CLIMATE HISTORY AND THE SCIENCE UNDERLYING FATE, TRANSPORT, AND HEALTH EFFECTS OF MERCURY EMISSIONS
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U.S. Senate, Tuesday, July 29, 2003
Committee on Environment and Public Works Washington, D.C.

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TUESDAY, JULY 29, 2003

U.S. Senate,
Committee on Environment and Public Works,
Washington, DC.

The committee met, pursuant to notice, at 9:00 a.m. in room 406, Senate Dirksen Building, Hon. James M. Inhofe [chairman of the committee] presiding.

Present: Senators Inhofe, Allard, Carper, Clinton, Cornyn, Jeffords, Thomas and Voinovich.

OPENING STATEMENT OF HON. JAMES M. INHOFE, U.S. SENATOR FROM THE STATE OF OKLAHOMA

Senator Inhofe. The meeting will come to order.

We have a policy that we announced when I became chairman of the committee that we will start on time, whether anyone is here or not here, members, witnesses or others. So I appreciate all of you being punctual in spite of the fact that the Senators are not.

One of my primary objectives as chairman of the committee is to improve the way in which science is used. I think that when I became chairman of this committee, I announced three very outrageous things that we were going to do in this committee that have not been done before. Number one, we are going to try to base our decisions, things that we do, on sound science. Number two, we are going to be looking at the costs of some of these regulations, some of these policies that we have, and determine what they are going to be. And number three, we are going to try to reprogram the attitudes of the bureaucracy so that they are here not to rule, but to serve.

Good public policy decisions depend on what is real or

probable, not simply on what serves our respective political agendas. When science is debated openly and honestly, public policy can be debated on firmer grounds. Scientific inquiry cannot be censored. Scientific debate must be open. It must be unbiased. It must stress facts rather than political agendas.

Before us today, we have two researchers who have published what I consider to be a credible, well-documented, and scientifically defensible study examining the history of climate change. Furthermore, these are top fields of inquiry in the Nation's energy environment debate and really the entire world's energy environment debate. We can all agree that the implications of this science are global, not only in terms of the environmental impacts, but also energy impacts, global trade impacts, and quite frankly, no less than global governance impacts.

We could also all agree that as a result of the import and impact of these issues, it is absolutely crucial that we get this science right. False or incomplete or misconstrued data are simply not an acceptable basis for policymaking decisions in which the Congress of the United States is involved. Such data would violate the Data Quality Act, which we passed on a bipartisan basis here in the Senate and which we have bipartisanly embraced. If we need more data to satisfy our standards, then so be it.

This Administration is prepared to do so in an aggressive strategy that the climate change strategic plan outlines. The 1000-year climate study that the Harvard-Smithsonian Center for Astrophysics has compiled is a powerful new work of science. It has received much attention, and rightfully so. I would add at this time, it did not receive much attention from some of the liberal media who just did not want to believe that any of the

facts that were disclosed were accurate.

I think the same can be said in terms of work that has recently received attention of the hockey stick study. In many important ways, the Harvard-Smithsonian Center's work shifts the paradigm away from the previous hockey stick study. The powerful new findings of this most comprehensive study shiver the timbers of the adrift Chicken Little crowd.

I look forward to determining whose data is most comprehensive, uses the most proxies, maintains the regional effects, avoids losing specificity through averaging statistics, considers more studies, and most accurately reflects the realities of the Little Ice Age, reflects the realties of the Medieval Warming Period, and more.

Mercury presents a different set of issues. That would be our second panel. It is well-established that high levels of exposure to methyl-mercury before birth can lead to neuro-development problems. But what about mercury consumed through fish, the most common form of prenatal exposure? Mercury makes its way into fish through various ways, but primarily though deposition from air emissions, with 80 percent of emissions deposited either regionally or globally, not locally. Global mercury emissions are about 5,000 tons a year. About half of those are manmade emissions.

In the United States, a little more than 100 tons are emitted from non-power plant sources. Industry is making great strides in reducing these emissions. I would like to submit for the record this EPA document available on their Web site which indicates that when rules now on the books are fully implemented at non-power plant, nationwide emissions will be cut by nearly 50 percent. Power plants emit about 50 tons of mercury annually,

about one percent of the worldwide emissions.

In setting policy, key questions need to be answered, such as how would controls change this deposition; what portion of mercury exposure can be not control; and what are the health impacts of prenatal exposure. We will hear testimony today that indicates any changes to mercury exposure in fish would be minimal under even the most stringent proposal to regulate mercury. Today, we will also hear testimony that the most recent and comprehensive study to date found no evidence that prenatal mercury exposure from ocean fish presents a neurological risk.

So we have diverse opinions that will be discussed today, and that is the reason for this hearing, to wade through that so that those of on the panel that will be making policy decisions will understand. I think it is no secret that we are not scientists up here, so we look at things logically.

With that, I would recognize one of my colleagues here that I have a great deal of respect for. Senator Voinovich and I started out together as we were mayors of cities almost 25 years ago. I consider him to be one of the really experts in the area of air. In fact, I can remember calling him in as an expert when he was Governor of Ohio and we were holding these hearings and I was chairman at that time of the Clean Air Subcommittee. I would recognize Senator Voinovich for any comments he would like to make or opening statements.

OPENING STATEMENT OF HON. GEORGE V. VOINOVICH, U.S. SENATOR FROM THE STATE OF OHIO

Senator Voinovich. Thank you, Mr. Chairman.

I want to congratulate you for the very comprehensive floor

speech that you gave yesterday on the issue of climate change.

Senator Inhofe. I guess I should apologize. It was 12,000 words and I know you were anxious to get some floor time, so I appreciate your patience.

Senator Voinovich. Your words were much more scientifically based than mine.

[Laughter.]

Senator Voinovich. The two issues that we are going to explore at the hearing today, the science of mercury and the science of climate change, are both important and timely. I commend you for holding this hearing.

I think I do not have to remind you that we have had hearings on climate change now during the last four or five years. I think I had a couple when I was chairman of even the Transportation Infrastructure Committee. Senator Lieberman had hearings over in Governmental Affairs when he was chairman of the committee a year or so ago. So it is not a subject that is brand new to this committee.

I have stated time and time again here in the committee and on the floor that we must recognize that energy policy and environmental policy are two sides of the same coin, and the Senate has responsibility to harmonize these policies. We have an obligation here in the committee to ensure that legislation that we consider will protect our environment. We also have an obligation to ensure that any legislation we consider takes into account its potential impact on our economy and we have a moral obligation to ensure that we consider a bill's particular impact on the poor and the elderly who must survive on fixed incomes.

When the Senate takes up consideration of climate change and multi-pollutant legislation, we must keep that moral obligation in mind. We must ensure that we do not pass legislation that will significantly drive up the cost of electricity and home heating for those who can least afford them.

Several members of this committee have introduced pieces of legislation this year to reduce power plant emissions, including mercury, and address the issue of carbon emissions and climate change by capping carbon. Examples include Jeffords-Lieberman four-P bill, the Carper four-P bill, and the McCain-Lieberman climate change bill, which I understand will likely be offered as an amendment to the energy bill, just this week we are going to be considering it.

These bills will establish a nationwide cap on carbon emissions and their passage would force the utility sector, that is now using coal to generate over half of our Nation's electricity. To rely solely on natural gas for generation, we will have fuel switching -- capping carbon equals fuel switching equals no-coal -- to rely on natural gas regeneration despite the fact we have over a 250-year supply of domestic coal and are currently in the grips of a natural gas crisis in this country.

This crisis is a result of environmental policies that have driven up the use of natural gas in electricity generation significantly, while domestic supplies of natural gas have fallen, partly because we cannot do the exploration that we need to do for natural gas.

The result is predictable: tightening supplies of natural gas, higher natural gas prices, and higher electricity prices. Home heating prices are up dramatically, forcing folks on low an and fixed incomes to choose between heating their homes and

paying for other necessities such as food or medicine. The language that has been offered by Senators Jeffords, McCain, Lieberman and Carper if enacted will force our utilities to fuel switch to natural gas; will significantly raise energy prices; and will cause thousands of jobs to be lost, particularly in manufacturing States like my State of Ohio, which is already under duress in terms of manufacturing.

During the debate last year on the Jeffords-Lieberman four-P bill, I put together a white paper that discussed the impact that the bill would have if it were enacted. The numbers are staggering: an overall reduction in GDP of $150 billion by 2020, the loss of over 900,000 jobs by 2020, and a decline in national household earnings of $550 annually.

The cost of climate-change language such as the McCain-Lieberman bill could come without any benefits to our air quality or public health. Not even the most ardent supporter, and I hope this comes up, of carbon regulation will claim that there are demonstrable health benefits from carbon regulation. Yet the Energy Information Administration estimates that the passage of the McCain-Lieberman bill, if enacted, will raise petroleum product prices by 31 percent, raise natural gas prices by 79 percent, raise electricity prices by 46 percent, and reduce GDP by up to $93 billion by 2025.

Carbon caps and unrealistic mercury caps means fuel switching, again. The fuel switching means the end of manufacturing in my State, enormous burdens on the least of our brethren. It means moving jobs and production overseas, where there are less stringent environmental programs. And will actually, if you really think about it, increase global levels of pollution.

The question we face in this committee is whether we should do something reasonable to improve our understanding of the issues surrounding carbon emissions and climate change, and attempt to reduce atmospheric concentration of carbon and mercury emissions without harming our economy, or rush into short-sighted policy that will cap carbon and mercury at unreasonable levels, shut down our economy, cut thousands of jobs, and move manufacturing overseas.

In a recent column, former Secretary of Energy James Schlesinger commented that "In climate change, we have only a limited grasp of the overall forces at work. Uncertainties have continued to abound and must be reduced. In any approach to policy formation, this is very important, under conditions of such uncertainty should be taken only on an exploratory or a sequential basis. A premature commitment to a fixed policy could only proceed with fear and trembling."

I would like to have that column inserted in the record, Mr. Chairman.

Senator Inhofe. Without objection, so ordered.

[The referenced document follows:]

Senator Voinovich. As I mentioned previously once or twice, I am working with Chairman Inhofe and the Administration on moving Clear Skies forward, which I intend to mark up in my subcommittee this fall. I am currently working with business and environmental groups to find a bipartisan compromise on dealing with carbon and global warming, with an emphasis on sound science, carbon sequestration, development of clean coal technologies, and a responsible approach that focuses more on consensus rather than politics.

We need more Senators to focus on moving forward in a responsible way and move away from harshly ideological positions that advance nothing other than the agenda of some environmental groups that have made carbon cap a political litmus test.

I thank the chairman for holding this important hearing and I look forward to hearing the testimony from our witnesses.

Senator Inhofe. That is an excellent opening statement, Senator Voinovich. I go back to one of your first sentences when you talked about the number of hearings we have had. We have to keep in mind that each new hearing has new data. For example, the 1,000-year Harvard-Smithsonian was not even out until March of this year. So there are new things that are coming along and I see a new trend-line which I discussed on the House of the Senate yesterday. So this will be a very valuable hearing.

Senator Cornyn, would you have any opening statement to make?

Senator Cornyn. I would like to reserve any statement until later, Mr. Chairman.

Senator Inhofe. Yes, that is fine. First, I would like to ask the first panel to come up. Dr. Legates, Dr. Willie Soon and Dr. Mann, would you three come up? First of all, we are honored to have who I consider three very excellent and professional scientific witnesses here today. Normally, we restrict the opening statements to five minutes, but it would be fine if you want to go about seven minutes because I know you have come a long way and what we are dealing with here is probably one of the most significant things facing America, facing our economy, facing our environment today.

So I would introduce all three. Dr. David Legates is the director of the Center for Climatic Research at the University of Delaware. Dr. Willie Soon is the astrophysicist at Harvard-Smithsonian Center for Astrophysics, and Dr. Michael Mann is associate professor at the University of Virginia Department of Environmental Sciences. I will first ask Dr. Willie Soon to give his opening statement.

STATEMENT OF WILLIE SOON, ASTROPHYSICIST, HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

Dr. Soon. Mr. Chairman, distinguished Senators, my fellow panelists, Dr. Mann and Dr. Legates, and members of the audience, my name is Willie Soon. About a month or two ago, I became a very proud and grateful U.S. citizen. I just cannot believe where I am sitting today.

I am an astrophysicist with the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. My training is in atmospherics and space physics. My research interests for the past 10 years include changes in the sun and their possible impact on climate.

I am here today to testify that the climate of the 20th century is neither unusual nor the most extreme. Around 1,000 years ago, the temperature over many parts of the world was warm. A widespread cooling then set in for several centuries, followed by a recovery to 20th century warming.

My colleague and I collected the information on climate by proxy. We studied environmental indicators of local climate change going back some 1,000 years from many locations around the world. Based on work of approximately 1,000 researchers and hundreds of peer-reviewed papers, we conclude the following three

points about climate history of the last 1,000 years.

On a location-by-location basis, point one, there was warming from 800 to 1300 A.D., all about 1,000 years ago, over many parts of the world. This period is called the Medieval Warm Period. Following the warming of 1,000 years ago was a general cooling from about 1300 to 1900 A.D. This period is called the Little Ice Age.

Point two, there is no convincing evidence from local proxy to suggest that the 20th century had higher temperatures or more extreme climate than the warm period 1,000 years ago.

Point three, local and regional, rather than global average changes are the most relevant and practical measure of climate changes and its impact. Much of the climate proxy results using our work are new. Most papers were published in the scientific literature in the recent five to ten years. There are two points to note about our methods. First, we keep the local or regional information contained in each climate proxy. This is important for studying geographical patterns of climate, which does not change everywhere at the same time.

Second, climate is more than just temperature, so we keep the climate information like rainfall, expansion or contraction of forests, all advances or retreats of glaciers, et cetera. Our approach makes use of the richness of information in climate proxies, which map out local environmental and climate properties, rather than just temperature alone.

The entirety of climate proxies over the last 1,000 years shows that over many areas of the world, there has been and continues to be large local climatic changes. Those changes provide important changes for the computer simulations of

climate. The full models which explore the Earth region by region can be tested against the natural patterns of change over the last 1,000 years that are detailed by the climate proxies.

Having computer simulation, we produced past patterns of climate which has been influenced predominantly by natural factors and is key to making an accurate forecast that includes all potential human-made warming and cooling effects.

In summary, based on expert conclusions from climate proxies in several hundred peer-reviewed papers by over 1,000 researchers from around the world, we find the following. One, from one location to another, large natural swings in climate have occurred over the last 1,000 years. Those patterns have not always been synchronous.

Two, there was widespread warmth about 1,000 years ago, followed by widespread cooling ending by the beginning of the 20th century.

Three, the local and regional climate proxies cannot confirm that the 20th century is the warmest or most extreme over much of the world, compared especially to the Medieval Warm Period approximately 1,000 years ago.

This is all for my oral remarks and I thank you for the opportunity to be here.

Senator Inhofe. Dr. Soon, we appreciate that excellent opening statement. You did not even take all of your time. That is very unusual.

At this time, Dr. Mann if you don't mind, I would like to interrupt your testimony. We have been joined by the Ranking

Minority Member, Senator Jeffords. Senator Jeffords, do you have an opening statement you would like to make at this time?

Senator Jeffords. I would ask unanimous consent that it be made as part of the record and would prefer listening to the witnesses.

[The prepared statement of Senator Jeffords follows:]

Statement of Senator James Jeffords
Committee on Environment and Public Works
Hearing on Climate Change and Mercury Pollution
Tuesday, July 29, 2003

We're here today to discuss two very important topics - climate change and mercury pollution. As most of you know, I am the author of ambitious legislation - the Clean Power Act of 2003 - which addresses these environmental problems, as well as ozone, acid rain, and human health damage from fine particulate matter.

Unfortunately, we aren't here today to talk about moving forward to find innovative solutions to these real world problems. Instead, today's hearing will largely be a mirror or the reverse of the robust and growing consensus in the mainstream scientific community on climate and mercury pollution.

The disappointing result will be more delay. Delay on the part of Congress, and even worse, the ongoing backsliding on the part of the Administration, means that we fail to act responsibly as a society to protect future generations. That means increasingly greater risks of global warming and mercury poisoning.

There is no doubt that the scientific process must inform policy makers as new information comes in. Unfortunately, there is no new information to be found here today that would dissuade us from acting quickly and responsibly to reduce greenhouse gas and mercury emissions. In today's discussion of a literature survey of climate research, the skeptics are trotting out an argument that is several years old and already discarded by their peers.

It is abundantly clear that now is the time to act.

--The National Academy of Sciences has said, "Despite the uncertainties, there is general agreement that the observed warming is real and particularly strong within the past 20 years."

--NOAA currently says that, "The climatic record over the last thousand years clearly shows that global temperatures increased significantly in the 20th Century, and that this warming was likely to have been unprecedented in the last 1200 years."

--EPA's website says that, "There is new and stronger evidence that most of the warming over the last 50 years is attributable to human activities."

One would have to be madder than a March hare to fail to see the need to act. Yet, the Administration=s new research plan falls squarely into hare territory - denying the reality staring them in the face.

I want to show you the latest odds on warming. MIT says that there is a one in five chance that the temperature of the earth will warm by approximately 4 or 5 degrees over the course of this century, assuming there is no action to reduce emissions.

As my dear departed friend, Senator John Chafee, said in 1989 - "It is clear that we are facing a serious threat. The scientists are telling us that if we continue to stroll along as if everything is fine, we will transform Earth into a planet that will not be able to support life as we now know it."

While mercury contamination does not have the same dramatic effect on earth=s systems, it is still a dangerous global and local pollutant because it is bio - accumulative and toxic to human health.

Long ago, Congress decided that toxic air emissions should be reduced and took very aggressive steps in 1990 to make that happen, especially if they fall into the Great Lakes and other great waters like Lake Champlain. Unfortunately, the Agency has fallen significantly behind in complying with the Clean Air Act=s schedule. A settlement agreement mandates controlling toxic air pollutants from utilities by 2008.

In 1998, related to the controversy around EPA=s late reports to Congress on utility air toxics, Congress directed the National Academy of Sciences (NAS) to recommend an appropriate reference dose for mercury exposure. In 2000, the NAS reported that EPA's reference dose was scientifically sound and adequate to protect most Americans. That NAS review considered all health effects studies, including the Seychelles study that we=ll discuss today.

We know that mercury is a potent toxic. It affects the human brain, spinal cord, kidneys, liver and the heart. It affects the ability to feel, see, taste and move. We know that mercury can affect fetal development, preventing the brain and nervous system from developing normally. Long term exposure to mercury can result in stupor, coma and personality changes.

"Mad as a Hatter" is the phrase that was used in the 1800's to describe the employees of the felt hat industry whose constant exposure to mercury changed their behavior. Fortunately, Americans exposure from commercial and recreational fish consumption is substantially less than that, though dozens of health warnings are posted nationwide.

But, it's crazy for anyone to suggest that we should not reduce mercury emissions

significantly, since we know its health effects and we have the technologies to control it.

We should have a hearing on how to export those control technologies and Congress should urge the Administration to negotiate binding global reductions in mercury, as the Senate did last year in the Energy bill for greenhouse gas emissions.

At a minimum, we should pass four-pollutant legislation now that gets reductions faster and deeper than required by the current Clean Air Act. I=m sad to say that there have been no negotiations on that front since I initiated some in early 2002. And the Administration has done nothing to reduce these emissions with its abundant authority in the Act.

We can't afford to leave these problems to future generations to solve. We can=t let our children and grandchildren wake up to find that our delays have cost them dearly in terms of health and the global and local environment. It's time to act responsibly.

Finally, I ask that material from the journal EOS, the NOAA website, the Atlanta Journal Constitution, the National Center for Atmospheric Research, and the American Geophysical Union be included in the hearing record.

Senator Jeffords. I might point out, we have got to do something about this traffic out there.

[Laughter.]

Senator Inhofe. Well, the name of our subcommittee is Transportation and Infrastructure, so maybe we can do something about the traffic out there.

Senator Jeffords. I hope so.

Senator Inhofe. Dr. Mann, you are recognized.

STATEMENT OF MICHAEL E. MANN, ASSOCIATE PROFESSOR, UNIVERSITY OF VIRGINIA, DEPARTMENT OF ENVIRONMENTAL SCIENCES

Dr. Mann. Senators, my name is Michael Mann. I am a professor in the Department of Environmental Sciences at the University of Virginia. My research involves the study of

climate variability and its causes. I was a lead author of the IPCC Third Scientific Assessment report. I am current organizing committee chair for the National Academy of Sciences' Frontiers of Science, and have served as a committee member or adviser for other National Academy of Sciences' panels.

I have served as editor for the Journal of Climate of the American Meteorological Society for three years and I am a member of the advisory panel for the NOAA Climate Change Data and Detection Program. I am a member of numerous other international and U.S. scientific working groups, panels and steering committees. I have coauthored more than 60 peer- reviewed publications on diverse topics within the fields of climatology and paleoclimatology.

Honors I have received include selection in 2002 as one of the 50 leading visionaries in science and technology by Scientific American magazine, and the outstanding scientific publication award of NOAA for 2000.

In my testimony here today, I will explain, one, how mainstream climate researchers have come to the conclusion that late 20th century warmth is unprecedented in a very long- term context and that this warmth is likely related to the activity of human beings; and two, why a pair of recent articles challenging these conclusions by astronomer Willie Soon and his coauthors are fundamentally unsound.

It is the consensus of the climate research community that the anomalous warmth of the late 20th century cannot be explained by natural factors, but instead indicate significant anthropogenic, that is human influences. This conclusion is embraced by the position statement on climate change and greenhouse gases of the American Geophysical Union, by the 2001

report of the IPCC, the Intergovernmental Panel on Climate Change, and by a National Academy of Sciences' report that was solicited by the Bush Administration in 2001.

More than a dozen independent research groups have now reconstructed the average temperature of the northern hemisphere in past centuries, both by employing natural archives of past climate information or proxy indicators such as tree rings, corals, ice cores, lake sediments and historical documents, and through the use of climate model simulations. If I can have the first exhibit here, as shown in this exhibit, the various proxy reconstructions agree with each other, as well as with the model simulations, all of which are shown, within the estimated uncertainties. That is the gray-shaded region.

The proxy reconstructions, taking into account these uncertainties, indicate that the warming of the northern hemisphere during the late 20th century, that is the northern hemisphere, not the globe, as I have sometimes heard my study incorrectly referred to, the northern hemisphere during the late 20th century, that is the end of the red curve, is unprecedented over at least the past millennium and it now appears based on peer-reviewed research, probably the past two millennia.

The model simulations demonstrate that it is not possible to explain the anomalous late-20th century warmth without the contribution from anthropogenic influences. These are the consensus conclusions of the legitimate community of climate and paleoclimate researchers investigating such issues.

Astronomers Soon and Baliunas have attempted to challenge the scientific consensus based on two recent papers, henceforth collectively referred to as SB, that completely misrepresent the past work of other legitimate climate researchers and are deeply

flawed for the following reasons. One, SB make the fundamental error of citing evidence of either wet or dry conditions as being in support of an exceptional Medieval Warm Period. Such an ill-defined criterion could be used to define any period of climate as either warm or cold.

