CLIMATE SCIENCE AND EPA'S GREENHOUSE GAS REGULATIONS

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND POWER

OF THE

COMMITTEE ON ENERGY AND COMMERCE

HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

FIRST SESSION

MARCH 8, 2011

Serial No. 112–16

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[1] Dr. Zwiers declined to answer the submitted questions for the record.

CLIMATE SCIENCE AND EPA'S GREENHOUSE GAS REGULATIONS

THURSDAY, MARCH 8, 2011

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

The subcommittee met, pursuant to call, at 10:02 a.m., in room 2123, Rayburn House Office Building, Hon. Ed Whitfield (chairman of the subcommittee) presiding.

Present: Representatives Whitfield, Terry, Burgess, Scalise, McMorris Rodgers, McKinley, Gardner, Griffith, Rush, Inslee, and Waxman (ex officio).

Staff Present: Michael Beckerman, Deputy Staff Director; Maryam Brown, Chief Counsel, Energy and Power; Ben Lieberman, Counsel, Energy & Power; Dave McCarthy, Chief Counsel, Environment/Economy; Gib Mullan, Chief Counsel, CMT; Mary Neumayr, Counsel, Oversight/Energy; Sean Bonyun, Deputy Communications Director; Andrew Powaleny, Press Assistant; Peter Spencer, Professional Staff Member, Oversight; Phil Barnett, Minority Staff Director; Greg Dotson, Minority Energy and Environment Staff Director; Jeff Baran, Minority Senior Counsel; Alexandria Teitz, Minority Senior Counsel, Environment and Energy; Karen Lightfoot, Minority Communications Director and Senior Policy Advisor; and Caitlin Haberman, Minority Policy Analyst.

OPENING STATEMENT OF HON. ED WHITFIELD, A REPRESENTATIVE IN CONGRESS FROM THE COMMONWEALTH OF KENTUCKY

Mr. WHITFIELD. We will call the meeting to order. And I want to thank our panel of witnesses. We appreciate your being here this morning very much. And of course, the title of today's hearing is Climate Science and the EPA's Greenhouse Gas Regulations.

This is our third hearing on the Energy Tax Prevention Act of 2011. The first two focused on the adverse impact that the Environmental Protection Agency's global warming regulatory agenda would have on jobs and the economy in America. We could have had other hearings on that as well, but we decided today to focus on the science.

I might say that I only brought one of my many books that questions global warming and the science on global warming. I am delighted to see that at least one member brought a number of books. I couldn't get all mine in the car. Anyway, that is the reason we have these hearings, to hear both sides of the issue.

I might say also that we have had 24 hearings in the House of Representatives over the past 4 years relating to the science for climate change and/or global warming. One thing that really stuck out to me is that these computer models seem to have difficulty making seasonal or yearly forecasts and they certainly, according to many scientists, have great difficulty trying to forecast 100 years down the road.

Science serves to inform us about the nature of a problem. And I look forward to listening to the presentation of all our witnesses today. But whether one thinks that science tells us that global warming is a serious problem, which some scientists do, a minor problem which some scientists do, or hardly a problem at all, which some scientists do, the real question before this committee is whether EPA's regulations under the Clean Air Act are a wise solution to the problem. And, in my view, clearly they are not.

In fact, one need not be a skeptic of global warming to be a skeptic of EPA's regulatory agenda. Case in point is EPA Administrator Lisa Jackson, and she warned us about how complex and costly greenhouse gas regulations under the Clean Air Act would be. Now, of course that was in 2009 and 2010, when the administration was trying to pass through Congress a cap-and-trade bill. It is only now that the cap-and-trade legislation was not adopted in the Congress that the administrator has changed her tune and emphasizes how reasonable and workable these rules would be.

I might also say that Administrator Jackson in testimony just a few weeks ago conceded that unilateral action by EPA would not make much of a difference, especially given the fact that China emits more greenhouse gases than the U.S., and its rate of emissions increases has become many times larger than ours in recent years. In fact, many people might be interested in knowing that carbon emissions actually fell 6 percent in 2009 in the United States, and China was responsible for 24 percent of global carbon emissions during that same year.

