature change from a suite of models if all the nations of the world did Kyoto. The dashed line underneath it—if we continued business as usual, I'm sorry. The dashed line underneath it is what happens if all the nations of the world did Kyoto.

The change in global surface temperature exerted by Kyoto in 50 years would be seven hundredths of a degree Celsius, fourteen hundredths of a degree Celsius in 100 years.

If we really are concerned about this problem, I suggest rather than mandating technologies that we specifically allow people to retain their income to invest in the technologies of the future that this Congress and no one on this panel can define. One hundred years ago, the technology that ran our society was radically different than it is today. One hundred years from now, it will be radically different. It will be more efficient. It must be, because that is what a market determines.

I think the best thing to do is to allow people to invest in those technologies, their own choice, rather than having governments, perhaps mistakenly, invest other people's monies in technologies that simply will not accomplish what many people on this panel think needs to be accomplished.

I believe our change to a less carbon based economy is an historical inevitability. All we have to do is get out of the way.

Mr. GREENWOOD. You would command us to command less.

We thank all of our witnesses for your presence and your testimony, and excuse you now. This hearing is adjourned.

[Whereupon, at 11:45 a.m., the subcommittee was adjourned.]

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