It is pure nonsense. Experienced paleoclimate researchers know that they must first establish the existence of a temperature signal in a proxy record before using it to try to reconstruct past temperature patterns. If I can have exhibit two, this exhibit shows a map of the locations of a set of records over the globe that have been rigorously analyzed by my colleagues and I for their reliability as long- term temperature indicators. I will refer back to that graphic shortly.

Two, it is essential to distinguish between regional temperature changes and truly hemispheric or global changes. Average global or hemispheric temperature variations tend to be far smaller in their magnitude than those for particular regions. This is due to a tendency for the cancellation of simultaneous warm and cold conditions in different regions, something that anybody who follows the weather is familiar with, in fact.

As shown by exhibit three, if I can have that up here as well now, thank you, this exhibit plots the estimated temperature for various locations shown in the previously displayed map. As you can see, the specific periods of relatively cold and warm, blue and red, differ greatly from region to region. Climatologists, of course, know this. What makes the late 20th century unique is the simultaneous warmth indicated by nearly all the long-term records. It is this simultaneous warmth that leads to the anomalous late-20th century warmth evident for northern hemisphere average temperatures.

The approach taken by SB does not take into account whether warming or cooling in different regions is actually coincident, despite what they might try to tell you here today.

Three, as it is only the past few decades during which northern hemisphere temperatures have exceeded the bounds of natural variability, any analysis such as SB that compares past temperatures only to early or mid-20th century conditions; you repeatedly hear Dr. Soon refer to the 20th century; climatologists do not consider that a meaningful baseline because there has been a dramatic warming during the 20th century and the early 20th century and the late 20th century are almost as different as the late 20th century and the other period during the past 1,000 years at least. So a study that refers only to early or mid-20th century conditions or generic 20th century conditions and does not specifically address the late 20th century, cannot address the issue of whether or not late-20th century warmth is anomalous in a long-term context.

To summarize, late-20th century warming is unprecedented in modern climate history at hemispheric scales. A flawed recent claim to the contrary by scientists lacking expertise in paleoclimatology is not taken seriously by the scientific community.

The anomalous recent warmth is almost certainly associated with human activity and this is the robust consensus view of the legitimate climate research community.

Thank you.

Senator Inhofe. Thank you, Dr. Mann.

Dr. Legates? First, I would ask Senator Allard, did you

want to make an opening statement?

Senator Allard. Mr. Chairman, I do have an opening statement and in deference to the panel and you I would just like to have it put in the record. If you would do that, then I would be happy.

Senator Inhofe. Without objection.

[The prepared statement of Senator Allard follows:]

Statement by Senator Wayne Allard
Tuesday July 29, 2003
Environment & Public Works Committee Hearing
To examine climate history and its implications,
and the science underlying fate, transport
and health effects of mercury emissions

Mr. Chairman, I want to thank you for holding this important hearing today.

As a veterinarian, I have some scientific training in my background. I strongly believe that we should use scientific principals as a guidepost when formulating any regulation. This scientific guidepost approach is particularly important when looking at regulations with the implications and magnitude of regulations on climate change and mercury control..

Climate change has been an ongoing discussion for many years. However, during the 1970s the concerns were exactly opposite what they are now. Then we were told that there was a threat of massive global cooling. Headlines screamed that we were in danger of entering another ice age. Now we are told that massive warming trends are going to cause overheating across the globe. We need answers, not rhetoric.

All of the witnesses here today have a great deal of experience. All of the witnesses here have spent many years analyzing data related to the areas of their expertise. But, I am concerned that, at times, data may be reviewed selectively and in isolation. I am also concerned that emphasis may fall on a limited number of studies. In science we have all learned that the only way to solidly prove a theory is by conducting tests, studies or experiments that repeatedly arrive at the same result. We cannot simply ignore the studies that do not have the outcome we are looking for. This applies whether we are looking at climate change, mercury or any other issue.

I want to spend most of my time and attention today on potential mercury regulations. While today's hearing is intended to focus on science, I would also like to touch on the impact

that potential regulations will have on the economy of my state and the west. As many of you know, western coal differs from other types of coal in several ways. The higher chlorine content in western coal makes it more difficult to remove mercury when burning it. And, while western coal does contain mercury, when it is burned it gives off mercury in the elemental form. It is my understanding that this is not the type of mercury that deposits in the ecosystem to potentially be absorbed by the environment.

The economies of Colorado, and the entire west, will be impacted by harsh regulations placed on their coal. Economies undoubtedly will be damaged by the decrease in use of coal mined in the West. In addition, while jobs are being lost due to the subsequent inability to fully utilize western coal supplies, if power can no longer be generated by using coal mined in the west, other less efficient coal types will have to be transported across long distances. This additional expenditure will add to the price of electricity generation, driving up electricity costs and further damaging an economy that will already be struggling.

This is why it is so important to me that we be cautious when dealing with situations such as these and why we should place strong emphasis on the use of sound science. Our regulations must be thoughtful reflections of what we know - they should not be reflexive or reactive attempts to legislate a cure before we know what the disease is.

Again, Mr. Chairman, thank you for holding this hearing. I look forward to hearing the witness testimony and discussions to come.

Senator Inhofe. And that being the case, let's dispense with any further opening statements.

Dr. Legates, thank you very much for being here. You are recognized.

STATEMENT OF DAVID R. LEGATES, DIRECTOR, CENTER FOR CLIMATIC RESEARCH, UNIVERSITY OF DELAWARE

Dr. Legates. Thank you. Mr. Chairman, distinguished senators, Doctors Mann and Soon, and members of the audience, I would like to thank the committee for inviting my commentary on this important topic of climate history and its implications. My research interests have focused on hydroclimatology. That is the study of water in the atmosphere and on the land, and as well as on the application of statistical methodology in climatological research.

I am familiar with the testimony presented here by Dr. Soon. My contributions to Dr. Soon's research stem from my grappling with the striking disagreement between the longstanding historical record and the time series recently presented by Dr. Mann and his colleagues. It also stems from my own experiences in compiling and merging global estimates of air temperature and precipitation from a variety of disparate sources.

My Ph.D dissertation resulted in the compilation of high-resolution climatologies of global air temperature and precipitation. From that experience, I have become acutely aware of the issues associated with merging data from a variety of sources and containing various biases and uncertainties. By its very nature, climatological data exhibit a number of spatial and temporal biases that must be taken into account. Instrumental records exist only for the last century or so, and thus proxy records can only be used to glean information about the climate for earlier time periods. But it must be noted that proxy records are not observations and strong caveats must be considered when they are used. It, too, must be noted that observational data are not without bias either.

Much research has described both the written and oral histories of the climate, as well as the proxy climate records. It is recognized that such records are not without their biases. For example, trees respond not to just air temperature fluctuations, but to the entire hydrologic cycle, including water supply, precipitation, and demand, which is only in part driven by air temperature.

Nevertheless, such accounts indicate that the climate of the last millennium has been characterized by considerable variability and that extended periods of cold and warmth existed. It has been generally agreed that during the early periods of the

last millennium, air temperatures were warmer and that temperatures became cooler towards the middle of the millennium. This gave rise to the terms the Medieval Warm Period and the Little Ice Age, respectively. However, as these periods were not always consistently warm or cold, nor were the extremes geographically commensurate in time, such terms must be used with care.

In a change from its earlier reports, however, the Third Assessment Report of the Intergovernmental Panel on Climate Change, and now the U.S. National Assessment of Climate Change, both indicate that hemispheric and global air temperatures followed a curve developed by Dr. Mann and his colleagues in 1999. This curve exhibits two notable features, and I will point back to Dr. Mann's exhibit one that he showed a moment ago. First is a relatively flat and somewhat decreasing trend in air temperature that extends from 1000 A.D. to about 1900 A.D. This feature is an outlier that is in contravention to thousands of authors in the peer-reviewed literature.

This is followed by an abrupt rise in the air temperature during the 1900s that culminates in 1998 with the highest temperature on the graph. Virtually no uncertainty is assigned to the instrumental record of the last century. This conclusion reached by the IPCC and the National Assessment is that the 1990s were the warmest decade, with 1998 being the warmest year of the last millennium.

Despite the large uncertainty, the surprising lack of significant temperature variations in the record gives the impression that climate remained relatively unchanged throughout most of the last millennium, at least until human influences began to cause an abrupt increase in temperatures during the last century. Such characterization is a scientific outlier.

Interestingly, Mann et al replace the proxy data for the 1900s by the instrumental record and present it with no uncertainty characterization. This, too, yields the false impression that the instrumental record is consistent with the proxy data and that it is error-free. It is neither.

The instrumental record contains numerous uncertainties, resulting from measurement errors, a lack of coverage over the world's oceans, and underrepresentation of mountainous and polar regions, as well as undeveloped nations and the presence of urbanization effects resulting from the growth of cities. As I stated before, the proxy records only in part reflect temperature. Therefore, a simultaneous presentation of the proxy and instrumental record is the scientific equivalent to calling apples and oranges the same fruit.

Even if a modest uncertainty of plus or minus one-tenth of a degree Celsius were imposed on the instrumental record, the claim of the 1990s being the warmest decade would immediately become questionable, as the uncertainty window would overlap with the uncertainty associated with earlier time periods. Note, too, that if the satellite temperature record, where little warming has been observed over the last 20 years, had been inserted instead of the instrumental record, it would be impossible to argue that the 1990s are the warmest decade. Such a cavalier treatment of scientific data can create scientific outliers, such as the Mann et al curve.

So we are left to question why the Mann et all curve seems to be at variance with the previous historical characterization of climatic variability. Investigating more than several hundred studies that have developed proxy records, we came to the conclusion that nearly all of these records show considerable fluctuations in air temperature over the last millennium. Please

note that we did not reanalyze the proxy data. The original analysis from the various experts was left intact, as it formed a voluminous refereed scientific literature. Most records show the coldest period is commensurate with at least a portion of what is termed the Little Ice Age, and the warmest conditions at concomitant with at least a portion of what is termed the Medieval Warm Period.

Our conclusion is entirely consistent with conclusions reached by Drs. Bradley and Jones and not all locations on the globe experience cold or warm conditions. Moreover, we chose not to append the instrumental record, but to compare apples with apples and determine if the proxy records themselves indeed confirm the claim that the 1990s being the warmest decade of the last millennium. That claim is not borne out by the individual proxy records.

However, the IPCC report in the chapter with Dr. Mann as the lead author and his colleagues as contributing authors, also concludes that the research "support the idea that the 15th to 19th centuries were the coldest of the millennium over the northern hemisphere overall." Moreover, the IPCC report also concludes that the Mann and Jones research shows temperatures from the 11th to 14th centuries to be "warmer than those from the 15th to 19th centuries." This again is entirely consistent with our findings and in contravention of their own error assessment.

Where we differ with Dr. Mann and his colleagues is in the construction of the hemisphere average time series and their assertion that the 1990s was the warmest decade of the last millennium. Reasons why the Mann et al curve fails to retain the fidelity of the individual proxy records are detailed statistical issues into which I will not delve. But a real difference of opinion focuses solely on the Mann et all curve, and how it is an

outlier compared to the balance of evidence on millennial climate change. In a very real sense, this is a fundamental issue that scientists must address before the Mann et al curve can be taken as fact.

In closing, let me state that climate is simply more than annually averaged global air temperature. Too much focus, I believe, has been placed on defining air temperature time series and such emphasis obscures the true issue in understanding climate change and variability. If we are truly to understand climate and its impacts and driving forces, we must push beyond the tendency to distill climate to a single annual number. Proxy records which provide our only possible link to the past are incomplete at best. But when these voluminous records are carefully and individually examined, one reaches the inescapable conclusion that climate variability has been a natural occurrence and especially so over the last millennium.

Given the uncertainties and biases associated with the proxy and instrumental records. . .

Senator Inhofe. Dr. Legates, we are going to have to cut it off. You have exceeded your time and I am sure you will have an opportunity to finish your thoughts during the question and answer period.

Dr. Legates. Thank you for the privilege.

Senator Inhofe. We are going to, if it is all right, use five minutes and maybe try to get a few rounds here. Is that acceptable? These will be five minute rounds for questioning. I will start.

First of all, Senator Thomas joined us. Thank you for

coming, Senator Thomas.

I will address my first question to Dr. Legates. In my speech on the Senate floor yesterday, I noted your comments regarding -- can you find that chart of those comments? -- the comments regarding Dr. Mann's work as shown on the chart. I have a small copy of this. No, that is not it. It is this chart right here. Okay.

First of all, this is a comparison. As I mentioned in my opening statement, we sit up here as non-scientists so we try to look at these things and see what is logical, how we should weigh and compare diverse opinions. Now, the first thing I noticed was that Dr. Mann, yours I believe was in the area of the time frame of 1999, and Dr. Soon, you are 2003. So I think that the timing would mean something because I know that this is not a static target. This is a moving target.

Dr. Mann. Excuse me. That is incorrect.

Senator Inhofe. May I first ask Dr. Legates, do you stand by the statements that are made on this chart up here, on the contrasting methods that were used?

Dr. Legates. I have not had a chance to actually look at the chart before now.

Senator Inhofe. Is this the one that he had here? Okay, let's put that up. All right, then, this statement here, "Although Mann's work is now widely used as proof of anthropogenic global warming. We have become concerned that such analysis is in direct contradiction to most of the research and written histories available. My paper shows this contradiction and argues that the results of Mann are out of step with the

preponderance of the evidence."

I am not Tim Russert, but do you stand by these statements?

Dr. Legates. I do stand by them, sir.

Senator Inhofe. All right. I note that you are an expert in statistical techniques. In my speech on the Senate floor yesterday, I noted that even assuming all of the science used by the political left, come the end of 50 years hence, the Kyoto Protocol would have no measurable affect on temperature. Do you agree with that?

Dr. Legates. Yes, generally.

Senator Inhofe. And if the Kyoto Protocol forces harsher mandates, does it follow that the weaker legislative proposals that are out there right now before us in the Senate would have likewise no measurable effect?

Dr. Legates. That is likely true.

Senator Inhofe. All right. Let's see. Dr. Mann, since you have characterized your colleagues there in several different ways as nonsense, illegitimate, and inexperienced, let me ask you if you would use the same characterization of another person that I quoted on the floor yesterday. I would like to call your attention to the recent op/ed in the Washington Post by Dr. James Schlesinger, who was Energy Secretary under President Carter. In it, he wrote, "There is an idea among the public that the science is settled. That remains far from the truth." He has also acknowledged the Medieval Warming Period and the Little Ice Age. Do you question the scientific integrity of Dr. Schlesinger?

Dr. Mann. I do not think I have questioned scientific integrity. I have questioned scientific expertise in the case of Drs. Willie Soon and David Legates with regard to issues of paleoclimate. As far as Schlesinger is concerned, I am not familiar with any peer-reviewed work that he has submitted to the scientific literature, so I would not be able to evaluate his comments in a similar way. If I could clarify one...

Senator Inhofe. Okay. Well, you can't because there isn't time. I am going to stay within my time frame and I want to get to questions so others will have plenty of opportunity to respond to questions I am sure.

Dr. Soon, how many studies did you examine in total and how many were appropriate for the criteria you established?

Dr. Soon. Senator, the number is roughly in the order of, if you speak in terms of the peer-reviewed literature, I would say several hundred. And the number of people involved in these paleoclimatic research, of course, I have to emphasize I am not a paleoclimate scientist, but all of us are ruled by one simple basis, to understand the nature of how climate works. That would be physics. That would be climate physics.

The short answer is there is a huge number of literature that we consulted that feed the criteria. This is why we wrote it as a scientific paper.

Senator Inhofe. I was trying to get to the 240 proxies that were used and the number used.

Dr. Soon. Yes.

Senator Inhofe. Lastly, I would say, do you have more data

in your study than Dr. Mann did in his 1999 work? And is your data newer?

Dr. Soon. The large majority of that, yes. As I emphasized, most of it comes, let's say the most recent five years.

Senator Inhofe. Thank you, Dr. Soon.

Senator Jeffords?

Senator Jeffords. Dr. Mann, would you care to respond?

Dr. Mann. Yes, first of all I wanted to clarify a misstatement earlier on the part of Senator Inhofe. The results that I showed in my first graphic which demonstrate that it is a clear consensus of the climate research community that a number of different estimates, not just ours, but at least 12 different estimates of the history of the northern hemisphere average temperature for the past 1,000 years give essentially the same result, within the uncertainties. We published a paper just a month ago demonstrating that that is a robust result of a large number of mainstream researchers in the climate research community.

Phil Jones and I also have a paper in press in the Journal of Geophysical Research letters, which demonstrates those results further. So in fact, the latest word and the word of the mainstream climate research community is the one that I have given you earlier.

Now, as far as the issue of data, how much data were used, there are a number of misstatements that have been made about our study. One of them is with regard to how much data we used. We

used literally hundreds of proxy records. We often represented those proxy records, as statistical climatologists often do, in what we call a state space. We represented them in terms of a smaller number of variables to capture the leading patterns of variability in the data. But we used hundreds of proxy indicators, more in fact than Dr. Soon referred to. In fact, we actually analyzed climate proxy records. Dr. Soon did not.

Senator Jeffords. Dr. Soon, in a 2001 article in Capitalism magazine, you said that because of the pattern of frequent and rapid changes in climate throughout the holocene period, we should not view the warming of the last 100 years as a unique event or as an indication of manmade emissions' effect on the climate.

But according to NOAA's Web site "upon close examination of these warm periods," including all the ones that you cited in your past and most recent article, "it became apparent that these periods are not similar to the 20th century warming for two specific reasons. One, the periods of hypothesized past warming do not appear to be global in extent or, two, the period of warmth can be explained by known natural climate forcing conditions that are uniquely different than those of the past 100 years."

Why didn't either of your articles make an impact on the state of the science or NOAA's position?

Dr. Soon. Thank you for your question, Senator. As you may be aware, my paper just got published this year, January of 2003 and April of 2003, so it is all fairly recent. I have just written up this paper very recently, so I do not know what impact it will have on any general community, but I do know all my works are done under solicitation from all the major climatologists in

the field.

As to the comments in this Capitalism magazine, I am not aware of that particular magazine. I do not know whether I submitted anything to this journal or this magazine. I do stand by the statement that it is important to look at the local and regional change before one takes and averages globally because climate tends to vary in very large swings in different parts of the world. That really is the essence of climate change and one ought to be really looking very carefully at the local and regional change first, and also no strictly looking at only the temperature parameters as Dr. Mann has claimed to have done. That I think is very important to take into account.

Senator Jeffords. Dr. Mann, could you comment?

Dr. Mann. Yes. Both of those statements are completely incorrect. If Dr. Soon had actually read any of the papers that we have published over the past five years or so, he would be aware of the fact that we use statistical techniques to reconstruct global patterns of surface temperature. We average those spatial patterns to estimate a northern hemisphere mean temperature, just as scientists today seek to estimate the northern hemisphere average temperature from a global network of thermometer measurements. We use precisely the same approach based on proxy reconstructions of spatial patterns of surface temperature.

So what Dr. Soon has said is completely inaccurate. The first line on that contrasting methods table up there is also completely inaccurate.

In terms of variables other than temperature, my colleagues and I have published several papers reconstructing continental

drought over North America and reconstructed sea- level pressure patterns. We have looked at just about every variable that climatologists are interested in from the point of view of paleoclimate indicators. I think Dr. Soon needs to review my work more carefully.

Senator Inhofe. Thank you, Senator Jeffords.

Senator Allard?

Senator Allard. Thank you, Mr. Chairman.

In my mind, I do not think there is any question that the climate has shown a period of warming here. The question that I bring up and where I see the debate is, what is causing it and whether it is the changes that are happening and whether they are significant or not.

I also wonder what your thinking this world might look like 1,000 years from now, looking at the data that we have now. I wondered if maybe each one of you would just give me a brief response as to what you think of what we are seeing today may look like projected out over 1,000 years from now. I will start with Dr. Soon.

Dr. Soon. Okay. The factors causing climate change are extremely complicated. As I emphasized already, I am very much interested to learn how climate change on local and regional scale first before I can speak in terms of global climate. After all, local and regional climate are indeed the most relevant climatic factors that human activities are being influenced by or the reverse way.

As to the factors of climate change, I believe that it is

extremely difficult yet still to confirm the facts of being, let's say, even the late 20th century has anything to do with CO2. We do know that the CO2 is rising, but at the same time we know that climate operates on many other factors. It could be internally just be doing it all by itself because of ocean current movements. It could be done, for example, by variability imposed externally from the sun, variable outputs. Our sun is a variable star. That is a very well known fact.

These are the kinds of factors one has to look very comprehensively at. And additional important factors of human activity would include land use changes. Those are very well known factors that one has to keep a good record, time history, to really understand what are the causes of the change.

I don't think I should speculate anything about futures. It is always very dangerous.

Senator Allard. Dr. Mann?

Dr. Mann. Yes. Well, I certainly agree with your statement that one of the key issues is what we call the detection or the attribution of human influence on climate, not just how has climate changed over the past 100 years or past 1,000 years, but can we actually determine the causal agents of change.

There has been a solid decade of research into precisely that question by, again, the mainstream climate research community in addressing the issue of the relative role of natural factors, as well as anthropogenic factors. That includes the role of the sun, the role of human land use changes, and the role of human greenhouse gas increases. The model estimates are typically consistent with what we have seen of the observations earlier.

As far as the next 1,000 years, that is not a particular area of expertise of mine, but I am familiar with what the mainstream climate research community has to say about that. The latest model-based projections indicate a mean global temperature increase of anywhere between .6 and 2.2 degrees C. That is one degrees to four degree Fahrenheit relative to 1990 levels by the mid-21st century under most scenarios of future anthropogenic changes.

While these estimates are uncertain, even the lower value would take us well beyond any previous levels of warmth seen over at least the past couple of millennia. The magnitude of warmth, but perhaps more importantly the unprecedented rate of warming, is cause for concern.

Senator Allard. Dr. Legates?

Dr. Legates. Yes. I agree, too, that attribution is one of our important concerns. As a climatologist, I am very much interested in trying to figure out what drives climate. We know that a variety of factors exist. These include solar forcing functions; these include carbon dioxide in the atmosphere; these include biases associated with observational methods; these also include such things as land use changes. For example, if we change the albedo or reflected amount solar radiation, that too will change the surface temperature.

So it is really a difficult condition to try to balance all of these possible combinations and to try to take a very short instrumental record and discern to what extent that record is being driven by a variety of different combinations.

My conclusion probably in this case to directly answer your question is that the temperature likely would rise slightly,

again due to carbon dioxide, but it would be much more responsive to solar output. If the sun should quiet down, for example, I would expect we would go into a cooling period.