Of course, the rhetoric coming from the White House is that the sky is falling and carbon emissions are going through the roof.

The number one reason for the reduction in carbon emissions is the downturn in our economy. So it is pretty obvious that these greenhouse regulations will have a major impact on our economy, mainly because we don't yet have an available technology to control carbon emissions on a commercial scale.

Thus far, only one global warming rule has been analyzed by EPA, and that is, the new motor vehicle standards. The Agency estimated that, as a result of that, they would be able to reduce the earth's future temperature by almost 1/100th of a degree by the year 2100. Not much progress. I want you to keep that in mind, however, when you hear about these scary global scenarios.

Even if you believe every word of them, the Agency rules are no solution. In fact, they are counterproductive, because these unilateral regulations would impose an unfair disadvantage on domestic manufacturers and chase some of our manufacturing jobs to nations like China that have no such restrictions in place and no plans to institute them. Manufacturing jobs would go overseas to countries whose emissions per unit output are considerably higher.

There is no question EPA rules are bad economic policy, but they may very well also be bad environmental policy.

The Energy Tax Prevention Act, far from being an attack on global warming science, as some have suggested, is, in fact, a repudiation of a regulatory scheme that will harm the American economy and destroy jobs. It is also a repudiation of the attempt by unelected bureaucrats in government to bypass the will of Congress. Congress has spoken on this issue three specific times and each time has said no.

H.R. 910 is not about global science. It is about stopping regulation certain to do more harm than good, regardless of how one interprets the science. It is about a dangerous and job-destroying attempt to transform the economy in ways that Congress has repeatedly rejected.

As I said, we look forward to your testimony. At this time, I recognize the gentleman from Illinois for 5 minutes for his opening statement.

[The prepared statement of Mr. Whitfield follows:]

STATEMENT OF HON. ED WHITFIELD

- This is our third hearing on the Energy Tax Prevention Act of 2011.
- The first two focused on the adverse impact that the Environmental Protection Agency's global warming regulatory agenda would have on jobs and the economy. At both hearings, several supporters of EPA's regulations wanted to change the subject and talk about global warming science instead. I don't really blame them, given what we are learning about the harm these regulations would do to domestic manufacturing, energy production, small business, farming, and other job creating sectors. And from a Kentucky perspective, what I learned about these regulations and what they would do to coal mining jobs and to those who rely upon coal-fired electricity was particularly worrisome.
- We could probably have another hearing on the economic impacts, as we still have not heard from some of the many job creating sectors that consider EPA's global warming agenda to be one of if not the biggest regulatory threat they face. But the minority wanted a separate science hearing and we have agreed to their request.
- In my view, holding yet another science hearing is rather excessive, given that we have had 24 such hearings in the House of Representatives over the past 4 years. But I suppose some on this committee have already read those 24 hearing reports from cover to cover, and need additional information. In any event, I am pleased to have this diverse scientific panel today.
- Science serves to inform us about the nature of a problem, and I look forward to listening to the presentations that follow. But whether one thinks the science tells us that global warming is a serious problem, a minor problem, or hardly a problem at all, the real question before this committee is whether EPA's regulations are a wise solution to that problem. Clearly they are not.
- In fact, one need not be a skeptic of global warming to be a skeptic of EPA's regulatory agenda. No less an authority than EPA Administrator Lisa Jackson warned about how complex and costly greenhouse gas regulations under the Clean Air Act would be. Of course, that was in 2009 and 2010 when the administration was trying to scare Congress in to enacting cap and trade legislation as the preferred option. It is only now that cap and trade is dead that the Administrator has changed her tune and emphasizes how reasonable and workable these rules will be.
- In addition, Administrator Jackson has conceded that unilateral action by EPA would not make much difference, especially given the fact that China emits more greenhouse gases than the US and its rate of emissions increases has been many times larger than ours in recent years.
- Thus far, only one global warming rule had been analyzed by EPA, the new motor vehicle standards. The agency has estimate that it will reduce the earth's future temperature by about one one-hundredth of a degree by the year 2100.
- Keep that in mind when you hear about these scary global warming scenarios. Even if you choose to believe every word of them, the agency's rules are no solution. In fact, they are counterproductive, because these unilateral regulations would im-

pose an unfair disadvantage on domestic manufacturers, and chase some of those manufacturing jobs to nations like China that have no such restrictions in place and no plans to institute them. Manufacturing jobs would go overseas to countries whose emissions per unit output are considerably higher. There's no question EPA's rules are bad economic policy, but they may very well also be bad environmental policy.

- The Energy Tax Prevention Act, far from being an attack on global warming science as some have suggested, is in fact a repudiation of a regulatory scheme that will only succeed in harming the American economy and destroying jobs. It is also a repudiation of the attempt by unelected bureaucrats to bypass the will of Congress.
- HR 910 is not about global warming science, it is about stopping regulations certain to do more harm than good, regardless of how one interprets the science. It is about a dangerous and job destroying attempt to transform the economy in ways Congress has repeatedly rejected.

OPENING STATEMENT OF HON. BOBBY L. RUSH, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF ILLINOIS

Mr. RUSH. I want to thank you, Mr. Chairman. And I must also commend you for allowing us to hold this very important hearing today. Mr. Waxman and I, as well as our colleagues on this side of the aisle, were adamant in requesting that this hearing be held because we believe this subcommittee would be doing a disservice to all of our constituents as well as to the entire committee process if we were to proceed to marking up the Upton-Inhofe bill, which would repeal EPA's ability to regulate greenhouse gases, without first hearing from actual scientists about what the scientific evidence says regarding greenhouse gas emissions and their efforts and their effects on both climate change and the overall public health.

Let us make no mistake about it. With respect to all of the witnesses that we will hear from today, that there is really no widespread debate among the scientific community on whether greenhouse gases contribute to climate change.

Mr. Chairman, I must note that it seems, though, from your opening statement, you are coming over to our side of the issue. On the one side, you have over 95 percent of respected scientists and scientific organizations worldwide, I might add, including the National Academy of Sciences, the American Association for the Advancement of Science, the American Geophysical Union, the American Meteorological Society, the U.S. Global Change Research Program, as well as the Intergovernmental Panel on Climate Change. All of these organizations are in agreement that man-made greenhouse gases do contribute to climate change, and these impacts can be mitigated through policy to curb these emissions.

On the other side, you have a very small, less than 5 percent, of the scientists in the community, who range from straight-out climate change denial to those who would dispute the certainty that the claims that human behavior is contributing to climate change.

I recognize that there is a real fear out there by those who believe the EPA's attempt to regulate greenhouse gases, even if it were only by the largest emitter, would lead to job loss in some very important sectors of our economy.

I represent Illinois, which is one of the largest coal States in the country, and I recognize that any policy regulating greenhouse gases will have a real consequence on the jobs and the economy in my State. And I sincerely believe, because the science tells me so, that these gases must be regulated because they have a serious and costly impact on somebody's health in my State and around the country. And as we look out for those people across this Nation that are being affected by the pollution associated with greenhouse gases, then we must find a way to sensibly address this issue in a balanced and in a measured way. For me, the cost of doing nothing outweighs the cost of action, because the science tells us that we cannot keep living by the status quo.

I believe we can enact sensible measures that will both protect the public's health and create new jobs so that we are not making our citizens choose between clean air to breathe and jobs to feed their families.

Mr. Waxman and I sent a letter to you dated September 17, Mr. Chairman, asking you work with us in drafting clean energy standards so we can move our Nation forward in creating new energy jobs and technologies that will put people to work, clean our air, and keep America on the forefront of the environmental protection industry, an industry that was projected to reach $700 billion last year.

Initially, Mr. Chairman, I would be happy to work with you on the clean coal industry, such as expanding programs like the Future Gen project which just began operation in Morgan County, Illinois; and hopefully we will provide answers on whether coal demonstration can be expanded for commercial use. So I ask you, Mr. Chairman, and all my Republican colleagues, to remember to listen to what the science is telling us, and let's work together to move this country forward by creating a clean energy standard by working to promote clean coal initiatives, and by showing the American people that we can be serious about finding solutions and that we are not just here for political infighting and scorekeeping.