Senator Allard. I guess the question that I would have, now, you know you have increased CO2. So how is the environment in the Earth going to respond to increased CO2? Have any of you talked to a botanist or anything to give you some idea of what happens when CO2 increases in the atmosphere? Plants utilize CO2, extract oxygen. We inhale oxygen and extract CO2. Will plants be more prosperous with more CO2? How does that impact the plant life? Can that then come back on the cycle and some century later mean more O2 and less CO2?

So I am wondering if any of you have reviewed some of these cycles with botanists and see if they have any scientific data on how plants respond to CO2 when that is the sole factor. I am not sure I have ever seen a study. There is moisture and other things that affect plant growth, but just CO2 by itself. Have any of you seen any scientific studies in that regard?

Dr. Soon. I have seen of that. In fact, I have written also a small paper that has a small section regarding that.

Senator Allard. And what was their conclusion?

Dr. Soon. Their conclusion is that in general, of course, under enrichment of the CO2 in the free air, that yes, plant growth, for example being put up as a crop here, the crop yield will be 30 percent higher, for example. And all these examples are very well known and well verified in the field of botany.

Senator Allard. My time has run out. Would the other two agree with what he said?

Dr. Mann. Not quite.

Senator Allard. What is your modification?

Dr. Mann. In fact, a number of studies have been done, what are called "FACE" experiments. They are open canopy experiments in which CO2 is elevated in the forest and scientists examine the changes in the behavior of that forest. And what scientists at Duke University are finding is that while there is a tendency for an uptake of CO2 by the plants in the near term, what happens is eventually those plants will die. They will rot. And when that happens, this happens on generational time scales.

Senator Allard. Just CO2 being the variable and not moisture and anything else?

Dr. Mann. Just CO2. The CO2 will go back into the atmosphere because the plants that take it up...

Senator Allard. Do they have an explanation of why the rot occurred?

Dr. Mann. Well, just when things die, they will rot and they will give up their CO2 back to the atmosphere eventually.

Senator Allard. Well, that really does not get to the point I was trying to make. Doctor?

Dr. Legates. To follow on that, enhanced CO2 and dying plants would also provide the ability for more plants to therefore grow in its place. In particular, one of the people on our study, Dr. Sherwood Idso, has done a lot of this study with carbon dioxide and enhanced where you can control the amount of water and energy available to plants associated with lowered CO2

and higher CO2.

Senator Allard. So your conclusion is that CO2 increases plant growth?

Dr. Legates. Yes.

Senator Allard. Okay.

Thank you, Mr. Chairman.

Senator Inhofe. Thank you, Senator Allard.

Senator Carper, we were going to go by the early bird rule. Is it all right if Senator Thomas goes ahead of you here?

Senator Carper. Sure.

Senator Inhofe. Senator Thomas?

Senator Thomas. Thank you. I am a little confused about where we even ask the questions. Obviously, there is a difference of view. We are expected to make some policy decisions based on what we ought to be doing with regard to these kinds of things, but yet there does not seem to be a basis for that kind of a decision. Where would you suggest we get the information that is the best information we could get to make policy decisions for the future? Would each of you like to comment shortly on that?

Dr. Mann. Sure. I guess I would reiterate the comments that I made earlier, that in a National Academy of Sciences study that was commissioned by the Bush Administration in 2001, the National Academy of Sciences in essence stated their agreement

with the major scientific findings of the Intergovernmental Panel on Climate Change, the IPCC, which is the United Nations panel of scientists, thousands of scientists from around the world who put together a report on the state of our knowledge about all of these things -- climate change scenarios, our uncertainty about various attributes of the climate system. The conclusions that I stated earlier are the consensus conclusions of the IPCC.

Senator Thomas. That is where you would go.

Dr. Mann. That is where they have gone, yes.

Dr. Legates. I would generally argue the IPCC is a bit of a political document to the extent to which it does present some biased science. There is a lot of good science in there, but a lot of the conclusions are sort of not borne out by the facts. Having been president of the Climate Specialty Group of the Association of American Geographers, which is probably the largest group of climatologists available, I know from talking to rank-and-file members that they generally my impression is that most climatologists agree it takes a rather strong viewpoint.

So I have real serious concerns that it really represents a consensus, and in particular when, for example, in this discussion when we change dramatically what a lot of people have held true, that is the Little Ice Age, Medieval Warming and so forth, and replace it with a flat curve very quickly, I do not think we have given it enough time to really decide if in fact that is an appropriate change in paradigm.

Dr. Soon. Although I am not able to comment on anything on public policies, I am certainly able to testify that the science is completely unsettled. There are just so many things that we do not know about how the climate really works and what are the

factors that cause it to change, to really jump to the conclusion that it will all be CO2.

Senator Thomas. Thank you. That helps a lot.

[Laughter.]

Senator Inhofe. You still have some time remaining. Did you have an opportunity to see the chart up here that Dr. John Reilly, MIT Joint Program on Science Policy and Global Change? On the floor yesterday, I talked at some length on this. There seems to be a lot of consensus that there are some very positive benefits.

Senator Thomas. It is really interesting, you know, in Schlesinger's thing it indicates that the temperature after 1940 dropped until 1977. So that makes you wonder what we ought to do. The rise in temperature during the 20th century occurred between 1900 and 1940. And so now we are faced with making policy decisions where there is no real evidence that the things that the greenhouse gases measurable by the U.N. is the basis for doing these things.

I know in science everyone has a little different ideas, but I do think we are going to have to, Mr. Chairman, as you pointed out yesterday, either take it a little more slowly in terms of policy, or we are not going to have something more basic to base it on than we have now in order to make significant policy changes.

Thank you.

Senator Inhofe. Thank you, Senator Thomas.

Senator Carper?

Senator Carper. Thank you, Mr. Chairman. I want to welcome our witnesses this morning. Dr. Legates, it is great to have a fighting Blue Hen here from the University of Delaware. We are delighted that you are here. Dr. Mann, thanks for coming up, and Dr. Soon, welcome. We thank you for your time and your interest and your expertise on these issues, and your willingness to help us on some tough public policy issues that we face.

Dr. Mann, I would start off if I could and direct a question to you. I understand we have had thermometers for less than 200 years, and yet we are trying to evaluate changes in temperature today in this century and the last century with those that occurred 500 or 1,000 or 2,000 years ago. I understand that we use proxies for thermometers, if you will, and for those kinds of changes in temperature.

I wonder if you could help me and maybe the committee better understand how we compare today's temperature measurements to the proxies of the past. Are there potential risks with relying on some of those proxies?

Dr. Mann. Absolutely. We have to use them carefully when we try to reconstruct the past temperature history. So when I say we have to use them carefully, it means some of the things that I discussed in my testimony earlier, that we need to actually verify that if we are using a proxy record to reconstruct past temperature patterns, that proxy record is indeed reflective of temperature changes. That is something that typically paleoclimate scientists first check to make sure that the data they are using are appropriate for the task at hand. Of course, we have done that in our work. I did not see evidence that Soon and colleagues have done that.

First of all, we next have to synthesize the information. There have been some misleading statements made here earlier on the part of the other testifiers with regard to local versus regional or global climate changes. Of course, we have to assimilate the information from the locale scale to the larger scales, just as we do with any global estimate of quantity. So we take the regional information; we piece together what the regional patterns of change have been, which may amount to warming in certain areas and cooling in other areas. Only when we have reconstructed the true global or hemispheric regional patterns of change can we actually estimate the northern hemisphere average, for example.

A number of techniques have been developed in the climate research community for performing this kind of estimate. My colleagues and I have described various statistical approaches in the detailed climate literature. Some of the estimates are based on fairly sophisticated techniques. Some of them are based on fairly elementary techniques. Yet all of the results that have been published in the mainstream climate research community using different techniques and different assortments of proxy data have given, as I showed earlier in my graph, the same basic result within the uncertainties. That has not changed. An article that appeared last month in the American Geophysical Union, which is actually the largest professional association of climatologists, showed that indeed that is the consensus viewpoint of the climate research community.

Senator Carper. Thank you.

Dr. Legates, if I could ask a question of you, please. Have you or anyone of your colleagues at the University of Delaware to your knowledge studied the historical climate and temperature records in our part of the country, in Delaware, the Delmarva

Peninsula, or the mid-Atlantic region?

Dr. Legates. We do not have anybody on staff presently that does paleoclimatology. One of the basic understandings that you must come up with when you study climate is that you must understand various things of hydroclimatology, physic climatology, and that includes paleoclimate study. So you must be at least versed in these things if you are not necessarily a paleoclimatologist.

We do have Dr. Brian Hanson at the University of Delaware who has looked at glacier movements over long time periods, as well as Dr. Fritz Nelson who has looked at changes associated with permafrost locations.

Senator Carper. If someone were to do a study for our part of the country, what do you think they might find?

Dr. Legates. A study regarding?

Senator Carper. Historical climate and temperature changes.

Dr. Legates. Over the East Coast of the United States? Most of the assessments indicated that generally the East Coast has gone through a variety of changes over long time periods. Historically, we have had a condition where in the 1960s, for example, we had conditions where there was much more snowfall. We have had a lot of variability associated with air temperature rising and falling over the local conditions. Variability is usually the characteristic of climate over the near-term as well.

Senator Carper. Okay. Dr. Soon, if I could ask you and maybe Dr. Legates the same question, the following question. That question is, do you believe that it is possible to emit

unlimited amounts of CO2 into our atmosphere without having any impact on climate or temperature?

Dr. Soon. That one, I do not know how to answer precisely, the question, I mean, fill up every single molecule of the air with CO2. That would be poisonous, of course. I do not know the answer to the question, but I do like to add about the evidence available on climate change.

Senator Carper. Before you do that, let me direct, if I could, the same question to Dr. Legates. I do appreciate your candor. It is not everyday that we find that here in this hall.

Dr. Legates. Generally, what we have found is that as carbon dioxide has increased, the temperature has followed, where in some cases historically the temperature has gone up and the carbon dioxide has fallen. So generally from a purely physical point of view, if you do increase the carbon dioxide, you should wind up with some trapping of gases, and hence wind up with a slightly increased temperature.

The question is, there is a lot of additional feedbacks associated with it. For example, warmer surface temperature leads to more instability or rising air which leads to more cloudiness. Clouds can warm at night, but also reflect energy in the daylight. So you have these odd playbacks into the climate system which make it very difficult to say that if I hold everything else constant and change one variable, what will happen. Well, in reality, it is impossible to hold everything constant because it is a very intricate and interwoven system that one change does have feedbacks across the entire spectrum.

Senator Carper. Thanks. I think my time has expired, Mr. Chairman. Is that correct?

Senator Inhofe. Yes. Thank you, Senator Carper.

Senator Carper. Thank you.

Senator Inhofe. We will have another round here. In fact, I will start off with another round. Let's start with Dr. Legates. Dr. Legates, was the temperature warmer 4,000 to 7,000 years ago than it is today?

Dr. Legates. My understand was during about 4,000 to 7,000 years ago, in a period referred to as the climatic optimum, which sort of led to enhanced agriculture and led to development of civilization, generally the idea is that warmer temperatures lead to more enhanced human activity; colder temperatures tend to inhibit. Again, as we get back 4,000 to 7,000 years ago, it becomes, the error bars are getting wide as well. But the general consensus is that temperatures were a bit warmer during that time period.

Senator Inhofe. Okay. Senator Thomas had something about, he had alluded to 1940. Yesterday when I was giving my talk and going the research for that, it was my understanding that the amount of CO2 emitted since the 1940s increased by about 80 percent. And yet that precipitated a period of time from about 1940 to 1975 of a cooling-off period. Is that correct?

Dr. Legates. That is correct. It is sort of a perplexing issue in the time series record that from 1940 to 1970 approximately, while carbon dioxide was in fact increasing, global temperatures appear to be decreasing.

Senator Inhofe. Dr. Mann, you have I might say impugned the integrity of your colleagues and a few other people during your presentation today. The Wharton Econometric Forecasting

Associates did a study as to the effect of regulating CO2 and what would happen. American consumers would face higher food, medical and housing costs; for food, an increase of 11 percent; medicine, an increase of 14 percent; and housing, an increase of 7 percent. At the same time, the average household of four would see its real income drop by $2,700 in 2010.

Under Kyoto, the energy and electricity prices would nearly double and gasoline prices would go up an additional 65 cents a gallon. I guess I would ask at this point, what is your opinion of the Wharton study?

Dr. Mann. Okay. First, I would respectfully take issue with your statement that I have impugned the integrity of the other two testifiers here. I have questioned their, and I think rightfully, their qualifications to state the conclusions that they have stated. And I provided some evidence of that.

Senator Inhofe. Well, illegitimate, inexperienced, nonsense -- that is a matter of interpretation.

Dr. Mann. Those are words that I used. Correct.

Senator Inhofe. Go ahead.

Dr. Mann. I would furthermore point out that the very models that I have referred to track the actual instrumental warming and the slight cooling in the northern hemisphere. There was no cooling of the globe from 1940 to 1970, the northern hemisphere...

Senator Inhofe. Okay. The question I am asking you is about WEFA.

Dr. Mann. I am not a specialist in public policy and I do not believe it would be useful for me to testify on that.

Senator Inhofe. Dr. Legates, have you looked at the report that Wharton came out with concerning the possible effects, economic results of this?

Dr. Legates. Again, I am not a public policy expert either, and so the economic impacts are not something which I would be qualified to testify on.

Senator Inhofe. Okay, Dr. Legates, do you think you have more data than Dr. Mann?

Dr. Legates. I think we have looked at a large variety of time series. We have looked at essentially a large body of literature that existed both prior to Dr. Mann's analysis and since Dr. Mann's analysis, in attempting to figure out why his curve does not reflect the individual observations. It is one issue associated with when you put together data sets, to make sure that the composite sort of resembles the individual components.

Senator Inhofe. Okay. The timeline, Dr. Mann, is something I have been concerned with, and those of us up here are listening to you and listening to all three of you and trying to analyze perhaps some of the data that you use and the conclusions you came to, having been four or five years back, compared to a study that was done referring to Smithsonian-Harvard, the 1,000-year study that was just completed, or at least given to us in March of this year. I would like to have each of you look at the chart up here and just give us a response as to what you feel in terms of the data that both sides are using today.

Dr. Mann. I guess you referred to me first?

Senator Inhofe. That is fine. Yes.

Dr. Mann. Okay. Well, I think we have pretty much demonstrated that just about everything there is incorrect. In a peer-reviewed publication that was again published in the Journal Eos of the American Geophysical Union about a month ago, that article was cosigned by 12 of the leading U.S. and British climatologists and paleoclimatologists. We are already on record as pretty much pointing out that there is very little that is valid in any of the statements in that table. So I think I will just leave it at that.

Senator Inhofe. Do the other two of you agree with that?

Dr. Legates. If I may add, the Eos piece was actually not a refereed article. It is an Eos Forum piece, which by definition is an opinion piece by scientists for publication in Eos. That is what is contained on the AGU Web site for Eos Forum.

Senator Inhofe. All right. Let me ask one last question here. Dr. James Hansen of NASA, considered the father of global warming theory, said that the Kyoto Protocol "will have little affect on global temperatures in the 21st century." In a rather stunning follow up, Hansen said it would take 30 Kyotos, let me repeat that, 30 Kyotos to reduce warming to an acceptable level. If one Kyoto devastates the American economy, very much by the findings of Wharton, what would 30 Kyotos do? Is Dr. Hansen one of the most respected scientists in your field or is he way off base?

Dr. Mann. Dr. Hansen is certainly one of the most respected scientists in my field and I personally have great scientific

respect for him. I think that his conclusions have been grossly taken out of context. His point is simply that Kyoto would, and this is his point, these are not my opinions, would do very little to ameliorate the warming over the next century for two reasons.

One, there is something that scientists call the commitment to warming. Once we put CO2 into the atmosphere, it takes many decades, on orders of decades to maybe centuries for it fully to equilibrate with the ocean and the atmosphere. So some of that CO2 is taken up by the ocean. So the effect of it is delayed. So cutting back on CO2 now may not affect global temperatures for 50 years, but 50 years later it is going to come back to roost.

Senator Inhofe. All right, that was a rather long answer, so let me just, with the indulgence of my fellow senators here, I just want to ask one last question. I quoted Dr. Frederick Seitz, the past president of the National Academy of Sciences yesterday, and professor emeritus at Rockefeller University, who compiled an Oregon petition which says there is no convincing scientific evidence that human release of carbon dioxide, methane and other greenhouse gases is causing, or will in the foreseeable future cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate.

Moreover, there is substantial scientific evidence that increases in atmospheric carbon dioxide produce many beneficial effects upon the natural plant and animal environments of the Earth. Do each of the three of you agree or disagree with his statement?

Dr. Soon. I agree.

Dr. Mann. I find little in there to agree with.

Dr. Legates. I would tend to agree.

Senator Inhofe. All right. Senator Jeffords?

Senator Jeffords. As you may know, this is to all of you, the editor-in-chief of the magazine Climate Research resigned the position yesterday over problems with Dr. Soon's paper. In an e-mail sent to my staff, he said "My view, which is shared by many, but not all editors and review editors of Climate Research, is that the review of the Soon et al paper failed to detect significant methodological flaws in the paper. The critique published in the Eos journal by Mann et al is valid. The paper should not have been published in this forum, not because of the eventual conclusion, but because of the insufficient evidence to draw this conclusion."

What methodological flaws does the mean? Dr. Mann?

Dr. Mann. Well, I have tried to outline the most severe of those methodological flaws. I believe it is the mainstream view of just about every scientist in my field that I have talked to that there is little that is valid in that paper. They got just about everything wrong. They did not select the proxies properly. They did not actually analyze any data. They did not produce a reconstruction. They did not produce uncertainties in a reconstruction. They did not compare to the proper baseline of the late-20th century in trying to make conclusions about modern warmth.

So I think it is the collective view of our entire research community that that is one of the most flawed papers that has appeared in the putative peer-reviewed research in recent years.

Senator Jeffords. Dr. Soon, do any scientists besides your

coauthors support using wetness or dryness as indicators of past temperatures, instead of actual temperatures or proxy data that reflects temperatures?

Dr. Soon. As we explain clearly in our paper, of course, it is also highly mischaracterized by my fellow colleague here, Dr. Mann, we certainly when we speak in term of the Medieval Warm Period, certainly temperature is one of the important parameters. As we emphasize endlessly and specify in every single word that I have said, it is that climate is not temperature alone. One has to look in terms of the water cycle, in terms of even the air cycles, in terms of the vegetation changes. These are the kind of details that we did not make any presumptions, but simply want to look at the patterns of change geographically all over the world, and see how complete the datas are, and then begin to start to see how do we assemble all such information.

Senator Jeffords. This is for the whole panel. I would like to know whether the unusual melting of Greenland ice sheets shown in this picture over the years 2001, 2002 and 2003, has been matched in the long-term climate history any other time? And according to NASA, by the end of the year 2002 season, the total area of surface melt in the Greenland ice sheet had broken all known records. By the end of that summer "Sea ice levels in the Arctic were the lowest in decades and possibly the lowest in several centuries."

NASA says this warming is happening faster and earlier than in previous periods. What is happening now and what is going to happen if this continues? Dr. Mann?

Dr. Mann. Well, this is, of course, one particular region, one potentially isolated region, Greenland, in which there is evidence of mass oblation of ice. But if we look at what is

going on the world over, mountain glaciers in the tropics throughout the world, glaciers in both the northern hemisphere and the southern hemisphere, what is seen is that glacial retreat during the late 20th century is unprecedented on similar time scales to the time scales I have spoken of before, the past 1,000 to 2,000 years.

I believe Professor Lonnie Thompson of Ohio State University has testified in this Senate before with regard to the dramatic evidence of worldwide glacier retreat. So that is a cause for concern. It is a harbinger of the warming because in fact the warming that is shown in those glacier retreats is actually warming that we are already committed to for decades to come.

Dr. Legates. Historically, it has been demonstrated in the refereed literature that much of this glacial retreat actually began in the late 1800s, before much of the carbon dioxide came into the atmosphere. This is very much consistent with the demise of the Little Ice Age and longer time-scale variations. Therefore, it is very difficult to say that these kind of events are directly attributable to human impacts on the climate, when they in fact pre-date human impacts on the climate.

Senator Jeffords. Dr. Soon?

Dr. Soon. My only comment regarding that kind of chart or the claim that it has never happened before is simply that just think about the available observation that we have of such details. We do not really have any satellite record longer than 20 to 30 years, so the statement that it has never happened before I think is dangerously inaccurate.

Senator Jeffords. Dr. Mann?

Dr. Mann. Yes. It is unfortunate to hear comments about the supposed inconsistencies of the satellite record voiced here, years after that has been pretty much been debunked in the peer-reviewed literature, in Nature and Science. Both journals have in recent years published several rigorously peer-reviewed articles indicating that in fact the original statement that the satellite record showed cooling was flawed because the original author, John Christy, did not take into account a drift in the orbit of that satellite, which actually leads to a bias in the temperatures from the satellite.

Christy and colleagues have claimed to have gone back and fixed that problem, but just about every scientist who has looked at it says that their fix is not correct. And if you fix it correctly, then the satellite record actually agrees with the surface record, indicating fairly dramatic rates of warming in the past two decades.

Senator Jeffords. I have one last question, Dr. Mann. What are the implications of your peer-reviewed work for future manmade warming?

Dr. Mann. As I said before, there have been a number of modeling simulations that have shown a fairly good match to our reconstruction and that of several independent research groups who have also produced these reconstructions of northern hemisphere temperature. So to the extent that the models match that record of the past 1,000 years when they are forced with various estimates of natural changes in the system, it gives us reason to trust what the models way about the future. As I testified before, the models tell us that we are likely to see a one degree to four degree Fahrenheit warming by the mid-20th century, given most predicted scenarios of continued anthropogenic influence on the climate.

Dr. Legates. If I may add something, one of the things I have heard is that science has been debunked and, for example, we pointed to Dr. Christy's curve up here and said that because one paper has been written, that curve is now called into question. We have talked about, you mentioned von Storch's resignation from Climate Research because apparently he has admitted that this paper never should have been published.

I want to point out that science debate goes on and on. In particular, Dr. Christy has had some very important contributions to indicate that his curve is not incorrect. That is part of scientific debate. Furthermore, I will say with respect to Climate Research, Otto Kinne, who is director of Inter-Research, the parent organization of Climate Research, asked Chris de Freitas who was the editor who served on the Soon and Baliunus papers, and I can relay this because I am a review editor of Climate Research so I am familiar with what has been taking place.

There were several people complaining that Chris de Freitas should be removed simply because he published the Soon and Baliunus paper. That question was brought to Otto Kinne. He asked for Chris de Freitas to provide him with the reviews, the changed manuscripts and so forth. He provided a letter in late June to all of us in which he said, I have reviewed the evidence and I have indicated that the reviews, four for each manuscript, in fact there was a second or an earlier Soon and Baliunus article on another topic that was also called into question by these people leveling charges.

Essentially what he concluded was that the reviewers provided good and appropriate comments; that Doctors Soon and Baliunus provided an appropriate dressing or incorporation of these concerns; and that Chris de Freitas had in fact provided

analysis appropriately.