Mr. Chairman, I have here something that I think is very telling and a demonstration in fact. It comes from the USA Today. And the cartoon states: "What if it is a big hoax and we create a better world for nothing?" But what would we be creating? Energy independence, preserve rainforests, sustainability, green jobs, liveable cities, renewables, clean air, clean water, healthy children, et cetera, et cetera.

So, Mr. Chairman, even if it is a big hoax, it is a hoax that will provide many, many benefits for the American people. But I do believe that this is not a hoax. This is the real deal. The science says so and the scientists say so.

Thank you very much Mr. Chairman. I yield back the balance of my time.

[The prepared statement of Mr. Rush follows:]

PREPARED STATEMENT OF HON. BOBBY L. RUSH

Thank you, Mr. Chairman, and I must also commend you for allowing us to hold this very important hearing today.

Mr. Waxman and I, as well as all our colleagues on this side of aisle, were adamant in requesting this hearing because we believe this subcommittee would be doing a disservice to all of our constituents, as well as to the entire committee process, if we were to proceed to marking up the Upton-Inhofe bill, which would repeal EPA's ability to regulate greenhouse gases, without hearing from actual scientists about what the scientific evidence says regarding greenhouse gas emissions and their effects on both climate change and the overall public health.

Let us make no mistake about it, with respect to all of the witnesses that we will hear from today, there really is no widespread debate among the scientific community on whether greenhouse gases contribute to climate change.

On the one side you have over 95% of respected scientists and scientific organizations, worldwide, including the National Academy of Sciences, the American Association for the Advancement of Science, the American Geophysical Union, the American Meteorological Society, the U.S. Global Change Research Program, as well as the Intergovernmental Panel on Climate Change, all in agreement that man-made greenhouse gases do contribute to climate change, and these impacts can be mitigated through policy to curb these emissions.

And on the other side you have a very small group, less than 5% of the scientific community, who range from straight-out climate change deniers to those who would dispute the certainty of the claims that human behavior is contributing to climate change.

I recognize that there is real fear out there by those who believe that EPA's attempt to regulate greenhouse gases, even if it is by only the largest emitters, will lead to job loss in some very important sectors in our economy.

I represent Illinois, which is one the largest coal states in the country, and I recognize that any policy regulating greenhouse gases will have real consequences on jobs and the economy in my state.

But I sincerely believe, because the science tells me so, that these gases must be regulated because they have a serious and costly impact on public health, in my state and around the country.

And it is our duty to look out for those people across the country, who are being affected by the pollution associated with greenhouse gases, and we must find a way to sensibly address this issue in a balanced and measured approach.

For me, the cost of doing nothing outweighs the cost of action because the science tells us that we cannot keep living by the status quo.

I believe we can enact sensible measures that will both protect the public health and help create new jobs so that we are not making our citizens choose between clean air to breathe and jobs to feed their families.

Mr. Waxman and I sent a letter to you dated February 7th, Mr. Chairman, asking you to work with us in drafting a clean energy standard, so that we can move our country forward in creating new energy jobs and technologies that would put people to work, clean our air, and also keep America on the forefront of the environmental protection industry, an industry that was projected to reach $700 billion last year.

Additionally, I would be happy to work with you, Mr. Chairman, on a clean coal initiative, such as expanding programs like the FutureGen project, which just began operations in Morgan County, IL, and hopefully, will provide answers to whether coal sequestration can be expanded for commercial use.

As this USA Today poster here highlights: there are so many more benefits in acting to address climate change, as the science tells us we must do, including energy independence, sustainability, cleaner air and water, and a healthier populace, to name a few, than living with the status quo and hoping beyond hope that the majority of the world's scientists are just wrong.

So I ask you, Mr. Chairman, and all of my Republican colleagues, to listen to what the science is telling us and let's work together to move this country forward by creating a clean energy standard, by working to promote clean coal initiatives, and by showing the American people that we can be serious about finding solutions and that we're not just here for political infighting and scorekeeping.

Thank you, Mr. Chairman, and with that I yield back my time.

Mr. WHITFIELD. Thank you, Mr. Rush.

At this time, I recognize for 5 minutes the gentleman from Texas, Mr. Burgess.

OPENING STATEMENT OF HON. MICHAEL C. BURGESS, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TEXAS

Mr. BURGESS. I thank the chairman for calling the hearing. I want to thank the witnesses for being here with us today. It is likely to be a very lively discussion. And some of you we have seen before, some of you this will be your first time here. So we are all looking forward to it.

The science is important. We talk a lot of times about the consensus from the International Panel on Climate Change at the

U.N., but science by consensus is fraught with some danger, and certainly Copernicus and Galileo, if they were still living, could testify to that effect.

My opinion, for what it is worth, is that the science behind global temperature changes is not settled. And the fact that we have this panel of experts in front of us today, who, I suspect at some point, will disagree with each other, is indicative of that.

Now, I do know this. We have had these hearings before, going back a number of years. In 2008, we saw very, very high energy prices, and those were the harbinger of a very significant economic collapse. As a consequence, carbon emissions in this country went down; but I don't want to do that again. And energy prices are on the way back up. We have done nothing in the meantime to protect the American people from the effect of those high energy prices. And I rather expect, if past is prelude, we may see yet another reduction in carbon emissions, but it will be brought because of another jolt through the American economy.

And the Administrator of the EPA, in fact, has testified to this effect. If Administrator Jackson's efforts are successful and if we were to ever pass Waxman-Markey and those efforts were to be successful, how do we do this by ourselves when it is, in fact, a global climate change that we are talking about?

So even if we do all of the things that have been suggested by the Administrator of the EPA, all of the things suggested by Ranking Member Waxman and Mr. Markey, without similar measures by other countries, we are damaging our own country and we are not saving anybody in the process.

Now, weather and climate are complex phenomena affected by a host of variables. In the 1970s, we have all seen the cover of Time Magazine. The earth was cooling and the next Ice Age was on the way. It was the consensus of scientists at that time that that was fact and there was no point in debating it any further. And, we have a very significantly different set of variables to contend with today.

Part of our issue today is, what is the role of the scientists in this debate? Are they there to function as a gatekeeper? Or, in fact, are they a broker for putting up the particular type of information, climate sensitivity to models and the way that has been interpreted over time, the role that these have had in the existing impacts in our public policy in regards to carbon and carbon regulation and the environment.

We have got a great panel of witnesses. I look forward to a lively interchange. I would like, since I am the chairman now, to yield the remaining time to Mr. Griffith from Virginia.

Mr. GRIFFITH. Thank you, Mr. Chairman. I may just have to speak loud. Dr. Roberts is a constituent, and it is the first time that I have had a constituent testify in front of a committee on which I have served. So welcome particularly to you, Dr. Roberts.

And then I would also say to you, Mr. Chairman, and to the others that being a Virginian and proud of the good things we have done in our history, although not perfect, we have done a lot of great things in the Commonwealth of Virginia, and sometimes that means standing alone, like when we were the only government in the world that recognized the rights to religious freedom. And I am often reminded, when folks show up and say, well, 95 percent are going this way and everybody but you is going that way that, Virginia chose a different course on religious freedom, and now the world recognizes that we were right. Just because you might be in the minority doesn't always mean you are wrong.

Thank you, Mr. Chairman. I yield my time back.

Mr. WHITFIELD. Thank you. Also, we have discovered the problems, Mr. Waxman, for the difficulty of speaking. We hit the "mute all" button, and nobody was allowed to speak. So we have now corrected that problem, and I will recognize the ranking member of the full committee, Mr. Waxman, for his 5-minute opening statement.

Mr. WAXMAN. Well, I am glad you found the scientific way to have all the microphones working, Mr. Chairman.