Towards that end, Dr. von Storch was approached. Climate Research was putting in an editorial stating essentially this article should never have been published. Otto Kinne was informed and he has asked him not to submit that because it is not founded, and as a result Dr. von Storch, I now understand, has said he would resign.

Senator Jeffords. Dr. Mann?

Dr. Mann. Yes, just a very short comment. It is unprecedented in my career as a scientist to hear of a publisher of a journal going in and telling the editor-in- chief that he cannot publish an editorial. I find that shocking and a bit distressing. I do not know what the circumstances are behind it, but it is disturbing.

Dr. Legates. It is also unprecedented to find an editor being attacked, and this has also happened with the editorial staff of Energy and Environment, which is the other paper, to find an editor attacked for simply publishing an article that has been peer-reviewed and approved by reviewers.

Senator Inhofe. All right. The time has expired. We are four minutes over.

Senator Jeffords. I think that my witness should have the last word on my question, if I could. Dr. Mann, do you have any response to that?

Dr. Mann. Actually, my understanding is that Chris de Freitas, the individual in question, frequently publishes op/ed pieces in newspapers in New Zealand attacking IPCC and attacking

Kyoto and attacking the work of mainstream climatologists in this area. So this is a fairly unusual editor that we are talking about.

Senator Inhofe. All right, thank you.

Senator Clinton has joined us. Senator Clinton would you like to have your round now?

Senator Clinton. Thank you very much, Mr. Chairman. I thank you for this hearing. I understand that the questioning and the testimony has been somewhat lively, if not controversial and contested. The bottom line for me is whether we are doing what we need to do to ensure the best possible climatology outcome for future generations. I would stipulate that the Earth's climate has changed through the millennia. There is no doubt about that. I have read enough to know that we have had ice ages and we have had floods and we have had volcanoes. We have had lots of naturally occurring events which have affected our climate. We have El Nino and his spouse, El Nina. We have all of that. That is not debatable.

The issue is whether the introduction and acceleration of anthropogenic activity primarily related to the burning of fossil fuels is putting into place conditions that will make it difficult, if not impossible for the Earth to regain its balance, that will support the conditions of life that we have inherited and are blessed with.

I know these debates have political implications because heaven forbid that we would tell somebody in the private sector not to do something, or that we might have to make sacrifices in the quality of our life for a future generations. I think that it is not useful to carry out this kind of argumentation when it

is clear that by the very nature of human development and industrialization, we have changed what is in the atmosphere, what is in the earth, what is in the waters.

That does not mean there was no change before we came along, and certainly in the last century that change has accelerated because the quality of life has improved, we have created chemicals that were never known in nature before. We have done a lot of things.

But I think that our goal should be to try to figure out how to do no harm or do the least amount of harm, and to ask ourselves, what are we willing to perhaps sacrifice to make sure that we are not contributing to irreversible changes. I know that academia is probably the most political environment in America. I was once on a staff of a law school. It was more difficult than any politics I had ever been involved in beforehand. I know that people have very strong opinions and hold on to them.

From my perspective, I just want to believe that I am making a contribution to ensuring that the quality of life for future generations is not demonstrably diminished. I would feel terrible if I participated, either as a willing actor or a bystander, in this potential undermining of our Earth's sustainability.

So Dr. Mann let me ask you, what was the Earth's climate like the last time that there was atmospheric concentration of carbon dioxide at today's levels of 370 parts per million?

Dr. Mann. Thank you, Senator, that is an excellent question. We have to go back fairly far into the past to find CO2 levels approaching the CO2 levels today. Ice core studies

that have been done over the past decade or so have told us that today's CO2 level is unprecedented now in at least four glacial or inter-glacial cycles. That is more than 400,000 years.

In fact, now as we look back from other evidence that is a bit more tentative, it appears that modern CO2 levels probably have not been observed in 10 million to 20 million years. So we have to go back to the time of dinosaurs probably to find CO2 levels that we know were significantly higher than CO2 levels today.

Some people will say, well look that was a great time. The dinosaurs were roaming near the poles. It was warm near the north pole. There were palm trees in the poles. Isn't that what we want? Well, that was a change that occurred on time-scales of tens of millions of years. What we are observing right now is a similar change that is occurring on time-scales of decades.

Senator Clinton. Thank you. Thank you, Dr. Mann.

Senator Inhofe. Senator Clinton, if you would like to have some more time, since we are on the second round now, feel free to take another couple of minutes.

Senator Clinton. Thank you very much, Mr. Chairman.

I guess that is, for me, the dilemma, because I certainly understand the testimony of the other two witnesses, and I read with great interest former Secretary Schlesinger's op/ed. I know that there are those, who are in a minority, let's at least admit that, who are in a minority, but who certainly have a very strongly held set of beliefs, and I respect that.

But I do believe that the compression of time in which these

changes are occurring is extraordinarily significant. We can go back and look at the Earth's natural 125,000-year cycle, but I do not think we want to risk the enormous changes that could occur. I do not think we have a million or 10 million years or even 100,000 to experiment.

I think that the challenge confronting us is not to put our heads in the sand and let the academic argument take place, but figure out how in a sensible, prudent manner we could ameliorate these changes significantly enough so that if Dr. Soon and Dr. Legates are right, no harm done. If Dr. Mann is right, we will have saved ourselves a lot of potential damage and difficulty.

So I hope that we could put our heads together. I commend my two colleagues, both Senator Jeffords and Senator Carper, who have very sensible legislative answers to trying to get a handle on this. As I have said in this committee before, I stand ready to figure out ways to hold harmless our industrial base and others. I think it is a significant enough political, economic and moral challenge that if there are ways to make it financially possible for companies to do what needs to be done with respect to carbon dioxide and other atmospheric pollutants that have accelerated their presence in our atmosphere so dramatically in the last 100 years, I think we should do that.

This is not just a private sector problem. We all have benefitted from the increasing use of fossil fuels, for example. Our standard of living is dramatically better. One of our problems is what is going to happen if China and India get a standard of living anywhere comparable to ours, and then begin to really -- and I see Dr. Soon nodding -- I mean really dump into the atmosphere untold amounts of new pollutants of whatever kind, leading certainly with carbon dioxide.

So this is a problem we need to get ahead of, and it is not a problem that the United States alone should be responsible for. It is not a problem that the private sector alone should be responsible for. But I believe, just as a prior generation of decisionmakers really put a lot of work into the law of the oceans and trying to figure out how we could protect our oceans, we need to do the same on the atmospheric level. There has got to be a way that we can come together on this big challenge.

So Mr. Chairman, I appreciate your continuing attention to this. I, for one, stand ready to work with you and our other colleagues because I just think this is too risky a proposition not to act on, given the weight of opinion, even with the dissenters, who I think do rightly point out the incredible natural cycle, but we are now so influencing that natural cycle, I do not know if we have the time to contemplate the balance once again regaining itself in our wonderfully regenerating Earth.

Senator Inhofe. Thank you, Senator Clinton.

Senator Carper?

Senator Carper. Thanks, Mr. Chairman. I just want to follow up. Senator Clinton was kind in her comments on the legislation, the one that Senator Jeffords has introduced and secondly on legislation I have introduced along with Senators Judd Gregg, Lincoln Chafee and Lamar Alexander.

Our any of you familiar with that legislation? Would you like to become familiar over the next five minutes?

[Laughter.]

Dr. Soon. No, we will stick to science. Politics is too

complicated.

Senator Carper. All right. That may be the best approach.

We are trying to figure out if there is a reasonable middle ground on this issue. I am part of a group that Buddy MacKay, a former colleague of mine from Florida, calls the flaming moderates or flaming centrists. We can spend a whole lot of time discussing the impact of Kyoto caps, or we can focus on what steps we actually need to take.

The approach that Senators Gregg and Chafee and Alexander and myself have taken, at least with respect to four pollutants, we say unlike the President's proposal where he only addresses sulfur dioxide and nitrogen oxide and mercury, and does not address CO2, as you know, because he thinks we need to study it a bit more. Our approach says that there ought to be caps on CO2; that they should be phased in; that we should use a cap and trade system; we should give utilities the opportunity to buy credit for levels of CO2 emissions that they maintain at high levels; and they should be able to contract with, among others, farmers and those who would be forced out of lands to change their planning patterns or change their animal feedlot operations in order to be able to sequester some of the CO2 that occurs in our planet.

We have something called new source review. The President would eliminate it entirely. I think in Senator Jeffords' approach, it is pretty much left alone. There is a good argument that says that utilities under current law, if they make some kind of minor adjustment and minor investment in their plant, that they have to make a huge investment with respect to the environmental controls. As a result, it keeps them from making even common sense kinds of investments in their plants -- sort of

the laws of unintended consequences. That is sort of the approach that we have taken.

Now that you know all about it, if you were in our shoes, what kind of an approach would you take? Let me just start with our University of Delaware colleague here, Dr. Legates.

Dr. Legates. Generally, I favor no regrets policies, where they have other applications as well. But again, getting into the politics and the non-science aspects of what to do is out of my area of expertise. I may have my own beliefs, but they are no more important or less important than the average person. I would rather not testify to those here.

Senator Carper. If you were convinced, and some of my colleagues have heard me talk about Dr. Thompson before, I don't know that they testified before this committee, but Doctors Knoll and Thompson spend their lives going around the world and they chart the disappearance of snow caps in some of the tallest mountains. I first met them here in Delaware about five or six years ago to receive an award for their research.

But they tell us that the snow caps around some of the tallest mountains in the world, the Himalayas and others, are not just disappearing, they will be gone, and they will be gone in our lifetime. When I heard them speak and talk about their work and what they were charting and finding, it got my attention. When you hear that, Dr. Legates and Dr. Soon, how does it affect you?

Dr. Soon. As a scientist, I am still questioning actually the evidence. The fact is that there are maybe some recorded, the things that we know about is that there are about 160,000 glaciers somewhere around the Earth, and there is only four

percent of it in which we have the actual data to try to see how much the ice has accumulated, how much ice has been oblated or gone away.

Some of the specific examples like Kilimanjaro that Dr. Lonnie Thompson has done or looked at, or some places in Peru, those are really in a sense that we do not have enough really strong evidence to really suggest that, and plus that these things have gone and it is unprecedented and disappeared completely. Climate change is part of nature. Climate, as I tried to emphasize in my research, looking carefully into all the climate proxies, is that there are large local swings in the changes.

Senator Carper. Dr. Soon, what would it take to convince you that this is a problem we need to deal with?

Dr. Soon. As to glaciers disappearing in some parts of the mountains, I do not consider that to be either a problem or...

Senator Carper. No, no, the big issue. What would it take with respect to the concerns about global warming fed by CO2 accumulation, what would it take to convince you that this is a problem we need to do something about?

Dr. Soon. Oh, okay, okay. Scientifically, I would go by this very simple test. The simple test should be that the warming should be occurring first at the troposphere, the layer of air about four kilometers above us. That is a very key effect that one should expect the CO2 greenhouse effect to work its way downward towards the surface. I would urge, of course, very, very serious so that we do not lose sight in all these debates about science, we must sustain a certain kind of level of observational effort to keep track so that while we are arguing

around what to do, that one has some records, evidence. We will continue to stay, but need to have very good records.

So what it would take is that the CO2 warming should happen at the layer of air four kilometers first. I would require it be strongly sustained for may 20 years or so, I would really believe, well, that is clear CO2 fingerprints somewhere.

Senator Carper. Mr. Chairman, I know my time has expired. Could I just ask that same question of Dr. Legates? What would it take to convince you?

Dr. Legates. Proof. Generally the problem we have seen in the record is that there is an awful lot of variability and there are things where changes occur, for example, between 1940 and 1970 where the temperature decreased, even though carbon dioxide was increasing. That sort of indicates to me that carbon dioxide may not be the biggest player in the game. Solar variability is likely to be the bigger player, changes in solar output. After all, if the sun goes out, our temperature drops considerably. We know historically that as the sun fluctuates in terms of its output, the climate does respond.

So there are a lot of other factors involved and I am not entirely convinced, based upon the proof, that carbon dioxide is a driving force. It is a contributory force in a small case, but not driving enough, because we wind up making policies potentially that can lead us to try to keep back the ocean, if you will. You cannot stop the waves from coming in.

Senator Carper. Dr. Mann?

Dr. Mann. Two quick points. First of all, it grates on me to hear this argument about cooling from 1940 to 1970 continually

cited her as evidence against anthropogenic climate change. That cooling was almost certainly anthropogenic and there has been a decade of research demonstrating that, anthropogenic sulphate aerosols, which have cooling effect on the climate. What is happening now is that the much greater effect of increasing greenhouse gas concentrations is overtaking that small cooling effect of sulphate aerosols, also an anthropogenic influence, but not the one that is going to take us to doubled levels of CO2 in the next century.

One quick other comment, if I could. Lonnie Thompson's work, which is some of the best work in our field, it is not like he has been looking for ice cores that are melting. He is actually looking for ice cores that are not melting because he wants to get long records. So if there is any belief that there might be some bias in the glaciers that he has gone to, if anything it is the opposite. He is looking for long records, so that makes it that much more impressive that they are all melting.

Senator Carper. Thank you.

Senator Inhofe. Senator Allard?

Senator Allard. Thank you, Mr. Chairman.

What agency do you think we probably have the most expertise in as far as climatology change and what is happening with global climate? Would that be the agency on the National Oceanographic and Atmospheric Science, would that probably be where we would have most of our experts? If not, which agency do you think we would have most of our experts as far as the government is concerned? To any member of the panel, I would like to know whether any of you concur or not.

Dr. Mann. Well, I think that the different agencies specialize in different areas of the climate change research question, if you will. NOAA's specialty is in looking at climate variability, particularly with regard to oceanic variability. So they emphasize that area of the research. A lot of the peer research, for example Lonnie Thompson's work that we just spoke of, is funded by the National Science Foundation in large part. There are other organizations.

Senator Allard. The Foundation, is that an agency of the Federal Government?

Dr. Mann. Well, not directly.

Senator Allard. The question is, what is an agency of the Federal Government? The only one that I could think of was NOAA, but are there other agencies?

Dr. Legates. NASA does a lot of research, satellite-related efforts trying to estimate climate trends, incorporating satellite measurements as well.

Dr. Mann. As well as the Department of Energy and EPA.

Senator Allard. Yes, the Department of Energy.

Dr. Legates. The Department of Interior as well.

Senator Allard. Okay. But we do not have any, say, each agency would have their own area of interest, but it seems to me that we need to look at global warming from a total perspective and I am trying to figure out if there is an agency that does that. I have talked to people within NOAA. There are arguments going on within that agency on the very topic that we are talking

about here. There is absolutely no consensus within the agency, and I am trying to figure out if there is an agency out here that is taking on an overall view. I guess really there is not. We are just going to have to rely on the science community somehow or the other pulling all these views out from these various agencies. They look at the atmosphere, like you say, NASA looks at the stratosphere and higher up where your satellites are.

Dr. Legates. On the surface, too.

Senator Allard. We need somebody that looks at the effect on plant life, animal life, the total cycle; oxygen, CO2 and all that before you reach conclusions. I am just wondering who pulls all this together so that we can come up with a total picture of what is happening as far as changes to this Earth is concerned, because it is more than just one science.

Dr. Mann?

Dr. Mann. There is a program, the U.S. Global Change Research Program, which seeks to coordinate the various agencies on issues of fundamental importance in the research of climate variability and climate change. So I think that is their role.

Senator Allard. Okay. I want to get back a little bit to the absorption of sunlight, for example, on the Earth's surface. It seems to me, and I don't know how accurate this is. I want to check this out because it has been suggested to me by a number of people, that our absorptive surface on the Earth has increased. We still have the same amount of surface, but for example you have pavement in urban areas. We know that pavement is absorptive. Has that had an impact on global warming?

Dr. Mann. Most definitely.

Senator Allard. In your view?

Dr. Mann. Yes, your statement is correct. The main increase in the absorption by the Earth's surface is due to the melting of snow and ice. That has certainly had a very large influence on the warming, but it is part of the warming.

Senator Allard. So you do not think the construction of, we have more pavement than we did two centuries ago or a century ago.

Dr. Mann. Most models suggest that that is a cooling.

Senator Allard. Is there enough of that that we have more fields probably because of agriculture throughout the world, just not the United States. This is all over the world.

Dr. Mann. Yes. Most estimates suggest that there is a small cooling of the Earth's surface due to those changes.

Senator Allard. Would you all agree to that?

Dr. Legates. The pavements are associated with the urbanization effect, which is part of the problem associated with where we have observational measurements. Generally where you have a decrease in the light and heat exchange that is evaporation of water taking place because we have removed trees; the fact that you have darker surfaces; you have canyon-like effects. All of these lead to warmer temperatures in the city. The urban heat ion effect is well-documented and that is where virtually all of our observations are located.

But there are also changes in land surface effects by the fact that we are removing vegetation and replacing it with

grasslands, for example, deforestation, de-vegetation. A lot of these are on very large-scales too, and they do change the color and character of the Earth's surface and hence the absorptive characteristic.

A lot of the cryosphere, a lot of the ice and snow is temporally variable. We have a growing area and decreasing area, so that does integrate itself out over time to some extent.

Senator Allard. Does the absorptive surface of the Earth's surface have an impact on whether we have a warmer temperature or not today?

Dr. Legates. Yes, absolutely.

Dr. Soon. Oh certainly, yes.

Senator Allard. I am a little bit confused of what the final view is. Do we increase temperature or do we cool the temperature?

Dr. Mann. Can I comment?

Senator Allard. Yes. You said that it cooled.

Dr. Mann. Yes, the effects that...

Senator Allard. Okay, now, I would like to hear from...

Dr. Mann. ... that is not the whole story. What he said is correct, but the effect that is dominant in models in about three or four different studies published in the past two years on precisely this question is actually the change in absorption by the land surface due to deforestation and other agricultural

changes. That leads to an overall cooling of the globe, even in the face of other possible effects of warming.

Senator Allard. Would you agree with that?

Dr. Legates. Not necessarily. In particular, you are changing a characteristic, but you are also changing the other interactions. You are changing the vegetation and you are changing the evaporative characteristics.

Senator Allard. But your bottom line is that you think that, with increased absorptive rate on the Earth's surface, it has a cooling or a warming effect?

Dr. Legates. If you increase the absorption rate on the Earth's surface, you will have to have a net warming effect.

Dr. Soon. You have to have a warming.

Senator Allard. You have a warming.

I mean, to me this is a fairly fundamental concept, and here we are, we have disagreement at this table about that.

Dr. Soon. I don't think Dr. Mann is listening to your question.

Senator Allard. To me, from my practical experience, it seems to me that there is a warming effect. When I walk out on a pavement with my bare feet, they get burnt. If I walk on grass, my feet feel a lot cooler. I just look at it from a practical aspect. So Dr. Mann, would you explain to me why there is a difference in what you say and what I am feeling physically when I walk on the surface of the Earth?

Dr. Mann. Sure. When you are talking, you are only covering a pretty small fraction of the surface area of the Earth. And the effect that you are talking about, for example, the urban heat island effect of blacktop and its tendency to absorb heat, that is overwhelmed by larger-scale changes that we do not necessarily see because they are not where we are walking around. Large areas of the surface area of the Earth are being changed in terms of their vegetation characteristics. That has a net cooling. The answer on that is clear in the peer-reviewed research.

Senator Allard. The reason I bring this up is that in the State of Colorado we have a lot of variation. We go from 3,000 to over 14,000 feet and we have a lot of different ecological systems in Colorado, depending on altitude and moisture and everything.

We have a weather reporting station in a rural area, in the plains of Colorado, and the data that I am getting from them that there is no indication of change as far as temperature is concerned. Yet as we move into the more urban areas, then we get weather stations that are indicating a higher temperature. So I am wondering worldwide, with the urbanization of the world, is there a possibility that we could be dealing with some temperature changes that are a result of the absorptive surface on the Earth like urbanization, you mentioned urbanization, we have a lot more than we used to have. Doesn't this have an impact on temperature?

Dr. Legates. Yes, definitely. Essentially, I do not think Dr. Mann answered the question appropriately in that your basic question was, if we absorb more radiation at the surface, will the temperature not go up? And that is correct. The temperature will go up. In a sense, that is physics.

Senator Allard. Would you agree with that, Dr. Mann?

Dr. Mann. No. He has gotten about three different things wrong here.

Senator Allard. No, listen.

Dr. Mann. His first statement is wrong.

Senator Allard. I understand your statement. You are taking a broader atmospheric picture. You are taking a total picture. But the statement he made at this point, would you agree with that?

Dr. Mann. No. It is not correct.

Senator Allard. You would not agree?

Dr. Mann. The statement that he made was that there is an urban heat bias in the estimate of the surface temperature changes of the Earth.

Senator Allard. I did not hear him say that.

Dr. Mann. He said that earlier when he talked about urban heat bias.

Senator Allard. I am talking about the comment that he just made. Would you repeat the comment, Dr. Legates?

Dr. Legates. I essentially said the basic physics is that if you make the Earth's surface darker, you will absorb more energy, you will reflect less energy, as a result the surface temperature should increase.

Senator Allard. Would you agree with that scientific fact?

Dr. Mann. That statement would be in the first chapter of most textbooks. Yes.

Senator Allard. Dr. Soon, I did not mean to ignore you. You wanted to say something?

Dr. Soon. I tried to just emphasize that that is all you are asking.

Senator Allard. Yes.

Dr. Soon. If you increase absorptivity of the surfaces by changing it through any means, then you increase, more heat will retain.

Senator Allard. I think part of the problem that we are running into here on the testimony is that we are not talking on the same terms. I think that we have to be very careful when we review the record and when we are listening to the witnesses here, Mr. Chairman, that we understand that we are all talking on the same terms in making the same point. I think the committee gets confused when we start talking from different terms and different perspectives.

I am just trying to simplify this argument down. I guess what I am coming to is that, as I have stated earlier, it is easy for me to believe that there is a trend in warming. The bottom line is what is causing it and what is going to be the long-term effects with this.

To me, the science is not entirely clear on that, and I do not see that that is being entirely clear on this panel because

when I asked that question earlier, nobody gave me a specific on what they saw the effects were going to be. Maybe Dr. Mann did, and said that there was going to be warming. But most scientists when I talk to them just won't give me what they think the Earth is going to look like 1,000 years from now, or they will not necessarily step right out and say what are the causes of it because there are an awful lot of variables. I am not sure that scientists understand all those variables.

Dr. Legates. I think that is the issue. It is so uncertain and there are so many things that go into the mix, that to say fairly definitively it will be such in the future is very difficult to say.

Dr. Soon. We have to keep emphasizing that CO2 is not the only player, the only factor. It is just highly short- sighted to just look at CO2 as just one sole cause of change for every other change that we see or variations that we see.

Senator Allard. Yes. And when we talk about greenhouse gases, I think there is a tendency for us to think just in terms of CO2.

Dr. Soon. Right.

Senator Allard. But isn't water vapor? Water vapor is a big part of greenhouse gases.