Today's hearing is a crucial opportunity for this committee to understand what is at stake before it considers legislation to block action on climate change. Our health and lives, our economic strength, our national security, all are threatened by climate change.

As we will hear today from some of the world's leading experts, human-induced climate change is happening. We are already seeing its effects and harm from climate changes growing. Members of Congress have the responsibility to consider the threats facing the Nation and making careful choices about how to address them. We owe that to our constituents and to future generations.

I am disappointed that this hearing is happening only because committee Democrats insisted on it, but I commend the majority for agreeing to our request.

We now have the opportunity to hear the scientists explain the scope and magnitude of harm from climate change. I hope the members of this committee are willing to listen.

The Upton-Inhofe bill would overturn EPA's scientific finding that greenhouse gas emissions endanger health and the environment. That determination was based on the science we will hear about today.

The Upton-Inhofe bill would remove EPA's authority to protect the American public from carbon pollution and the impacts of climate change. The bill would legislate a scientific finding out of existence, and it would remove the administration's main tools to address one of the most critical problems facing the world today.

The premise of this radical legislation, as stated by its lead Senate sponsor, is that climate change is a hoax. So before we act on this legislation, the members of this committee must decide: Do we act because the personal opinions of Senator Inhofe; or, do we accept the vast body of scientific understanding, based on multiple lines of evidence across multiple scientific disciplines, which says that the climate change is real and dangerous?

None of us would hesitate in our own lives. If my doctor had told me I had cancer, I wouldn't scour the country to find someone to tell me that I didn't need to worry about it. Just because I didn't feel gravely ill yet, I wouldn't assume that my doctor was falsifying the data. And if my doctor said he didn't know how long I had to live, I wouldn't say, well, if he is uncertain about that, he is probably wrong about the whole thing. I would try to get a second opinion from the best expert I could find about the diagnosis. But I would never call the findings of the medical experts a hoax.

Most of us don't substitute our own judgment for that of experts when it comes to medicine, nuclear engineering, building bridges, designing computer security, trying to figure out how to turn the microphones on in the committee room. The experts on climate change include atmosphere, chemists and physicists, meteorologists, biologists, statisticians, computer scientists, paleontologists, and geologists, thousands of highly-trained professionals, who have published tens of thousands of research papers in the world's top scientific peer-reviewed journals. To reject that body of research by experts is breathtakingly irresponsible.

Chairman Upton and Chairman Whitfield, I am not wedded to the language of last year's energy bill. I am willing to work with you on new approaches and creative ideas. We can start from a blank piece of paper. I am prepared to meet with you without preconditions for as long as it takes to find the basis for common ground. But we need to find a way to work across party lines to address this threat to our health, our economic prosperity, and our national security. We have an opportunity to act now to forestall great harm to our Nation and our world if we don't address this challenge, we do not meet our moral obligations to our children and to the future, and history will not judge us kindly.

I yield back the balance of my time.

Mr. WHITFIELD. Thank you, Mr. Waxman. And now we are prepared to hear the testimony of the panel. I would like at this point to introduce the panel.

First, we have Dr. Richard Somerville, who is a Professor Emeritus of Scripps Institution of Oceanography, University of California, San Diego; we have Dr. John Christy, who is Director, Earth System Science Center, University of Alabama, Huntsville; we have Dr. Christopher Field, who is the Director, Department of Global Ecology, Carnegie Institution of Washington in Stanford, California; we have Dr. Roger Pielke, Sr., who is senior research scientist, Cooperative Institute for Research in Environmental Sciences at the University of Colorado; we have Dr. Francis Zwiers, who is the Director, Pacific Climate Impacts Consortium, University of Victoria, Victoria, British Columbia; we have Dr. Knute Nadelhoffer, who is the Director, University of Michigan Biological Station, University of Michigan; and we have Dr. Donald Roberts, who is Professor Emeritus at the Uniformed Services University of the Health Sciences in Bethesda, Maryland.

We welcome all of you. And you will each have 5 minutes for your statement, and then we are going to open it up to the panel for questions. And we look forward to your testimony.

Dr. Somerville, you are recognized for 5 minutes.

STATEMENTS OF RICHARD SOMERVILLE, DISTINGUISHED PROFESSOR EMERITUS, SCRIPPS INSTITUTION OF OCEANOGRAPHY; JOHN R. CHRISTY, DIRECTOR, EARTH SYSTEM SCIENCE CENTER, UNIVERSITY OF ALABAMA; CHRISTOPHER FIELD, DIRECTOR, DEPARTMENT OF GLOBAL ECOLOGY, CARNEGIE INSTITUTION OF WASHINGTON; KNUTE NADELHOFFER, DIRECTOR, UNIVERSITY OF MICHIGAN BIOLOGICAL STATION, UNIVERSITY OF MICHIGAN; ROGER PIELKE, SR., SENIOR RESEARCH SCIENTIST, COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES, UNIVERSITY OF COLORADO AT BOULDER; DONALD ROBERTS, PROFESSOR EMERITUS, UNIFORMED SERVICES, UNIVERSITY OF THE HEALTH SCIENCES; AND FRANCIS W. ZWIERS, DIRECTOR, PACIFIC CLIMATE IMPACTS CONSORTIUM, UNIVERSITY OF VICTORIA

STATEMENT OF RICHARD SOMERVILLE

Mr. SOMERVILLE. Mr. Chairman and members of the subcommittee, I appreciate this opportunity to testify concerning the science of climate change. Since 1979, I have been a professor at Scripps Institution of Oceanography, University of California at San Diego. Today, however, I am speaking on my own behalf as a climate scientist.

To date, the great preponderance of experts agree on the following facts: One, the essential findings of mainstream climate science are firm; the world is warming. There are many kinds of evidence: Air temperatures, ocean temperatures, melting ice, rising sea levels, increasing water vapor in the atmosphere, twice as many new high temperature records as new low temperature records, and much more. Many lines of evidence also clearly demonstrate that most of the observed warming is due to human activities.

Two, the greenhouse effect is well understood. It is as real as gravity. We have known for 150 years that adding man-made carbon dioxide to the atmosphere will amplify the natural greenhouse effect and trap heat. We know carbon dioxide is increasing. We measure that. We know the increase is human caused. We analyze the chemical evidence for that.

Three, our climate predictions are coming true. Many recently observed climate changes like rising sea levels are occurring at the high end of the predicted ranges. Some changes, like disappearing arctic summer sea ice, are happening faster than the anticipated worst case. Urgent global action is needed if climate disruption is to be limited to moderate levels, like the 3.6 degrees Fahrenheit or 2 degree Celsius target above pre-industrial 19th century temperatures, a target not set by scientists, but by governments and agreed to by the G–8 and G–20 nations and the European Union.

Four, the standard skeptical or contrarian arguments have been refuted many times over in technical papers published in the peer-reviewed scientific research literature. Nobody today should be impressed by these discredited claims.

Five, science has its own high standards. Science works by qualified scientists doing careful research and publishing it in well-reviewed scientific journals. It doesn't work by opinion-makers on the Internet or television or by bloggers or op ed pieces.

Six, the leading scientific organizations of the world, including National Academies of Science and professional scientific societies, have carefully evaluated the results of climate science and endorsed these results. If the world is to confront the challenge of climate change wisely, it must first learn what science has discovered, then accept that, and then act.

We are already experiencing impacts of climate change today on health, safety, food, water, and security. Some further climate change is inevitable, but how much is up to us. This problem is solveable. The future lies in our hands. We have the technology. We must find the will. The road forks now.

We can choose a little more warming with relatively mild impacts or a lot more warming with serious consequences. If we, the world, continues on the current course of increasing emissions, there will be a lot more impacts. We and our children and grandchildren will experience more floods, droughts, and heat waves. We will see severe impacts on food, water, energy, and security as global climate is disrupted.

Humanity can choose today among three courses of action: One, to reduce emissions; two, to adapt to the impacts; and, three, to suffer. How much of each depends on what we choose to do. The more we reduce the emissions, the less adapting and suffering will be required.