Dr. Soon. That would be the area of expertise by Professor David Legates. He studied that for almost 20 years.

Senator Allard. I do not know as we understand all of the aspects of each one of those fractionated, if we were to pull out each CO2 or put out water vapor. What other gases do we have out

there? Those are the main ones.

Dr. Mann. The other two have commented. May I comment as well?

Senator Allard. Let me finish my point. What are the greenhouse gases that we have?

Dr. Mann. I will speak to that.

Dr. Soon. Methane.

Senator Allard. Oh, methane. Okay. We have methane. But the main ones are water vapor and CO2. Water vapor being the largest, right?

Dr. Soon. Yes.

Dr. Mann. Can I comment on that?

Senator Allard. Dr. Mann?

Dr. Mann. Yes. There are trace gases like methane, carbon dioxide, chlorofluorocarbons, which we can actually control.

Senator Allard. Well, carbon dioxide is a very small part of greenhouse gases? Is that what you are saying?

Dr. Mann. No. There are several different greenhouse gases that we have to keep in mind, and it would be short- sighted to only talk about carbon dioxide. That is absolutely true.

Senator Allard. Right.

Dr. Mann. It is extremely misleading, however, when scientists cite the role of water vapor as a greenhouse gas. The concentration of water vapor in the atmosphere cannot be controlled by us directly, unlike the other trace gases. It is fixed by the surface temperature of the Earth itself. This is actually another chapter one textbook-type of result that we know to be true in the scientific community.

So we cannot change that freely. We can only change the other trace gases. When we do change those, we warm the Earth. We evaporate more water vapor and that gives us what we call a positive feedback that actually exaggerates the problem. But the water vapor itself cannot be the source of the problem.

Dr. Soon. It is really also scientifically inaccurate to say that we can really control CO2. The global climate cycles, we do not understand it well enough to really match other CO2 that we emitted. How much of it is really going into the ocean? How much of it has really gone into the forest? We do not have actually a full control of those parameters, as Dr. Mann would like to state on the record.

Senator Allard. Dr. Legates, do you have any comment?

Dr. Legates. Generally, the idea is that water vapor is the most important greenhouse gas. Period. That is, yes, chapter one of any introductory text. The issue is, then, if we are associating with the effects of carbon dioxide and methane, which by the way has actually started to decrease in time, what we have found out is that in particular we are
playing with small potatoes, where the big issues are sort of not controllable.

Again, the sun is the biggest game in town and it is not

controllable. At least I do not know that we can turn off the sun or control its output.

Senator Allard. Okay. Senator Carper I think has a few questions.

Senator Inhofe. We have a serious problem here now, I am sorry to say, and that is that we are 30 minutes past our first panel and we are going to have to cut it off right now.

Senator Allard. Okay, Mr. Chairman.

Senator Inhofe. I am very, very sorry. Thank you very much. I appreciate the fact that you are here.

We would call our next panel up. I apologize to the next panel because of the length of the first panel, we will have to cut this one short.

Dr. Leonard Levin is the program manager, Electric Power Research Institute; Dr. Gary Myers, professor of neurology and pediatrics, University of Rochester Medical Center; and Dr. Deborah Rice, the toxicologist, Maine Department of Environmental Protection, Bureau of Remediation and Waste Management.

I would like to ask each of you to confine your opening comments to five minutes, if you would. Your entire statement will be made a part of the record. We would start, Dr. Levin, with you.

STATEMENT OF LEONARD LEVIN, PROGRAM MANAGER, ELECTRIC POWER RESEARCH INSTITUTE

Dr. Levin. Thank you, Mr. Chairman, members of the

committee.

I am Dr. Leonard Levin. I have come to discuss recent findings on mercury in the human environment. I serve as technical leader at EPRI, which is a nonprofit collaborative research organization. My remarks today represent my synthesis of research findings and are not an official statement of EPRI position.

It is a privilege to provide the committee this testimony on the science of mercury. I would like to address three key questions: sources of mercury; its deposition from the atmosphere to the Earth's surface; its potential accumulation in fish.

Where does mercury in the U.S. environment originate? Mercury is clearly a global issue. Recent estimates are that 2,340 tons of industry-related mercury are emitted globally. Over half of these originated from Asian sources. Of the global total, the United States is estimated to emit roughly 166 tons in total; U.S. utilities about 46 tons. In addition, it is estimated that another 1,300 tons of mercury emanates from land-based natural sources around the globe, and another 1,100 or so tons comes from the world's oceans.

Recent findings from the joint U.S. and Canadian METAALICUS field experiment show that a fairly small amount of deposited mercury, no more than 20 percent or so, readmits to the atmosphere, even over a two-year period. The implications are that mercury may be less mobile in the environment than we previously thought.

Studies by EPRI have shown that much of the mercury depositing in the U.S. may originate on other continents. Model

results show that for three-quarters of the continental United States land area, more than 60 percent of the mercury received comes from outside the country. Only eight percent of U.S. territory receives two-thirds or more of its mercury from U.S. sources.

To check this with data, aircraft measurements were carried out by EPRI and the National Center for Atmospheric Research in Boulder, Colorado. Mercury and winds from the Shanghai, China region were tracked over the Pacific for 400 miles towards the U.S. A second set of flights from Monterey, California found that same plume from China crossing the California coast and entering U.S. territory. One implication is that there may be a management floor for U.S. mercury, a level below which the amount of mercury depositing to the surface cannot be reduced by domestic action alone.

Secondly, what are the primary sources of mercury in fish in the environment? Global mercury emissions appear to have peaked in the 1980s and declined or held steady since then. Professor Francois Morel or Princeton University, and colleagues, recently analyzed specific tuna for mercury, comparing recent catches with those from the 1970s. Despite changes in mercury emissions over those 30 years, mercury levels in tuna did not change between the samples. One conclusion they reached is that the mercury in such marine fish is not coming from emission sources on land, but from natural submarine sources of mercury. Again, this implies there may be a management floor for mercury in marine fish, which make up most of the U.S. fish diet.

Third, how can potential mercury reductions change mercury deposition? EPRI recently completed work to assess what might ensue in the atmosphere and in U.S. fish if further mercury emission reductions are carried out in the U.S. The approach

linked models of atmospheric mercury chemistry and physics with Federal data on mercury in fish in the U.S. diet, along with a model of costs that would be needed to attain a given reduction level. There are currently about 179 tons of mercury depositing each year in the U.S. from all sources, global and domestic. Current U.S. utility emissions of mercury are about 46 tons per year.

EPRI examined one proposed management scenario that cut these utility emissions from 46 tons to 25 tons per year. The analysis showed that this emissions cut of 47 percent resulted in an average 3 percent decline in mercury deposition in the U.S. Some isolated locations making up less than one one- hundredth of the U.S. land area experienced drops of up to 30 percent. The economic model showed that costs to attain these lower levels would be between $2 billion and $5 billion per year for 12 years. This demonstrated U.S. mercury patterns may be relatively insensitive to the effects of this single category of sources.

In addition, most of the fish consumed in the U.S. are ocean fish which would be only slightly impacted by a reduction of 24 tons of mercury per year solely in the U.S., out of 2,300 tons globally. Wild freshwater fish within the U.S. might show a greater reduction in mercury content, but they make up a very small part of the U.S. diet, compared to ocean or farm-raised fish.

These deposition changes were translated into how much less mercury might enter the U.S. diet via these three categories of fish. We found that less than one-tenth of one percent fewer children would be born at-risk due to their mother's taking in mercury at lower levels from fish consumed in the diet.

So to summarize, a drop of nearly half in utility mercury

emissions resulted in an average drop of three percent in mercury depositing to the ground, and a drop of less than one- tenth of a percent in the number of children at risk. These recent findings are a small part of the massive international research effort to understand mercury and its impacts. EPRI and others, including U.S. EPA and the Department of Energy, are jointly racing to clarify the complex interactions of mercury with natural systems, an important part of its cycling, and its impacts on human health. With improved understanding, informed decisions can be made on the best ways to manage mercury.

Thank you for this opportunity to deliver these comments to the committee.

Senator Inhofe. Thank you, Dr. Levin.

Dr. Rice?

STATEMENT OF DEBORAH C. RICE, TOXICOLOGIST, BUREAU OF REMEDIATION AND WASTE MANAGEMENT, MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION

Dr. Rice. I would like to thank the committee for this opportunity to present information on the adverse health consequences of exposure to methyl-mercury in the United States.

I am a neurotoxicologist who has worked on the neurotoxicity of methyl-mercury for over two decades and have published over 100 papers on the neurotoxicity of environmental chemicals. Until three months ago, I was the senior toxicologist at the Environmental Protection Agency. I am a coauthor of the document that reviewed the scientific evidence on the health effects of methyl-mercury for EPA. This document included the derivation of the acceptable daily intake level for methyl-mercury.

I would like to focus on four points. One, there is unequivocal evidence that methyl-mercury harms the developing human brain. Two, EPA used analyses of three large studies in its derivation of an acceptable daily intake, including the studies in the Seychelles Islands which found no adverse effects. Three, eight percent of women of childbearing age have levels of methyl-mercury in their bodies above this acceptable level, and studies have documented cardiovascular disease in men at low levels of methyl-mercury, suggesting that an additional potentially large segment of the population is at risk.

Studies performed around the world have documented harmful effects of environmental methyl-mercury exposure on children's mental development. Three major studies were analyzed by the National Research Council panel in their expert review: In the Faroe Islands in the North Atlantic, and the Seychelles Islands in the Indian Ocean, and in New Zealand. Two of these major studies, as well as six smaller studies, identified impairment associated with methyl-mercury exposure. The Seychelles Island study is anomalous in finding no effects. Adverse effects include decreased IQ and deficits in memory, language processing, attention and fine motor coordination.

The NRC modeled the relationship between the amount of methyl-mercury in the mother's body and the performance of the child, and calculated the level associated with the doubling of the number of children that would perform in the abnormally low range. The NRC panel did this for each study separately and for all of the three studies combined, including the negative Seychelles study.

EPA used the NRC analyses in deriving its acceptable daily intake level of methyl-mercury. EPA performed the relevant calculations based on each of the two positive studies, as well

as the integrative analysis of all three studies. The acceptable level is the same whether it is based on the integrative analysis of all three studies, or on the Faroe Islands study alone.

The acceptable level would be lower if only the New Zealand study were considered. Only if the negative Seychelles study alone were used, while ignoring the values calculated for the Faroe Islands and New Zealand studies, would the acceptable intake level be higher than the current value. EPA believed that to do so would be scientifically unsound and would provide insufficient protection to Americans.

Data from a survey representing the U.S. population collected over the last two years revealed that about eight percent of women of childbearing age had blood concentration of methyl-mercury above the level that EPA believes is safe. This translates into over 300,000 newborns at risk for adverse effects on intelligence and memory, ability to pay attention, language skills and other abilities that are required to be successful in our highly technological society.

There is an additional concern regarding the potential for harm as a result of environmental methyl-mercury exposure. Three studies found a relationship between increased methyl-mercury levels and atherosclerosis, heart attacks and death, and it is unknown whether there is a level of mercury that will not produce harm. It is important to understand that the cardiovascular effects associated with methyl-mercury may put an additional very large portion of the population at risk.

In summary, there are four points that I would like the committee to keep in mind. First, at least eight studies based on populations around the globe found an association between methyl-mercury levels and impaired neuropsychological function in

children. The Seychelles Islands study is anomalous in finding no effects. Second, both the NRC and the EPA included the Seychelles Islands study in their analysis. The only way that the acceptable intake of methyl-mercury could be higher would be to ignore the two major positive studies, as well as six smaller studies and rely solely on the one study that showed no effects.

Third, there is a substantial percentage of women of reproductive age in the United States with levels of methyl-mercury in their bodies above what EPA considers safe. As a result, over 300,000 newborns each year are exposed to potentially harmful levels of methyl-mercury. Fourth, increased exposure to methyl-mercury may result in cardiovascular disease and even death in men from heart attack, suggesting an additional large segment of the population is at risk.

Additional information has been provided to the committee. Thank you for your time and attention.

Senator Inhofe. Thank you, Dr. Rice.

Dr. Myers?

STATEMENT OF GARY MYERS, PROFESSOR OF NEUROLOGY AND PEDIATRICS, DEPARTMENT OF NEUROLOGY, UNIVERSITY OF ROCHESTER MEDICAL CENTER

Dr. Myers. Thank you for the opportunity to present the views of our research group on the health effects of methyl-mercury exposure. My name is Gary Myers. I am a pediatric neurologist and a professor at the University of Rochester in New York, and just one member of a large international team that has been studying the human health effects of methyl-mercury for nearly 30 years. For 20 of those years, our group has specifically studied the effects of prenatal methyl-mercury

exposure.

In 1971 and 1972, there was an epidemic of methyl-mercury poisoning in Iraq. The source of exposure, unlike in Japan, was maternal consumption of sea grain coated with a methyl-mercury fungicide. We looked at a number of children in that study and measured the exposure of the fetus using the maternal hair as the biomarker. It is the only biomarker that has been correlated with brain levels. We concluded that there was a possibility that exposure as low as 10 parts per million in maternal hair might be associated with adverse effects on the fetus. This value is over 10 times the average in the U.S. and five times the average in Japan, but individuals consuming large quantities of fish can easily achieve this level.

The hypothesis of our study in the Seychelles was that methyl-mercury from fish consumption might affect child development. In fact, we all thought it would. Since millions of people around the world consume fish as their primary source of protein, we thought it was only reasonable to investigate the question directly. We selected the Seychelles because of two reasons. First, they eat large amounts of fish. The average mother eats 10 times as much as women here in the U.S.

Second, the fish in Seychelles has an average mercury content of about 0.3 parts per million, which is approximately the same as commercial fish here in the U.S. The Seychelles study is a collaborative study which was begun under the auspices of the WHO and has been carried out by a U.S.-led team of international researchers from the University of Rochester, Cornell University and the Ministries of Health and Education in Seychelles. The funding has come from the National Institutes of Environmental Health Sciences, with some minor funding from the Food and Drug Administration and the governments of Seychelles

and Sweden.

The Seychelles was chosen for a number of reasons, primarily because there was no overt mercury pollution and many of the factors that complicate epidemiological studies of low-level exposures were simply not present. There was universal free and readily available health care in Seychelles. Prenatal care is nearly 100 percent. The birthrate is high and the general health of the mothers and children is very good. In addition, education is free, universal, and it starts at age three-and-a-half.

Before starting the study, we carefully controlled for a number of things. To minimize the possibility of bias, a number of decisions were made. First, no one in Seychelles, including any of the researchers who visit the island, would know the level of exposure of any child or mother unless our results indicated that children were indeed at risk. Second, because of the known problems with developmental delay in certain disorders, those children would be excluded from the study. Third, the tests administered would include all of the tests that have been used in other studies, plus other things that we thought might detect subtle changes.

Fourth, we would do this testing at specific age windows. Fifth, we would adjust for multiple confounding factors, things that are actually known to affect child development such as socioeconomic status, the mother's intelligence, and birth weight. And sixth, we established a data analysis plan before the data were collected to minimize the possibility that the data would just be repeatedly analyzed until the anticipated effect was in fact determined.

We have now carried out five evaluations of the children over nine years. The study has focused on prenatal exposure.

The exposure of both mothers and children has been in the range of concern, from 1 to 27 parts per million. We have done extensive testing with over 57 primary endpoints determined so far. The study has found three statistical associations with prenatal methyl-mercury exposure. One was adverse; one was beneficial; and one was indeterminate. These results might be expected to occur by chance and do not support the hypothesis that adverse developmental effects result from prenatal methyl-mercury exposure in the range commonly achieved by consuming large amounts of fish.

The findings from our research have been published in the world's leading medical journals, including the Journal of the American Medical Association, the Lancet, and a soon-to-be-published review in the New England Journal of Medicine. We do not believe that there is presently good scientific evidence that moderate fish consumption is harmful to the fetus. In the words of Dr. Lyketsos, a distinguished researcher from Johns Hopkins, who wrote the editorial with our Lancet articles "On balance, the evidence suggests that methyl-mercury exposure from fish consumption during pregnancy of the levels seen in most parts of the world does not have measurable cognitive or behavioral effects in later childhood. However, fish is an important source of protein in many countries and large numbers of mothers around the world rely on fish for proper nutrition. Good maternal nutrition is essential to the baby's health."

Thank you.

Senator Inhofe. Thank you, Dr. Myers.

We are going to try to adhere to a five-minute round of questioning. Let me just share with you, which I think you already know, you folks are looking at the medical effects of

mercury. We also up here have to consider the economic effects, the problems that are out there. Right now on the Senate floor, they are debating the energy bill. We have an energy crisis in this country, and if cofire should go out, and that could happen from either CO2 or mercury, it would be a very serious crisis. I think anticipating that this will happen, several people have moved off-shore, moved to other places. So that is something that is really I guess you would say our major, at least one of my major concerns.

Now, just for all of the witnesses, you stated that the United States utility mercury emissions are 46 tons a year. Tell us what happens to this mercury. Help us visualize where does it come from; where does it go; how much is deposited in the United States; how does this compare with the amount that is deposited in the United States from global sources.

Would you like to start, Dr. Rice?

Dr. Rice. That is really not my area of expertise, so I cannot speak to it.

Senator Inhofe. All right. Dr. Myers?

Dr. Myers. It is not my area of expertise.

Senator Inhofe. Come on, Dr. Levin?

Dr. Levin. All right.

[Laughter.]

Dr. Levin. Utility mercury of the various sources of mercury is probably the best-studied category, partially because

there are more individual sources than there are of many of the other categories. We believe that roughly half on average coming out from utilities is made up of the divalent form of mercury, which is about a million times or so more soluble in water than the elemental form, which is the silvery liquid that you probably remember from high school chemistry. So of this mercury emitting from all utilities in the U.S., roughly half of it is more highly water soluble and the other half will tend to go into regional and global circulation.

We calculate that about 70 percent or so of the mercury emitted from utilities leaves the U.S., and the other 30 percent or so deposits within the U.S. across the country. These are somewhat similar to the numbers that EPA is deriving as well. Some of this mercury that deposits to the surface will wind up in receiving waters, and a very small fraction of it, probably less than one percent, will eventually be turned into the organic form by bacterial action. It is that organic form that has the potential to reach humans through accumulation in some fish.

Again this does not happen in all waterways and with all fish species. It tends to happen in waterways that have full food webs that go to high-level fish that grow quite large, and it is larger, older fish that tend to accumulate more mercury.

Of the exposure in the community in the U.S., almost all of it is through intake from fish and the mercury in those fish, although the levels taken in can vary from very little or almost none, to amounts of concern. There is almost no exposure by inhalation. That is a very small part of the exposure.

So our concern is to follow this mercury from its sources through to where it winds up in fish and eventually may be consumed by humans. That is the trick, scientifically.

Senator Inhofe. Thank you, Dr. Levin.

Dr. Rice, the American Heart Association and the World Health Organization recommend that fish should be a part of everyone's diet, concluding that the benefits of eating fish outweigh the risks of adverse effects, which as you state in your testimony are potential risks. Since eating fish offers substantial health benefits, shouldn't the EPA's referenced dose be revised to take this into account, or does it?

Dr. Rice. Well, I agree totally, and I have to say that I am no longer with EPA so I am not speaking as a representative of the agency. I need to make that clear. So some of these opinions will be those of the agency when I left, and some will be mine.

But the scientific community at large and the EPA and me personally recognize that fish is a good source of protein. It also confers cardio-protective effects. There are also omega-three fatty acids in fish that are essential when the fetus is building its brain. There is new evidence that eating fish also may be beneficial to the mental development or the mental function of the elderly. I suspect that it is probably important for all of us.

So the dichotomy is not eat fish/don't eat fish. The important thing to be able to do is to come out with some recommendations to the community that allow people to eat fish, but not to eat fish that has increased levels of methyl-mercury. So EPA thinks that, I was part of that EPA panel, so when I was part of that EPA panel we firmly believe that the RFD should not be any higher, and in the light of some evidence that we were not able to analyze at the time, might even should be lower than it is presently.

So it is not a question of increasing the reference dose. It is a question of making sure that the American public can eat fish that does not have undue levels of methyl-mercury in them.

Senator Inhofe. Thank you very much.

Dr. Myers, in selecting the Seychelles as a location for your research, what other locations did you consider other than the Seychelles Islands?

Dr. Myers. We started studies on the coast of South America and looked also at the Maldive Islands as another possibility.

Senator Inhofe. Yes. I kind of wanted to get to the Faroe Islands. Did you consider them for your research?

Dr. Myers. We did not consider the Faroes in our research.

Senator Inhofe. It is my understanding that, and for those of us who are not scientists here, that some of the problems, let's take the Faroe Islands and see if I have this right, that there is a inordinate amount of whale meat that is consumed there and there are PCBs in there. I do not know whether you can distinguish between the harm of one or the other, but is this a factor that should be considered?

It is my understanding, and I won't say this right, but there are different levels of mercury that are found. One is from the primary fish, and the other is from whales that eat other fish, so it has a multiplying effect. Is this taken into consideration?

Dr. Rice. The Faroe Islands study and the Seychelles Islands together have been reviewed by at least two very

distinguished peer-review panels. That issue, the issue of the pattern of intake of methyl-mercury and potential co- exposure for PCBs has been discussed extensively by the scientific community.

The Faroe Islands' population does eat whale meat. They may eat a large whale dinner occasionally. They also tend to dry the whale meat, and so they snack on it in addition to eating a so-called bolus dose, what we call a bolus dose. So they have a low level of methyl-mercury intake which may be occasionally punctuated with a higher intake level. The source of methyl-mercury does not matter, whether it is through fish or through whale. So the fact that it is whale meat per se is not really relevant.

None of the panels, including the National Research Council panel, could come to any kind of conclusion about the importance of the pattern of intake, because the data just are not available. There just are not scientific data that speak directly to that. But what the Faroe Islands investigators have done because this was raised as a concern and because they have hair, and they had hair from their population that was stored, they were able to go back and do segmental analysis, so that you cut the hair up into tiny little pieces and look at mercury levels across the length of the hair.

What they did was they eliminated the mothers that had the most variable hair levels that might suggest that there was this bolus exposure these particular women and these particular fetuses. What they found was that the effect was actually stronger when they eliminated these women, which makes a certain amount of sense because you are decreasing variability when you do that.

Senator Inhofe. Thank you, Dr. Rice.

Senator Jeffords?

Senator Jeffords. Thank you all for your testimony on this very important and timely topic.

Some of you have seen this morning's New York Times full-page article on mercury and its health effects. This helps to set a context for our discussion.

Dr. Rice, what exactly is a reference dose level and what does it mean in terms of the so-called safe levels of fish consumption? And does EPA reference dose level include a built-in ten-fold safety threshold?

Dr. Rice. The reference dose is designed to be a daily intake level that a person could consume over the course of their lifetime without deleterious effects. So it is designed to be the amount of mercury you could eat every day in your life and not harm yourself.

Now, when EPA did its calculation, it is important to understand that when the National Academy of Sciences modeled a number of endpoints for each of the studies, and those were the Faroe Islands study, the New Zealand Study, both of which found effects, as well as the Seychelles study which did not, they identified not a no-effect level. They identified a very specific effect level. That effect level is associated with a doubling of the number of children that would perform in the abnormal range, in other words, the lowest five percent of the population. So this is in no way a no-effect level.

To that, the EPA applied a ten-fold so-called uncertainty

factor. The point of that was to take into account things that we did not know, data that we did not have, as well as the pharmacodynamic and the pharmacokinetic variability. Now, there were actually data that was again modeled by the NAS and reviewed by the NAS, that says that the pharmacokinetic variability, in other words the woman's ability to get rid of methyl-mercury from her body, differs by a factor of three. So that already takes up half of the uncertainty factor.

But in addition to that, it is important to understand that when the Faroe Islands folks analyzed their data, they eliminated mothers with mercury levels above 10 ppm in their hair, which was really right about at the effect level that the NAS identified. The effects were just about as strong even below 10 ppms. So again, that is very strong evidence that there is not a factor of 10 safety.

In addition to that, when the NAS modeled their data, it turned out that both of the New Zealand study and the Faroe Islands study not only was there no evidence that there was a threshold, in other words a level below which there were no effects, but in fact the curve was actually steeper at the lower levels. The NAS used a straight line when they modeled the data because they were uncomfortable about using curves that were steeper at the lower end than they were at the higher end, but subsequent to that there have been studies come out with regard to lead exposure, for example. There are now several studies where that has also been found for lead exposure.

So this may in fact be a very real effect. So not only is there not a safety factor of 10. There might be virtually no safety factor at all.

In addition to that, something that EPA recognized at the

time, but we were not able to quantitate because we did not have the data, but it has now been quantitated, we assumed that the relationship between the mother's blood level of methyl-mercury and the fetus' blood level of methyl-mercury were the same, because of course we have the body burden; we have cord blood in the fetus, we have to get back to intake by the mother. We know now that in fact the ratio is more like 1.7, and for some mothers it is as much as over 3.

So if we were to recalculate the reference dose jus based on this new information, it would decrease from 0.1 to 0.06.

Senator Jeffords. Dr. Rice and Dr. Myers, would you recommend that members of Congress and regulatory agencies base their decisions on whether and how much to reduce human- made mercury emissions on the findings from any one study?

Dr. Myers. Our group has been involved in the science of studying whether you could find effects at low levels, and we have not been involved in policy. There is a general scientific principle, I think it is important to look at multiple different studies. However, these studies are complicated and one has to look at what kind of studies you are dealing with. Some are simply descriptive. They take a group of people and describe something. It is a basic epidemiological principle that you cannot assign causation from a descriptive study.

So one has to look at the studies that are larger and follow children over time, and control for a lot of confounding factors which complicate these type of studies very much actually. The Seychelles study in fact is not a negative study, as has been stated. We did in fact find associations with things that are known to affect child development, such as socioeconomic status, maternal intelligence, the home environment and other things.

What we did not find was an adverse association with prenatal methyl-mercury exposure in the Seychelles.

Senator Jeffords. Dr. Rice?

Dr. Rice. I agree with Dr. Myers. These studies are very complex. I think that that is even more reason not to rely on one study while eliminating other studies for consideration.

Again, these studies have been peer-reviewed numerous times. The Seychelles Islands study and the Faroe Islands study have been reviewed now by several panels. They are both thought to be very high quality, very well-designed and well- executed studies.

The NAS, as well as the previous panel, talked at great length about what might account for the differences between these studies. We really do not know what accounts for the differences between these studies. The NAS modeled three studies. The New Zealand study was also a positive study.

The National Academy of Sciences and the EPA agreed with them that it was not scientifically justifiable for protection of the health of the American public to rely on the negative study and exclude the two positive studies. I said at least a couple of times in my testimony that what the NAS did to try to address that was to do an integrative analysis that included all three studies, including the Seychelles Islands study, and modeled it statistically.

When EPA then took those analyses and derived, what we did was we derived a series of reference doses, kind of sample reference doses, that were based on a number of endpoints from both the New Zealand study and the Faroe study, as well as the integrative analysis of all three studies. The integrative

analysis of all three studies also yields a reference dose of 0.1. So that made me personally very comfortable that we were doing the right thing scientifically in our derivation of the reference dose.

Senator Inhofe. These are supposed to be five-minute rounds and it has been eight minutes, so we will recognize Senator Allard.

Senator Allard. Dr. Rice and Dr. Myers, you have in your comments talked about methyl-mercury as being the toxic compound as far as human health is concerned. Are there other mercurial compounds that are toxic to humans?

Dr. Rice. Yes. All forms of mercury are toxic to humans.

Senator Allard. Including the elemental form?

Dr. Rice. Yes.

Senator Allard. Okay.

Dr. Rice. But in terms of environmental exposure, it is really the methyl-mercury form that we are worried about because that is the form that gets into the food train and is concentrated and accumulated up the food train. That is what people actually end up being exposed to.

Senator Allard. Okay. Thank for clarifying that. I appreciate that. So this gets into the environment and consequently in the fish or food chain or whatever. Is the starting point always bacteria operating on the elemental form of mercury? Or is it these various compounds that bacteria operate on and then end up being assimilated into the food chain? How

does that happen?

Dr. Rice. In most circumstances, it is the inorganic form, not the elemental mercury, but the inorganic form that is available to be taken up by various microorganisms.

Senator Allard. How do we get to that organic form, the methyl-mercury? How do we get there?

Dr. Rice. The microorganisms actually put a methyl group on as part of their metabolic processes.

Senator Allard. Do they get that from elementary mercury? Is that the origin, or is it various compounds of mercury?

Dr. Rice. Yes, it is just straight mercury. Now, in the Japanese outbreak, it was actually methyl-mercury that was put into the water, but that is a relatively unusual situation.

Senator Allard. I see. Okay, so my understanding, Dr. Levin, is that a lot of the mercury that is introduced into the environment of this country does not originate within the borders of this country. Is that correct? The suggestion is that a lot of the sources of mercury that come across that we may pick up in the soil is actually carried over by wind and what not from the Asian countries. Is that correct?

Dr. Levin. That is correct, Senator, as far as the modeling shows, and that is consistent with work that EPRI has done, EPA and others have also done in the modeling.

Senator Allard. And is this the elemental mercury that is being brought over?

Dr. Levin. It is elemental, or the elemental form. It is also the inorganic form or the form that can be combined into salts.

Senator Allard. Now, the inorganic form is not processed into the food chain? Did I understand that correctly?

Dr. Levin. It is the inorganic form that is processed into the food chain.

Senator Allard. Yes, it is the organic form.

Dr. Levin. The two forms that are emitted from combustion sources are the elemental form, the chemicals found on the periodic chart.

Senator Allard. Right.

Dr. Levin. And the inorganic form, which combines with, for example, chlorine, to form the pure chloride, or is the form also found in minerals. Those two forms that wind up in the proper aquatic environments, it is the inorganic form that may be methylated and turned into the organic form.

Senator Allard. Right.

Dr. Levin. But it has to go from elemental to inorganic before the methylation can occur.

Senator Allard. But my question is, is that the type of mercury that is being brought in from Asia, what form of mercury is that?

Dr. Levin. Because of its long-range transport, it is

primarily the elemental form, but the atmospheric chemistry of mercury changes that progressively into the inorganic form, which is the form that readily deploys.

Senator Allard. Now, can the inorganic form be transferred into methyl-mercury?

Dr. Levin. Yes, sir. That is the form.

Senator Allard. So all those type of compounds get acted on by bacteria and then that is how that gets into the food chain.

Dr. Rice. The elemental form and the inorganic form are converted back and forth.

Senator Allard. I see.

Dr. Rice. So it does not make any difference whether it reaches the North American shores as elemental mercury or inorganic mercury. Once it is deposited into the soil or the river, it is going to become inorganic mercury that then becomes available to be able to be turned into methyl-mercury.

Senator Allard. Okay, thank you.

Now, here is the question, and I would like to have all of you respond to this. In your opinion, would a decrease in U.S. anthropogenic mercury emissions have an effect on global mercury levels? And part of the rest of the question is, apparently there is a high percentage of mercury present in the United States from outside our borders, so what effects can we expect from a decrease in our emissions? We have a couple of questions there and I would like to have all of you respond to those if you would.

Dr. Rice. There is no question that there is a global cycling of mercury. A lot of the mercury in the United States comes in from someplace else, comes in from the west, but some of it may have in fact originated in the United States originally. This stuff really does circle the globe. So just because it is coming in from the west does not mean it wasn't ours to start with.

Senator Allard. We do not know how much starts here.

Dr. Rice. No, we do not, and I am not a modeler so I really cannot speak to that. But what I do know is that there is local deposition. In other words, the mercury that is released from power plants in the Midwest ends up downwind. I just moved to Maine, and Maine is the so-called tailpipe for that local deposition, for that local emission. There is a percentage of it, and Dr. Levin can tell you what the percentage is better than I can, that is locally deposited. I think it is something like 30 percent.

And so getting rid of those local sources would certainly at least help the Northeastern United States. And originally, the modeling, it was thought that this would take a long, long time. There are newer data now where small studies have actually been done that suggest that it might not be as grim as we originally thought; that these local changes can take place in a relatively shorter time, over the course of several years, rather than decades and decades as we originally may have feared.

Senator Allard. Dr. Myers, do you have a comment on that?

Dr. Myers. It is outside of my area of expertise.

Senator Allard. Dr. Levin?

Dr. Levin. Dr. Rice is primarily correct on that. The deposition within the U.S. makes up about 30 percent of U.S. emissions. The rest of the emission go globally. Our modeling considered the fate of U.S. emissions and accounted for the amount that basically circles the globe and comes down after one trip around the world.

It is also correct that there is local deposition that in some cases may be significant near particular groupings of sources. I indicated that in my testimony, that although the average change in deposition for the scenario was three percent, there were some small areas where it was as much as 10 times that on a percentage basis.

So it calls for more detailed studies and particularly more looking at the science of tracking mercury found in fish back to its sources scientifically, that is, figuring out where it came from.

Senator Allard. Thank you, Mr. Chairman. I believe my time has expired.

Senator Inhofe. Yes, thank you.

Senator Carper?

Senator Carper. Thank you, Mr. Chairman.

To our witnesses, again thank you for joining us. Thank you for your patience in bearing with us.

Dr. Rice, did I understand you to say you have concluded two decades or work at EPA?

Dr. Rice. Well actually most of it was not at EPA. I was at Health Canada for 22 years. I am American, but I graduated from the University of Rochester, got my Ph.D. from the University of Rochester so I have known Dr. Myers for many years. Then I went up there to work at Health Canada.

Senator Carper. I see. Thank you for your service at EPA, and thank you all for real interesting testimony today.

Sometimes these are fairly technical issues. What is helpful for me as I listen to the comments of each of your testimonies and your responses to our questions is to look for threads of consensus; not to focus so much on where you disagree, but to find some areas where you agree. I would just ask each of you to take a minute or two and just to talk about some of the areas where you think you agree, and which might be helpful to us as we wrestle with whether to craft legislation, enact legislation along the lines that Senator Jeffords has introduced, I have introduced, or the President has proposed.

Can you help me with that? Dr. Levin, why don't you go first.

Dr. Levin. Thank you, Senator. We agree that mercury is a highly toxic compound. Its presence in the U.S. diet may in some instances cause concerns for development of children neurologically. We agree that there may be other effects that have to be looked for in terms of the health effects.

We also agree that the science of mercury is still emerging; that the linkage between health effects in particular areas, or for that matter in entire regions of the United States, and the sources of mercury is a critical question that would shape a wise course towards management decisionmaking. The work that I have

been describing today is a step in doing that. The work that has been described by the other two witnesses today on health effects is a critical part of that linkage.

Bringing this source-receptor issue together with the health effects on a specific geographic basis and among specific populations within the United States is a key part in answering the management questions.

Senator Carper. Thank you.

Dr. Myers, would you take a shot at my question please?

Dr. Myers. I think we all agree that mercury is poisonous, every form. In high enough amounts, it is not only damaging to human health, but fatal generally. We all agree that it is worthwhile cleaning up the environment, I think. The question resolves at what level and at what cost. I think we all agree that these studies are extremely difficult to carry out and they are equally difficult to interpret because there are so many details to them. So it is so easy to end up with a bias either knowingly or unknowingly, generally I think unknowingly, that the interpretation of the details becomes incredibly important in these studies.

Senator Carper. Thank you.

Dr. Rice?

Dr. Rice. I agree that we all know that methyl-mercury is toxic at high levels. There is absolutely no question about that. I agree with Dr. Myers that it is incredibly difficult to interpret these studies very often. They are very complex studies. There are a lot of variables, many of which we do not

know. Epidemiology is an extremely blunt instrument. So that is why I think that it is important to look at the weight of evidence. There are a number of studies in humans that have documented effects of methyl-mercury at relatively low body burdens. In addition to that, there is a huge animal literature documenting effects and looking at the mechanisms of effects.

We do not know why one study may be positive, whereas another may be negative. So we really have to go with the evidence as a whole.

Senator Carper. And maybe cite your most serious area of disagreement among you as panelists.

Dr. Levin. I would say disagreement probably rests in the question of the direction of research overall on the mercury issue, and how far that should continue.

Senator Carper. Dr. Myers?

Dr. Myers. I think the most serious area of disagreement is in the interpretation of the studies. We think that the Faroe Islands research is outstanding research. They have done a wonderful job. They have a great design. We are just not sure that they have been able to tease out from the mixture of chemicals present in whales a methyl-mercury component to it. That requires a lot of faith in their statistics and the details of the studies.

In the case of the New Zealand study, most people discounted the New Zealand study for many years. It was only when it was reanalyzed in the late 1990s that people began to start thinking of it in other terms. So I think our biggest disagreement is in the interpretation of it.

In addition, I think the weight of hundreds of small poorly done studies in difficult places such as the Amazon would never outweigh a really good study done looking at fish consumption.

Senator Carper. Dr. Rice?

Dr. Rice. I guess everything that Gary Myers just said is my biggest point of disagreement. All of the smaller studies are not poorly done. Some of them are well done. The Faroe Islands study and the Seychelles study have been extensively reviewed. They are both considered to be very, very good studies.

The National Academy of Sciences looked at the issue of PCB co-exposure very, very carefully and asked the investigators to go back and do a number of additional analyses. Their conclusion was that the effects seem to be independent of each other. These are both neurotoxicants. Although they both had effects in the study, the NAS conclusion was that they were independent.

Again, I think that we have go with a preponderance of evidence and not on just one study, no matter how well it has been done.

Senator Carper. Mr. Chairman, I think this panel has been especially helpful to me. We thank you very, very much for your contributions today. Thank you.

Senator Inhofe. Thank you, Senator Carper.

Senator Clinton?

Senator Clinton. Thank you, Mr. Chairman. I, too, want to thank the panel and welcome Dr. Myers from the University of Rochester, and Dr. Rice, your connection with Rochester, we will

claim that as well.

I want to pick up where Dr. Rice just concluded. We have set up a system of evidence in our legal system that looks at the preponderance of evidence; that looks at a reasonable person standard. I share Dr. Rice's concern that we are not adequately responding to the evidence we already have, which I think the preponderance of it, certainly based on the review by the National Academy of Sciences, suggests that we have a problem with the transmission mostly in utero by mother to child that leads to neurological problems that in turn lead to poor school performance.

The 2000 report of the National Academy of Sciences found, I believe, that about 60,000 children might be born in the United States each year with this level of exposure that could affect school performance, but in your testimony you claim that more recent results from the CDC's National Health and Nutrition Examination Survey translate into over 300,000 newborns per year. Is that correct?

Dr. Rice. Yes. When the NAS did their analysis, the NHANES data were not available. The NHANES just started taking mercury blood and hair levels a couple of years ago, so those data have really become available since the NAS. They state that their 60,000 children was an estimate. It is actually about 320,000 children. Based on actual data that is representative of the U.S. population, it is above the EPA's reference dose.

Senator Clinton. To me, this is truly alarming, that we have actual blood, hair sample, other kinds of physical examination which demonstrates that hundreds of thousands of our children are born each year potentially at risk for adverse affects on intelligence, memory, ability to pay attention,

ability to use language and other skills.

Mr. Chairman, we are facing an increasing number of children in our school systems with learning disabilities. There are not any easy answers as to why the numbers of children with such learning disabilities has increased. Senator Jeffords has been a champion of making sure that all children are given an adequate education. In New York alone, we have 260,000 learning-disabled children. That is 50 percent of our special ed population. We spend $43 billion each year -- $43 billion -- on special ed programs for individuals with developmental disabilities between three and twenty-one.

Of course, not all special ed needs are the direct result of methyl-mercury exposure, but if it is demonstrably shown as we now have with evidence from the CDC's annual survey that we have levels of methyl-mercury in our children's bodies that is above what the EPA has determined to be healthy, and in fact some of us think the EPA standard is too low, but nevertheless if it meets that standard, then I would argue we have got to figure out how to address this environmental health challenge in a very short order.

I have been working with a number of colleagues to try to address the better data collection and environmental health tracking that need in the Individuals With Disabilities Act, and I think similarly on the scientific side with respect to better research and better analysis. But it is troubling to me that we are looking at a problem where the preponderance of the evidence I think is clear, where we know that there is a transmission, whether it is 60,000, 150,000, 300,000-plus children, and it needs some more effective response.

I wanted to ask you, Dr. Rice, now that you are in Maine,

from the State perspective, how closely do you work with the State health department on environmental health issues? Do you exchange information with the State health department and even with the State education department about some of the work that you are doing?

Dr. Rice. I actually knew the State toxicologist for Maine quite well before I went up there, so I do interact with the health department. The methyl-mercury issue is very important to Maine. Maine has a very good program for trying to get rid of methyl-mercury from dental amalgams, from thermometers, from the kinds of things that can be controlled; to not put mercury in landfills because Maine understands that we are at the end of the pipeline for methyl-mercury deposition. Maine has a terrible problem with fish advisories. There are a lot of places where fish cannot be eaten in Maine because of the deposition of methyl-mercury.

So I do work closely with the folks over there, and in fact my way here was paid by the air office, the Maine air office because the State of Maine is so very concerned about this issue. Maine is rural and it is poor, and it cannot really absorb the consequences of these kinds of additional exposures on the health of the people of Maine.

Senator Clinton. Similarly, new science is demonstrating that we need lower standards for lead, based on what we are now determining. A lot of that groundbreaking work was done at the University of Rochester about lead exposures and the impacts of lead exposure. We can take each of these chemicals or compounds piece by piece, but I think that certainly when it comes to mercury and lead and their impacts on children's development, it is not something I feel comfortable studying and waiting too much longer on, particularly because there are so many indirect costs.

I know that Dr. Levin's work looked at some of the risks and cost-benefits, but people do not seem to factor in this special education population that has been growing.

Dr. Rice. If I may make a comment, I think your analogy is an apt one, and I think it is a very informative one. In 1985, there was a report to Congress on the cost-benefits of lead, of keeping lead out of gasoline, in fact. The benefits based on not only special education and things like lower birth weight with respect to lead, but also just the economic consequences of lowering the IQ of workers amounted to billions and billions of dollars a year in 1985 dollars or 1994 dollars. So as this effort goes forward in terms of figuring out how much it is going to cost to reduce mercury emissions, this other side of the equation, how much it is going to cost not to, needs to be kept very, very well in mind.

Senator Clinton. Thank you, Dr. Rice.

Senator Inhofe. Thank you, Senator Clinton.

I thank the panel very much for their testimony.

Senator Jeffords. I had a couple more questions.

Senator Inhofe. Well, all right. It has to end at 12 o'clock. Go ahead.

Senator Jeffords. Dr. Levin, before setting a mercury max standard, would you agree that it makes sense for EPA to conduct a full modeling analysis of all available technology options and their emissions reduction potential, including the most stringent options?

Dr. Levin. Yes, Senator. I think it is important for EPA to carry out a parallel study as EPRI has done, and to make that study public, as we have as well. I am not aware yet that they have actually done any modeling of a max standard since there has been no official proposal of one yet.

Senator Jeffords. Dr. Myers, I believe your testimony is that the fish consumed with an average mercury content of 0.3 parts per million has about the same mercury concentration as commercial fish in the U.S. What are the concentration in non-commercial fish?

Dr. Myers. Are you talking about the U.S. or the Seychelles?

Senator Jeffords. In the U.S.

Dr. Myers. Well, all fish has some mercury in it. Most of the commercial fish in the U.S., I understand, has less than 1/2 part per million, but some of the fish, I am not sure what the non-commercial ones are, but it can go up to over two or three parts per million in some freshwater fish.

Senator Jeffords. Dr. Rice and Dr. Myers, can you characterize the body burden of the pollutants like mercury in American children compared to the levels found in the Seychelles children?

Dr. Myers. The average hair level in the mothers in Seychelles is 6.9 in the group we were studying. The average in the U.S. is less than one part per million. The average in Japan is somewhere around two parts per million.

Senator Jeffords. Dr. Rice, any comment?

Dr. Rice. No. That is correct, but I think it is important to understand that the NHANES data did identify some women, a very small percentage of women with higher hair mercury levels. I think it is important also to understand that the NHANES data are designed to be representative of the U.S. population as a whole, so that women who may eat more fish and may be at more risk for increased body burdens of methyl-mercury, such as immigrant populations or populations of people who are subsistence anglers and who eat inland fish. This is not captured. These populations are not captured by the NHANES data and I think that this needs to be kept in mind.

Senator Jeffords. I have some further questions I would like to submit.

Senator Inhofe. That would be perfectly appropriate. I appreciate it very much, and I appreciate the panel coming and also your patience from the long first session.

We are now adjourned.

[Whereupon, at 12:00 p.m. the committee was adjourned, to reconvene at the call of the Chair.]

[Additional statements submitted for the record follow:]

Statement of David R. Legates to the Committee on Environment and Public Works United States Senate, March 13, 2002

Distinguished Senators, panelists, and members of the audience: I would like to thank the Committee for inviting my commentary on this important topic of climate history and its implications. My name is David R. Legates and I am an Associate Professor and Director of the Center for Climatic Research at the University of Delaware in Newark, Delaware. My research interests have focused on hydroclimatology – the study of water in the atmosphere and on the land – and on the application of statistical methods in climatological research.

I am familiar with the testimony presented here by Dr. Soon. I agree with his statements and I will not reiterate his arguments. My contributions to Dr. Soon's research stemmed from my grappling with the apparent tautology between the long-standing historical record and the time-series recently presented by Dr. Mann and his colleagues. It also stems from my own experiences in compiling and merging global estimates of air temperature and precipitation from a variety of disparate sources.

My Ph.D. dissertation resulted in the compilation of high-resolution climatologies of global air temperature and precipitation. From that experience, I have become acutely aware of the issues associated with merging data from a variety of sources and containing various biases and uncertainties. By its very nature, climatological data exhibit a number of spatial and temporal biases that must be taken into account. Instrumental records exist only for the last century or so and thus proxy records can only be used to glean information about the climate for earlier time periods. But it must be noted that proxy records are not observations and strong caveats must be considered when they are used. It too must be noted that observational data are not without bias either.

The Historical Record of the Last Millennium

Much research has described both the written and oral histories of the climate as well as the proxy climate records (e.g., ice cores, tree rings, and sedimentations) that have been derived for the last millennium. It is recognized that such records are not without their biases – for example, historical accounts often are tainted with the preconceived beliefs and limited experiences of explorers and historians while trees and vegetation respond not just to air temperature fluctuations, but to the entire hydrologic cycle of water supply (precipitation) and demand (which is, in part, driven by air temperature). Nevertheless, such accounts indicate that the climate of the last millennium has been characterized by considerable variability and that extended periods of cold and warmth existed. It has been generally agreed that during the early periods of the last millennium, air temperatures were warmer and that temperatures became cooler toward the middle of the millennium. This gave rise to the terms the "Medieval Warm Period" and the "Little Ice Age", respectively. However, as these periods were not always consistently warm or cold nor were the extremes geographically commensurate in time, such terms must be used with care.

A Biased Record Presented by the IPCC and National Assessment

In a change from its earlier report, however, the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), and now the US National Assessment of Climate Change, both indicate that hemispheric or global air temperatures followed a curve developed by Dr. Mann and his colleagues in 1999. This curve exhibits two notable features. First is a relatively flat and somewhat decreasing trend in air temperature that extends from 1000AD to about 1900AD and is associated with a relatively high degree of uncertainty. This is

followed by an abrupt rise in air temperature during the 1900s that culminates in 1998 with the highest temperature on the graph. Virtually no uncertainty is shown for the data of the last century. The conclusion reached by the IPCC and the National Assessment is that the 1990s are the warmest decade with 1998 being the warmest year of the last millennium.

Despite the large uncertainty, the surprising lack of variability in the record gives the impression that climate remained relatively unchanged through most of the last millennium – at least until human influences began to cause an abrupt increase in temperatures during the last century. Interestingly, Mann et al. replace the proxy data for the 1900s by the instrumental record and no uncertainty characterization is provided. This too yields a false impression that the instrumental record is consistent with the proxy data and that it is 'error free'. It is neither. The instrumental record contains numerous uncertainties, resulting from a lack of coverage over the world's oceans, an under-representation of mountainous and polar regions as well as under-developed nations, and the presence of urbanization effects resulting from the growth of cities. Even if a modest uncertainty of a ±0.1˚C were imposed on the instrumental record, the claim of the 1990s being the warmest decade would immediately become questionable, as the uncertainty window would overlap with the uncertainty associated with earlier time periods. Note that if the satellite temperature record – where little warming has been observed over the last twenty years – had been inserted instead of the instrumental record, it would be impossible to argue that the 1990s are the warmest decade.

Rationale for the Soon et al. Investigation

So we were left to question why the Mann et al. curve seems to be at variance with the previous historical characterization of climatic variability. Investigating more than several hundred studies that have developed proxy records, we came to the conclusion that nearly all of these records show considerable fluctuations in air temperature over the last millennium. Please note that we did not reanalyze the proxy data – the original analysis from the various researchers was left intact. Most records show the coldest period is commensurate with at least a portion of what is termed the "Little Ice Age" and the warmest conditions are concomitant with at least a portion of what is termed the "Medieval Warm Period".

But our conclusion is entirely consistent with conclusions reached by Drs. Bradley and Jones that not all locations on the globe experienced cold or warm conditions simultaneously. Moreover, we chose not to append the instrumental record, but to compare apples-with-apples and determine if the proxy records themselves indeed confirm the claim of the 1990s being the warmest decade of the last millennium. That claim is not borne out by the individual proxy records.

However, the IPCC report, in the chapter with Dr. Mann as a lead author and his colleagues as contributing authors, also concludes that research by Drs. Mann, Jones, and their colleagues "support the idea that the 15th to 19th centuries were the coldest of the millennium over the Northern Hemisphere overall." Moreover, the IPCC report also concludes that the Mann and Jones research "show[s] temperatures from the 11th to 14th centuries to be about 0.2˚C warmer

than those from the 15th to 19th centuries." This again is entirely consistent with our findings. Where we differ with Dr. Mann and his colleagues is in their construction of the hemispheric averaged time-series, their assertion that the 1990s are the warmest decade of the last millennium, and that human influences appear to be the only significant factor on globally averaged air temperature. Reasons why the Mann et al. curve fails to retain the fidelity of the individual proxy records are detailed statistical issues into which I will not delve. But our real difference of opinion focuses solely on the Mann et al. curve and how we have concluded it misrepresents the individual proxy records. In a very real sense, this is an important issue that scientists must address before the Mann et al. curve is taken as fact.

Our work has been met with much consternation from a variety of sources and we welcome healthy scientific debate. After all, it is disagreements among scientists that often lead to new theories and discoveries. However, I am aware that the editors of the two journals that published the Soon et al. articles have been vilified and the discussion has even gone so far as to suggest that Drs. Soon and Baliunas be barred from publishing in the journal Climate Research. Such tactics have no place in scientific debate and they inhibit the free exchange of ideas that is the hallmark of scientific inquiry.

Climate is More Than Mean Global Air Temperature

In closing, let me state that climate is more than simply annually-averaged global air temperature. Too much focus has been placed on divining air temperature time-series and such emphasis obscures the true issue in understanding climate change and variability. If we are truly to understand climate and its impacts and driving forces, we must push beyond the tendency to distill it to a single annual number. Proxy records, which provide our only possible link to the past, are incomplete at best. But when these records are carefully and individually examined, one reaches the conclusion that climate variability has been a natural occurrence, and especially so over the last millennium. And given the uncertainties in the proxy and instrumental records, an assertion of any decade as being the warmest in the last millennium is premature.

I'm sorry that a discussion that is best conducted among scientists has made its way to a United States Senate committee. But hopefully a healthy scientific debate will not be compromised and we can push on towards a better understanding of climate change.

I again thank you for the privilege of speaking before you today.

Selected Publications

Mahmood, R., Meo, M., Legates, D.R., and Morrissey, M.L. (2003). The CERES-Rice model based estimates of potential monsoon season rainfed rice productivity in Bangladesh. The Professional Geographer, forthcoming.

Soon, W., Baliunas, S., Idso, C., Idso, S., and Legates, D.R. (2003): Reconstructing climatic and environmental changes of the past 1000 years: A reappraisal. Energy and Environment,

14:233-296.

Jakubauskas, M.E., and D.R. Legates (2002). Crop Identification Using Harmonic Analysis of Time- Series AVHRR NDVI Data. Computers and Electronics in Agriculture, 37(1-3):127-139.

Jakubauskas, M.E., D.L. Peterson, J.H. Kastens, and D.R. Legates (2002). Time Series Remote Sensing of Landscape-Vegetation Interactions in the Southern Great Plains. Photogrammetric Engineering and Remote Sensing, 68(10):1021–1030.

Legates, D.R. (2000). Real-Time Calibration of Radar Precipitation Estimates. The Professional Geographer, 52(2):235–246.

Legates, D.R. (2000). Remote Sensing in Hydroclimatology: An Introduction to a Focus Section of The Professional Geographer. The Professional Geographer, 52(2):233–234.

Legates, D.R., and G.J. McCabe, Jr. (1999). Evaluating the Use of "Goodness of Fit" Measures in Hydrologic and Hydroclimatic Model Validation. Water Resources Research, 35(1):233–241.

Davis, R.E., M.B. Lowit, P.C. Knappenberger, and D.R. Legates (1999). A Climatology of Snowfall- Temperature Relationships in Canada. Journal of Geophysical Research, 104(D10): 11,985–11,994.

Legates, D.R., K.R. Nixon, T.D. Stockdale, and G.E. Quelch (1998). Use of the WSR-88D Weather Radars in Rangeland Management. Specialty Conference on Rangeland Management and Water Resources, American Water Resources Association, 55–64.

Legates, D.R., and R.E. Davis (1997). The Continuing Search for an Anthropogenic Climate Change Signal: Limitations of Correlation-based Approaches. Geophysical Research Letters, 24(18):2319–2322.

Legates, D.R. (1997). Comments on "Global and Terrestrial Precipitation: A Comparative Assessment of Existing Climatologies" — A Reply. International Journal of Climatology, 17:779–783.

Legates, D.R., K.R. Nixon, T.D. Stockdale, and G.E. Quelch (1996). Soil Water Management Using a Water Resource Decision Support System and Calibrated WSR-88D Precipitation Estimates. Symposium on GIS and Water Resources, American Water Resources Association, 427–435.

Janowiak, J.E., P.A. Arkin, P. Xie, M.L. Morrissey, and D.R. Legates (1995). An Examination of the East Pacific ITCZ Rainfall Distribution. Journal of Climate, 8(11):2810–2823.

Legates, D.R. (1995). Global and Terrestrial Precipitation: A Comparative Assessment of Existing Climatologies. International Journal of Climatology, 15:237–258.

Groisman, P.Ya., and D.R. Legates (1995). Documenting and Detecting Long-Term Precipitation Trends: Where We Are and What Should be Done. Climatic Change, 31:601–622.

Legates, D.R., T.L. DeLiberty, and J.M. Salisbury (1994). Implications of Doubled Trace Gas Concentrations on Summer Precipitation Variability in the Southern Great Plains. Symposium on the Effects of Human-Induced Changes on Hydrologic Systems, American Water Resources Association, 755–762.

Groisman, P.Ya., and D.R. Legates (1994). Accuracy of Historical United States Precipitation Data. Bulletin of the American Meteorological Society, 75(2):215–227.

Legates, D.R. (1993). The Effect of Domain Shape on Principal Components Analyses: A Reply. International Journal of Climatology, 13:219–228.

Legates, D.R., and T.L. DeLiberty (1993). Measurement Biases in the United States Raingage Network. Symposium on Geographic Information Systems and Water Resources, American Water Resources Association, 547–557.

Legates, D.R., and T.L. DeLiberty (1993). Precipitation Measurement Biases in the United States. Water Resources Bulletin, 29(5), 855–861.

Willmott, C.J., and D.R. Legates (1993). A Comparison of GCM-Simulated and Observed Mean January and July Global Surface Air Temperature. Journal of Climate, 6:274–291.

Legates, D.R., and J.R. Mather (1992). An Evaluation of the Average Annual Global Water Balance. Geographical Review, 82:253–267.

Legates, D.R., and C.J. Willmott (1992). A Comparison of GCM-Simulated and Observed Mean January and July Precipitation. Global and Planetary Change, 97:345–363.

McCabe, G.J., Jr., and D.R. Legates (1992). General Circulation Model Simulations of Winter and Summer Sea-Level Pressures Over North America. International Journal of Climatology, 12:815–827.

UNITED STATES SENATE
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
JULY 29, 2003
TESTIMONY OF DR. WILLIE SOON
HARVARD - SMITHSONIAN CENTER FOR ASTROPHYSICS

Distinguished Senators, panelists, and audience: My name is Willie Soon. I am an astrophysicist with the Harvard-Smithsonian Center for Astrophysics in Cambridge Massachusetts. My training is in atmospheric and space physics and my sustained research interests for the past 10 years

include changes in the Sun and their possible impact on climate.

This very rich area of scientific research, though still far from having definitive answers, has seen exciting and important progress from our increasing technical ability to measure, quantify, and interpret the changes in the Sun which could be linked to changes of the Earth's climate.

Today I focus on my latest research conclusions regarding climate change over roughly the last 1000 years, especially the geographical pattern of those changes. My scientific study is only possible because of the careful research produced by nearly one thousand scientists around the world. Their expertise covers a very wide range, including physical, chemical, biological, and geological sciences.

Together with several colleagues whose names are listed in the two scientific papers that I am submitting today for the record of this testimony, we have synthesized the results from several hundred studies of proxy records of climate, including much new work that has appeared in the scientific literature in the last 5 to 10 years.

Climate proxies are indirect climate sensors based on information from tree rings, ice and seafloor sediment cores, corals, glaciers and other natural evidence. They also include important cultural and documentary records.

It is important to recognize that these climate proxies are not temperature readings, but some proxies may be calibrated to give temperature changes. One example is the measurement of the flow of heat in boreholes drilled through rocks or ice, yielding century-scale temperature changes over several millennia. On the other hand, some proxies are sensitive to local rainfall as well as temperature, as in the case of annual tree growth in the southwest United States. Any given proxy may respond to temperature differently from other proxies, depending on, for instance, the type of proxy, location, or season.

For all those reasons, it remains a big challenge to produce an accurate global temperature record over the past 1000 years from the diverse set of climate proxies.

But within the limits and lessons learned from our research papers, we can offer three conclusions:

First, local and regional, rather than "global", changes are the most relevant and practical measure of climate change and impact. This is because truly global averages rarely are available from the distant past, before modern satellite measurements, and because such averages can hide the significant changes that can occur over large parts of the Earth.

Second, on a location by location basis, there was a widespread Medieval Warm Period between approximately 800 and 1300 A.D. This Medieval Warm Period was followed by a widespread colder period, called the Little Ice Age, that lasted from approximately 1300 to 1900 A.D.

Third, there is no convincing evidence from each of the individual climate proxies to suggest that higher temperatures occurred in the 20th century than in the Medieval Warm Period. Nor is there any convincing evidence to suggest that either the rate of increase or the duration of warming during the 20th century were greater than in the Medieval Warm Period.

The fact that local and regional climate has been varying with significant swings in amplitude over many locations provides important challenges for computer simulation of climate. The full models that explore the Earth region by region can test for the natural patterns of change over the last 1,000 years through the use of the climate proxies we just discussed. In that way, the effects of human-caused climate change can be weighed against observed natural variability in the climate system. Having computer simulations reproduce past climate, which has been influenced predominantly by natural factors, is key to making an accurate forecast that includes all potential human-made warming and cooling effects.

Further research could yield a deeper, quantitative improvement to our knowledge of local and regional climate variability during the past 1000 years. As we could be inspired by Mr. Thomas Jefferson who remarked:

"It is a common opinion that the climates of the several states of our union have undergone a sensible change since the dates of their first settlements; that the degrees of both cold & heat are moderated. The same opinion prevails as to Europe; if facts gleaned from history give reasons to believe that, since the times of Augustus Caesar, the climate of Italy, for example, has changed regularly at the rate of 1 [degree] of Fahrenheit's thermometer for every century. May we not hope that the methods invented in latter times for measuring with accuracy the degrees of heat and cold, and the observations which have been & will be made and preserved, will at length ascertain this curious fact in physical history?" --- Marginal notes from Thomas Jefferson's Monticello Weather Diary (January 1, 1810 to December 31, 1816).

I strongly believe that the time for research in paleoclimatology to fulfill this important role is now.

Statement of Deborah C. Rice, Ph.D.,
Maine Department of Environmental Protection, Augusta, Maine
Health Effects of Methylmercury with Particular Reference to the U.S. Population
Hearing by the Senate Committee on Environment and Public Works, July 29, 2003
Deborah C. Rice, Ph.D., Maine Department of Environmental Protection, Augusta, Maine
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I would like to thank the Committee for this opportunity to present information on the adverse health consequences of exposure to methylmercury in the United States. Until three months ago, I was a senior toxicologist in the National Center for Environmental Assessment in the Office of Research and Development at the Environmental Protection Agency. I am a co-author of the document that reviewed the scientific evidence on the health effects of methylmercury for EPA, and which included the derivation of the acceptable daily intake level

for methylmercury.

I would like to focus my presentation on four points that are key to understanding the health-related consequences of environmental mercury exposure. One: there is unequivocal evidence that methylmercury harms the developing human brain. Two: the Environmental Protection Agency used analyses of three large studies in its derivation of an acceptable daily intake level, including the study in the Seychelles Islands which found no adverse effects. Three: eight percent of women of child-bearing age in the United States have levels of methylmercury in their bodies above this acceptable level. And four: cardiovascular disease in men related to low levels of methylmercury has been documented, suggesting that a potentially large segment of the population may be at risk for adverse health effects.

The adverse health consequences to the nervous system of methylmercury exposure in humans were recognized in the 1950s with the tragic episode of poisoning in Minamata Bay in Japan, in which it also became clear that the fetus was more sensitive to the neurotoxic effects of methylmercury than was the adult. A similar pattern of damage was apparent in subsequent episodes of poisoning in Japan and Iraq. These observations focused the research community on the question of whether exposure to concentrations of methylmercury present in the environment might be producing neurotoxic effects that were not clinically apparent.

As a result, over half a dozen studies have been performed around the world to explore the effects of environmental methylmercury intake on the development of the child. Studies in the Philippines (Ramirez et al., 2003), the Canadian Arctic (McKeown-Eyssen et al., 1983), Ecuador (Counter et al., 1998), Brazil (Grandjean et al., 1999), French Guiana (Cordier et al., 1999) and Madeira (Murata et al., 1999) all found adverse effects related to the methylmercury levels in the children's bodies. These included auditory and visual effects, memory deficits, deficits in visuospatial ability, and changes in motor function.

In addition to the above studies, there have been three major longitudinal studies on the effects of exposure to the mother on the neuropsychological function of the child: in the Faroe Islands in the North Atlantic (Grandjean et al., 1997), in the Seychelles Islands in the Indian Ocean (Myers et al., 1995), and in New Zealand (Kjellstrom et al., 1989). Two of these studies identified adverse effects associated with methylmercury exposure, whereas the Seychelles Islands study did not. Impairment included decreased IQ and deficits in memory, language processing, attention, and fine motor coordination. A National Research Council (NRC) National Academy of Sciences panel evaluated all three studies in their expert review, concluding that all three studies were well designed and executed (NRC, 2000). They modeled the relationship between the amount of methylmercury in the mother's body and the performance of the child on a number of neuropsychological tests. From this analysis, they calculated a defined adverse effect level from several types of behavior in each of the three studies. These adverse effect levels represent a doubling of the number of children that would perform in the abnormally low range of function. The National Academy of Sciences panel also calculated an overall adverse effect level of methylmercury in the mother's body for all three of the studies combined, including the negative Seychelles study. Thus the results of all three studies were

included in a quantitative manner by the NRC.

The Environmental Protection Agency (EPA) used the analyses of the NRC in the derivation of the reference dose, or RfD, for methylmercury. The RfD is a daily intake level designed to be without deleterious effects over a lifetime. The EPA divided the defined deleterious effect levels calculated by the NRC by a factor of 10 in its RfD derivation. There are two points that need to be made in this regard. First, the factor of 10 does not represent a safety factor of 10, since the starting point was a level that doubled the number of low-performing children. Second, the EPA performed the relevant calculations for a number of measurements for each of the two studies that found deleterious effects a well as the integrative analysis that included all three studies modeled by the NRC, including the negative Seychelles study. The RfD is 0.10 ug/kg/day based on the Faroe Islands study alone or the integrative analysis of all three studies. The RfD would be lower than 0.10 ug/kg/day if only the New Zealand study had been considered. Only if the negative Seychelles Islands study were used exclusively for the derivation of the RfD, while ignoring the values calculated for the Faroe Islands and New Zealand studies, would the RfD be higher than the current value of 0.10 ug/kg/day. EPA believes that to do so would be scientifically unsound, and would provide insufficient protection to the U.S. population.

A substantial portion of U.S. women of reproductive age have methylmercury in their bodies that is above the level that corresponds to the EPA's RfD. Data collected over the last two years as part of the National Health and Nutritional Examination Survey (NHANES 99+) designed to represent the U.S. population (CDC, Web) revealed that about eight percent of women of child-bearing age had blood levels of methylmercury above the level that the US EPA believes is "safe" (Schober et al., 2003). This translates into over 300,000 newborns per year potentially at risk for adverse effects on intelligence and memory, ability to pay attention, ability to use language, and other skills that are important for success in our highly technological society.

I would like to further comment here on the use of a factor of 10 by EPA to derive the allowable daily intake level (RfD) for methylmercury from the defined effect levels calculated by the National Research Council. The RfD corresponds to roughly 1 part per million (ppm) of methylmercury in maternal hair, from the defined effect level of about 11 ppm calculated by the NRC. But we know that there is no evidence of a threshold below which there are no adverse effects down to about 2–3 ppm in hair, the lowest levels in the Faroe Islands study. In fact, there is evidence from both the Faroe Islands (Budtz-Jrrgensen et al., 2000) and New Zealand (Louise Ryan, Harvard University, personal communication) studies that the change in adverse effect in the child as a function of maternal methylmercury level may be greater at lower maternal methylmercury levels than at higher ones. Therefore, the so-called safety factor almost certainly is less than 10, and may be closer to non-existent. Babies born to women above the RfD may be at actual risk, and not exposed to a level 10 times below a risk level.

There is an additional concern regarding the potential for adverse health consequences as a result of environmental exposure to methylmercury. Several years ago, a study in Finnish men

who ate fish found an association between increased methylmercury levels in hair and atherosclerosis, heart attacks, and death (Salonen et al., 1995, 2000). Two new studies in the U.S. and Europe found similar associations between increased methylmercury levels in the bodies of men and cardiovascular disease (Guallar et al., 2002; Yoshizawa et al., 2002). Effects have been identified at hair mercury levels below 3 ppm. It is not known whether there is a level of methylmercury exposure that will not cause adverse effects. It is important to understand that the cardiovascular effects associated with methylmercury may put an additional, very large proportion of the population at risk for adverse health consequences as a result of exposure to methylmercury from environmental sources.

In summary, there are four points that I would like the Committee to keep in mind. First, at least eight studies have found an association between methylmercury levels and impaired neuropsychological performance in the child. The Seychelles Islands study is anomalous in not finding associations between methylmercury exposure and adverse effects. Second, both the National Research Council and the Environmental Protection Agency included the Seychelles Islands study in their analyses. The only way the acceptable level of methylmercury could be higher would be to ignore the two major positive studies that were modeled by the NRC, as well as six smaller studies, and rely solely on the single study showing no negative effects of methylmercury. Third, there is a substantial percentage of women of reproductive age in the United States with levels of methylmercury in their bodies above what EPA considers a safe level. As a result of this, over 300,000 newborns each year are exposed to methylmercury above levels US EPA believes to be "safe". Fourth, increased exposure to methylmercury may result in atherosclerosis, heart attack, and even death from heart attack in men, suggesting that an additional large segment of the population may be at risk as a result of environmental methylmercury exposure.

Thank you for your time and attention.

References

Budtz-Jrrgensen, E., P. Grandjean, N. Keiding, et al. 2000. Benchmark dose calculations of methylmercury-associated neurobehavioral deficits. Toxicology Letters 112-113, 193-199.

Center for Disease Control and Prevention. Second National Report on Human Exposure to Environmental Chemicals. http://www.cdc.gov/exposurereport/pdf/SecondNER.pdf.

Cordier, S., and Garel, M. 1999. Neurotoxic risks in children related to exposure to methylmercury in French Guiana. INSERM U170 and U149—Study financed by the Health Monitoring Institute, National Institute of Health and Medical Research.

Counter, S.A., Buchanan, L.H., Laurell, G., and Ortega, F. 1998. Blood mercury and auditory neuro-sensory responses in children and adults in the Nambija gold mining area of Ecuador. Neurotoxicology 19, 185–196.

Grandjean, P., Weihe, P., White, R.F., Debes, F., Araki, S., Yokoyama, K., Murata, K., Srrensen, N., Dahl, R., and Jrrgensen, P.J. 1997. Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. Neurotoxicology and Teratology 19, 417-428.

Grandjean, P., White, R.F., Nielsen, A., Cleary, D., de Oliviera Santos, E.C. 1999. Methylmercury neurotoxicity in Amazonian children downstream from gold mining. Environmental Health Perspectives 107, 587-591.

Guallar, E., Sanz-Gallardo, M.I., van't Veer, P., Bode, P., Aro, A., Gómez-Aracena, J., Kark, J.D., Riemersma, R.A., Martín-Moreno, J.M., and Kok, F.J. 2002. Mercury, fish oils, and the risk of myocardial infarction. New England Journal of Medicine 347, 1747–1754.

Kjellstrom, T., Kennedy, P., Wallis, S., and Mantell, C. 1989. Physical and mental development of children with prenatal exposure to mercury from fish. Stage 2: Interviews and psychological tests at age 6. National Swedish Environmental Protection Board, Report 3642 (Solna, Sweden).

McKeown-Eyssen, C.E., Ruedy, J., and Neims, A. 1983. Methylmercury exposure in Northern Quebec II. Neurological findings in children. American Journal of Epidemiology 118, 470–479.

Myers, G.J., Marsh, D.O., Cox, C., Davidson, P.W., Shamlaye, C.F., Tanner, M.A., Choi, A., Cernichiari, E., Choisy, O., and Clarkson, T.W. 1995. A pilot neurodevelopmental study of Seychellois children following in utero exposure to methylmercury from a maternal fish diet. Neurotoxicology 16, 629–638.

Murata, K., Weihe, P., Renzoni, A., Debes, F., Vasconcelos, R., Zino, F., Araki, S., Jrrgensen, P.J., White, R.F., Grandjean, P. 1999. Delayed evoked potentials in children exposed to methylmercury from seafood. Neurotoxicology and Teratology 21, 343-348.

NRC (National Research Council). 2000. Toxicological effects of methylmercury. Committee on the Toxicological Effects of Methylmercury, Board on Environmental Studies and Toxicology, Commission on Life Sciences, National Research Council. Washington, DC: National Academy Press.

Ramirez, G.B., Pagulayan, O., Akagi, H., Rivera, A.F., et al. 2003. Tagum Study II, Follow-up study at two years of age after prenatal exposure to mercury. Pediatrics 111, e289–e295.

Salonen, J.T., Seppänen, K., Lakka, T.A., Salonen, R., and Kaplan, G.A. 2000. Mercury accumulation and accelerated progression of carotid atherosclerosis: a population-based prospective 4-year follow-up study in men in eastern Finland. Atherosclerosis 148:265–273.

Salonen, J.T., Seppänen, K., Nyyssönen, K., Korpela, H., Kauhanen, J., Kantola, M., Tuomilehto, J., Esterbauer, H., Tatzber, F., and Salonen, R. 1995. Intake of mercury from fish, lipid peroxidation and the risk of myocardial infarction and coronary, cardiovascular and any death in Eastern Finnish men. Circulation 91:645–655.

Schober, S.E., Sinks, T.H., Jones, R.L., Bolger, P.M., McDowell, M., Osterlob, J., Garrett, E.S., Canady, R.A., Dillon, C.F., Sun, Y., Joseph, C.B., and Mahaffey, K.R. 2003. Blood mercury levels in U.S. children and women of childbearing age, 1999–2000. Journal of the American Medical Association 289,1667–1674.

Yoshizawa, K., Rimm, E.B., Morris, J.S.,Spate, V.L., Hsiah, C.C., Spiegelman, D., Stampfer, M.J., Willett, W.C. 2002. Mercury and the Risk of Coronary Heart Disease in Men. New England Journal of Medicine 347, 1735–1736.

Statement by the University of Rochester Research Team Studying the Developmental Effects of Methylmercury read by Dr. Gary Myers to the US Senate Committee on Environment and Public Works July 29, 2003

Thank you for the opportunity to present the views of our research group on the health effects of methylmercury (MeHg) exposure. My name is Gary Myers. I am a pediatric neurologist and professor at the University of Rochester in Rochester, New York and one member of a large team that has been studying the human health effects of MeHg for nearly 30 years. For nearly 20 years our group has specifically studied the effects of prenatal MeHg exposure from fish consumption on child development.

Mercury Poisonings

In the 1950's, massive industrial pollution for over two decades in Japan resulted in high levels of MeHg in ocean fish. Several thousand cases of human poisoning from consuming the contaminated fish were reported. The precise level of human exposure causing these health problems was never determined, but was thought to be high. During that epidemic pregnant women who themselves had minimal or no clinical symptoms of MeHg poisoning delivered babies with severe brain damage manifested by cerebral palsy, seizures and severe mental retardation. This suggested that MeHg crosses the placenta from the mother to the fetus and that the developing nervous system is especially sensitive to its toxic effects.

In 1971-1972 there was an epidemic of MeHg poisoning in Iraq. Unlike the Japanese poisonings, the source of exposure in Iraq was maternal consumption of seed grain coated with a MeHg fungicide. Our research team studied the children of about 80 women who were pregnant during this outbreak. We measured mercury exposure to the fetus using maternal hair, the biomarker that best corresponds to MeHg brain level, and examined the children. We concluded that there was a possibility that exposure as low as 10 ppm in maternal hair might be associated with adverse effects on the fetus, although there was considerable uncertainty in this estimate. This value is over 10 times the average in US, but individuals consuming large quantities of fish can achieve this level.

Mercury found naturally in the environment

Mercury is a natural element in the earth's crust. In aquatic environments, bacteria can convert inorganic mercury to MeHg. Once MeHg enters the food chain, it is bioaccummulated and bioconcentrated. All fish contain small amounts, and predatory fish or mammals such as whales have larger amounts. Most commercial oceanic fish in the US has < 0.5 ppm MeHg in the muscle, but some freshwater fish have >1 ppm. In comparison, contaminated fish in Japan that caused poisoning had up to 40 ppm.

Everyone who consumes fish is exposed to MeHg, and regular fish consumption can lead to hair mercury levels as high as 10 ppm or more. The average hair mercury level in the US is < 1 ppm. If MeHg does affect the developing brain at such low levels, mothers who consume large amounts of fish would be exposing their babies to this risk.

The hypothesis of our study in the Seychelles was that prenatal MeHg from fish consumption might affect child development. Since millions of people around the world consume fish as their primary source of protein, we decided to investigate the question directly. We initiated the Seychelles Child Development Study in 1983 and began enrolling subjects in a pilot study in 1987. We selected the Seychelles as a sentinel population for the US for two reasons. First, they consume large amounts of fish. The average mother in our main cohort ate fish with12 meals per week or over 10 times that of US women. Second, the fish consumed in Seychelles (average mercury content 0.3 ppm) has approximately the same mercury concentration as commercial fish in the US

The Seychelles Child Development Study (SCDS)

The SCDS is a collaborative study carried on by researchers at the University of Rochester Medical Center in Rochester, NY and the Ministries of Health and Education in the Republic of the Seychelles. Funding has come from the National Institute of Environmental Health Sciences, the Food and Drug Administration, and the governments of Seychelles and Sweden. The Republic of the Seychelles is an island nation in the Indian Ocean off the East Coast of Africa.

Our original hypothesis was that prenatal MeHg exposure at levels achieved by regular maternal consumption of fish would be associated with adverse effects on child development that could be detected by clinical examination, or by the use of developmental tests that have previously been used to study the effects of environmental exposures on child development.

The Seychelles was chosen partly because there is no mercury pollution and many factors that complicate epidemiological studies of low-level exposure are not present. Health care is free, universal and readily available. Prenatal care is nearly 100%, the birth rate is high, and the general health of mothers and children is good. Education is free, universal, and starts at age 3.5 years. There is limited emigration and both the people and the government were cooperative and supportive.

Before starting a carefully controlled main study, we carried out a pilot study. We expected to find only subtle effects on children at these levels of exposure. Consequently, it was important to minimize any possibility of bias, so a number of decisions were made before the study began. First, no one in Seychelles including researchers visiting the island would know the exposure level of any child or mother, unless our results indicated that children were at risk from prenatal mercury exposure. Second, children with a known cause of developmental delay (meningitis, very low birth weight, or brain trauma) would not be studied. Third, the tests administered would include tests previously reported to show associations with MeHg exposure, tests used with other toxic exposures, and other tests that might detect subtle changes. Fourth, all testing would be performed within specific age windows to minimize the effect of age on test interpretation. Fifth, results would be adjusted for multiple confounding factors (covariates), including things like socioeconomic status, maternal intelligence and birth weight, which are known to have independent effects on child development and if not accounted for, could bias the results. Sixth, the data analysis plan would be determined before the data were collected to minimize the possibility that the data would be repeatedly analyzed until the anticipated effect was eventually found.

In 1989-90, we enrolled over 700 mothers and children in the SCDS main study. These children were evaluated on five occasions (6, 19, 29, 66 and 107 months of age) during the past nine years. When the children were about four years old their homes were visited and evaluated. The study focused on prenatal exposure. This was measured in the mothers' hair growing during pregnancy. Postnatal exposure was also periodically measured in the children's hair. The exposure of both mothers and children ranged from 1 to 27 ppm, the range of concern. The testing was extensive with over 57 endpoints being evaluated to date.

Through 107 months (9 years) and over 57 primary endpoints, the study has found only three statistical associations with prenatal MeHg exposure. One of these associations was adverse, one was beneficial and one was indeterminate. These results might be expected to occur by chance and do not support the hypothesis that adverse developmental effects result from prenatal MeHg exposure in the range commonly achieved by consuming large amounts of fish. The test results do show associations with factors known to affect child development such as maternal IQ and home environment so there is evidence that the tests are functioning well.

Our interpretation of the findings

We do not believe that there is presently good scientific evidence that moderate fish consumption is harmful to the fetus. However, fish is an important source of protein in many countries and large numbers of mothers around the world rely on fish for proper nutrition. Good maternal nutrition is essential to the baby's health. Additionally, there is increasing evidence that the nutrients in fish are important for brain development and perhaps for cardiac and brain function in older individuals.

The SCDS is ongoing and we will continue to report our results. Presently we are examining a new cohort to determine specific nutrients that might influence the effects of MeHg.

Appendix

Not read before the committee, but included in the handout

Because of the public health importance of the question being studied by the SCDS, the potential exists for differing opinions of scientific findings to become highly politicized. The SCDS has received only one published criticism (JAMA, 280:737, 1998), but other points have been raised at conferences. These questions are addressed here individually.

· Why did the SCDS measure mercury in the hair rather than in the cord blood? Hair mercury was used because it is the standard measure used in nearly all other studies of this question. Mercury is thought to enter the hair and brain in a similar fashion. Hair was also chosen because hair has been shown to follow blood concentrations longitudinally, and samples of hair can recapitulate the entire period of exposure, in this case the period of gestation. As part of our research we have shown that hair levels reflect levels in the target tissue, brain. Measuring mercury in blood requires correction for the red blood cell volume (hematocrit) since the mercury is primarily in red blood cells and reflects only very recent exposure. It can also vary if recent meals with high mercury content are consumed.

· Did the SCDS use subjects whose mercury values were too low to detect an association? No, the study's goal was to see if the children of women who consume fish regularly were at risk for adverse developmental effects from MeHg. Women in Seychelles eat fish daily and represent a sentinel population with MeHg levels 10 times higher than US women. Because of higher levels of exposure, their children should be more likely to show adverse effects if they are present. These children show no adverse effects through 9 years of age suggesting that eating ocean fish, when there is no local pollution, is safe. However, we cannot rule out an adverse effect above 12-15 ppm since we had too few cases to substantiate a statistical association if one really existed.

· Did the SCDS use the best tests available to detect developmental problems? Yes, the SCDS used many of the same neurodevelopmental and neuropsychological tests used in other developmental studies. These tests are deemed to be excellent measures for determining development at the ages studied. The tests examined specific domains of children's learning and were increasingly sophisticated as the children become older.

· Did the SCDS find expected associations between development and birth weight, socioeconomic factors, and other covariates? Yes, expected relationships with many covariates such as maternal IQ, family socioeconomic status and the home environment were found, indicating that our tests were sensitive to developmental differences.

· Did the removal of statistical outliers in the analysis bias the study? No. It is standard practice among statisticians to remove statistical outliers. Outliers are values that are inconsistent with the statistical model employed to analyze the data. Every statistical analysis depends on a model, and every statistical model makes assumptions about the statistical

(distributional) properties of the data that must be satisfied if the results of the analysis are to be interpreted correctly. Sound statistical practice requires that the necessary assumptions be checked as part of the statistical analysis. Examination of outliers constitutes one of these checks. Statistical outliers are defined by the difference between the actual test score for a child and the value predicted by the statistical model. Small numbers of such outliers occurred in test scores for children with widely varying MeHg exposures. The results of all analysis were examined both before as well as after the removal of outliers. For analyses in the main study the removal of statistical outliers did not change the conclusions.

· What about the Faroe Islands study where prenatal MeHg exposure was reported to adversely affect developmental outcomes? There are substantial differences between the Faroe Islands and Seychelles studies. The exposure in the Faroe Islands is from consuming whale meat and there is also concomitant exposure to PCBs and other neurotoxins. There are also differences in the measurement of exposure and the approach to statistical analysis. The Faroe Islands study reported associations between cord blood mercury levels and several tests. After statistical analysis they attributed the associations to prenatal MeHg exposure. Scientific studies are frequently open to different interpretations and some scientists do not agree with the researchers' interpretation. We believe the Seychelles study of individuals consuming fish more closely approximates the US situation.

· Are the children in Seychelles too developmentally robust to find the effects of MeHg if they are present? No, the children in Seychelles tested similar to US children on nearly all measures apart from motor skills where they were more advanced. There is no reason to think that they are too robust to show the effects of prenatal MeHg exposure if any are present.

· Are children in Seychelles exposed to PCBs or other food-born toxins that might have confounded the results? No, sea mammals are not consumed in Seychelles and measured PCBs in the children's blood were low.

· Should data from the Seychelles be considered interim? Maybe. Among developmental studies, a nine-year follow-up is considered very long and should be adequate to identify associations with most toxic exposures. However, very subtle effects can be more readily tested in older individuals and there is evidence from experimental animals that some effects of early mercury exposure may not appear until the animal ages.

<u>Scientific publications of the SCDS by the University of Rochester team</u>

Davidson PW, Myers GJ, Cox C, Shamlaye C, Sloane-Reeves J, Cernichiari E, Marsh DO, Clarkson TW, Tanner MA, the Seychelles Child Development Study Group. Measuring Neurodevelopmental outcomes of young children following prenatal dietary low-dose methylmercury exposures. Environmental Sciences 3:55-65, 1994.

Marsh DO, Clarkson TW, Myers GJ, Davidson PW, Cox C, Cernichiari E, Tanner MA, Lednar W, Shamlaye C, Choisy O, Hoareau C, Berlin M. The Seychelles Study of Fetal Methylmercury

Exposure and Child Development: Introduction. Neurotoxicology 16(4): 583-596, 1995.

Shamlaye C, Marsh DO, Myers GJ, Cox C, Davidson PW, Choisy O, Cernichiari E, Choi A, Tanner MA, Clarkson TW. The Seychelles Child Development Study on Neurodevelopmental Outcomes in Children following in utero Exposure to Methylmercury from a Maternal Fish Diet: Background and Demographics. Neurotoxicology 16(4): 597-612, 1995.

Cernichiari E, Toribara TY, Liang L, Marsh DO, Berlin M, Myers GJ, Cox C, Shamlaye CF, Choisy O, Davidson PW, Clarkson TW. The Biological Monitoring of Mercury in the Seychelles Study. Neurotoxicology 16(4): 613-628, 1995.

Myers GJ, Marsh DO, Cox C, Davidson PW, Shamlaye CF, Tanner MA, Choi A, Cernichiari E, Choisy O, Clarkson, TW. A Pilot Neurodevelopmental Study of Seychellois Children following in utero Exposure to Methylmercury from a Maternal Fish Diet. Neurotoxicology 16(4): 629-638, 1995.

Myers, GJ, Davidson, PW, Cox, C, Shamlaye, CF, Tanner, MA, Choisy, O, Sloane-Reeves, J, Marsh, DO, Cernichiari E, Choi A, Berlin M, Clarkson TW. Neurodevelopmental Outcomes of Seychellois Children sixty six months after in utero exposure to methylmercury from a maternal fish diet: Pilot study. Neurotoxicology 16(4): 639-652, 1995.

Myers GJ, Marsh DO, Davidson PW, Cox C, Shamlaye CF, Tanner MA, Choi A, Cernichiari E, Choisy O, Clarkson TW. Main neurodeveopmental study of Seychellois children following in utero exposure to methylmercury from a maternal fish diet: Outcome at six months. Neurotoxicology 16(4): 653-664, 1995.

Davidson PW, Myers GJ, Cox C, Shamlaye CF, Marsh DO, Tanner MA, Berlin M, C Sloane-Reeves J, Cernichiari E, Choisy O, Choi A, Clarkson, TW. Neurodevelopmental Test Selection, Administration and Performance in the Main Seychelles Child Development Study. Neurotoxicology 16(4): 665-676, 1995.

Davidson PW, Myers GJ, Cox C, Shamlaye C, Choisy O, Sloane-Reeves J, Cernichiari E, Marsh DO, Berlin M, Tanner MA, Clarkson TW. Longitudinal Neurodevelopmental Study of Seychellois Children following in utero Exposure to Methylmercury from Maternal Fish Ingestion: Outcomes at 19 and 29 Months. Neurotoxicology 16(4): 677-688, 1995.

Lapham LW, Cernichiari E, Cox C, Myers GJ, Baggs RB, Brewer R, Shamlaye CF, Davidson PW, Clarkson TW. An Analysis of Autopsy Brain Tissue from Infants Prenatally Exposed to Methylmercury. Neurotoxicology 16(4): 689-704, 1995.

Cernichiari E, Brewer R, Myers GJ, Marsh DO, Lapham LW, Cox C, Shamlaye CF, Berlin M, Davidson P, Clarkson TW. Monitoring Methylmercury During Pregnancy: Maternal Hair Predicts Fetal Brain Exposure. Neurotoxicology 16(4): 705-710, 1995.

Myers GJ, Davidson PW, Cox C, Shamlaye CF, Tanner MA, Marsh DO, Cernichiari E, Lapham LW, Berlin M, Clarkson TW. Summary of the Seychelles Child Development Study on the Relationship of Fetal Methylmercury Exposure to Neurodevelopment. Neurotoxicology 16(4): 711-716, 1995.

Myers GJ, Davidson PW, Cox C, Shamlaye CF, Tanner MA, Marsh DO, Cernichiari E, Lapham LW, Berlin M, Clarkson TW. Effects of prenatal methylmercury exposure from a high fish diet on developmental milestones in the Seychelles child development study. Neurotoxicology. 18:819-830, 1997

Davidson PW, Myers GJ, Cox C, Axtell CD, Shamlaye CF, Sloane-Reeves J, Cernichiari E, Needham L, Choi A, Wang Y, Berlin M, Clarkson TW. Effects of prenatal and postnatal methylmercury exposure from fish consumption at 66 months of age: The Seychelles Child Development Study. JAMA. 280:701-707, 1998

Axtell CD, Myers GJ, Davidson PW, Choi AL, Cernichiari E, Sloane-Reeves J, Shamlaye C, Cox C, Clarkson TW. Semiparametric modeling of age at achieving developmental milestones after prenatal exposure to methylmercury in the Seychelles Child Development Study. Environmental Health Perspectives. 106:559-564, 1998

Davidson PW, Myers GJ, Shamlaye CF, Cox C, Gao P, Axtell C, Morris D, Sloane-Reeves J, Cernichiari E, Choi A, Palumbo D, Clarkson TW. Association between prenatal exposure to methylmercury and developmental outcomes in Seychellois Children: Effects modification by social and environmental factors. Neurotoxicology. 20 (5): 833-842, 1999

Crump KS, Van Landingham C, Shamlaye C, Cox C, Davidson PW, Myers GJ, Clarkson TW. Benchmark Concentrations for Methylmercury Obtained from the Seychelles Child Development Study. Environmental Health Perspectives 108 (3): 257-263, 2000

Myers GJ, Davidson PW, Cox C, Shamlaye C, Cernichiari E, Clarkson TW. Twenty-Seven Years Studying the Human Neurotoxicity of Methylmercury Exposure. Environmental Research 83: 275-285, 2000

Davidson PW, Palumbo D, Myers GJ, Cox C, Shamlaye CF, Sloane-Reeves J, Cernichiari E, Wilding GE, Clarkson TW. Neurodevelopmental outcomes of Seychellois children from the pilot cohort at 108 months following prenatal exposure to methylmercury from a maternal fish diet. Environmental Research 84: 1-11, 2000

Myers GJ, Davidson PW, Palumbo D, Shamlaye C, Cox C, Cernichiari E, Clarkson TW. Secondary Analysis from the Seychelles Child Development Study: The Child Behavior Checklist. Environmental Research 84: 12-19, 2000

Axtell CD, Cox C, Myers GJ, Davidson PW, Choi A, Cernichiari E, Sloane-Reeves J, Shamlaye C, Clarkson TW. The Association Between Methylmercury Exposure from Fish Consumption

and Child Development at Five and a Half Years of Age in the Seychelles Child Development Study: An evaluation of nonlinear relationships. Environmental Research 84: 71-80, 2000

Palumbo D, Cox C, Davidson PW, Myers GJ, Choi A, Shamlaye C, Sloane-Reeves J, Cernichiari E, Clarkson TW. Association between prenatal exposure to methyl mercury and cognitive functioning in Seychellois children: A reanalysis of the McCarthy Scales of Children's Ability from the main cohort. Environmental Research 84: 81-88, 2000

Myers GJ, Davidson PW, Cox C, Shamlaye CF, Palumbo D, Cernichiari E, Sloane-Reeves J, Wilding GE, Kost J, Huang LS, Clarkson TW. Prenatal methylmercury exposure from ocean fish consumption in the Seychelles child development study. Lancet 2003: 361: 1686-1692

Huang LS, Cox C, Wilding GE, Myers GJ, Davidson PW, Shamlaye CF, Cernichiari E, Sloane-Reeves J, Clarkson TW. Using Measurement Error Models to Assess Effects of Prenatal and Postnatal Methylmercury Exposure in the Seychelles Child Development Study. Environ Research in press

Appended are the two key articles from the Seychelles study (bolded in bibliography above). Both were published in prestigious medical journals.