The future is not necessarily bleak. It is not too late to avoid the worst impacts of manmade climate change. But this is an urgent issue, and the urgency is scientific and not political or ideological. We have a window of opportunity in which to act. It closes soon. If humanity can greatly reduce the global emissions of manmade greenhouse gases like carbon dioxide and do it fast, then we can greatly reduce the risks of dangerous climate change. These will require that these emissions peak not in 50 or 100 years, but in 5 or 10 years and then decline rapidly so that global emissions are about 80 percent lower by mid century. The sooner we start, the lower the cost and the greater the chance of success.

Reducing emissions can be done in many ways, and the low-hanging fruit is to quickly improve energy efficiency. This also has many immediate benefits: Reducing dependence on imported oil, improving health, creating jobs, making cities cleaner and more liveable.

Our Nation's economic competitiveness depends on innovation. If this country takes reducing heat-trapping emissions seriously, we can lead in developing and producing the clean energy technologies of the future, rather than clinging to the dirty energy sources of the past.

I look forward to answering your questions. Thank you.

Mr. WHITFIELD. Thank you, Dr. Somerville.

[The prepared statement of Mr. Somerville follows:]

One-page summary of March 8, 2011 testimony by Richard C. J. Somerville

1. The essential findings of mainstream climate change science are firm, and it is extremely unlikely that future research will change them. The world is warming. Human activities are the main cause. The warming is not natural.

2. The greenhouse effect is well understood. Carbon dioxide traps heat. We know carbon dioxide is increasing because we measure it. We know the increase is due to human activities like burning fossil fuels, because we can analyze the chemical evidence for that.

3. Our climate predictions are coming true. Many observed climate changes, like rising sea level, are occurring at or beyond the high end of the range of predicted changes. Urgent action is needed if global warming is to be limited to moderate levels.

4. The standard skeptical or contrarian arguments against the central findings of mainstream climate science have been refuted many times over in technical papers published in the peer-reviewed scientific research literature.

5. Science has its own high standards. It does not work by unqualified people making claims and expressing opinions on television or the Internet. People who are not experts, who are not trained and experienced in this field, who do not do research and publish it following standard scientific practice, are not doing science.

6. The leading scientific organizations of the world have carefully examined the results of climate science and endorsed these results. It is silly to imagine that thousands of climate scientists worldwide are engaged in a massive conspiracy to fool everybody. The first thing that the world needs to do if it is going to confront the challenge of climate change wisely is to learn about what science has discovered and accept it.

ADVANCE WRITTEN TESTIMONY

Richard C. J. Somerville

Scripps Institution of Oceanography

University of California, San Diego

Hearing on "Climate Science and EPA's Greenhouse Gas Regulations"

Subcommittee on Energy and Power

Committee on Energy and Commerce

U. S. House of Representatives

Tuesday, March 8, 2011

2123 Rayburn House Office Building

1. Introduction

Mr. Chairman and members of the Subcommittee, I appreciate the opportunity to testify before you concerning the science of climate change. I am a climate scientist and have more than 40 years experience in that field of science. I hold a B. S. degree in meteorology from Pennsylvania State University, granted in 1961, and a Ph. D. degree in meteorology from New York University, granted in 1966. My main professional focus throughout my career has been research in weather and climate. Since 1979, I have been a professor at Scripps Institution of Oceanography, University of California, San Diego (UCSD). In 2007, I formally retired from teaching graduate-level courses there, but I remain active in research, advising graduate students, and outreach. My current title there is Distinguished Professor Emeritus and Research Professor. More details about my professional activities and my research are available at the following web sites:

http://richardsomerville.com

http://en.wikipedia.org/wiki/Richard_Somerville

In giving testimony in this hearing before this Subcommittee, I appear as an individual scientist, speaking only for myself, not on behalf of my employer or any other organization. My current research is on understanding and modeling clouds and cloud feedbacks and related aspects of the climate system. This current research is sponsored by two Federal agencies, the National Science Foundation (NSF) and the U. S. Department of Energy (DOE). In the past, I have also carried out research sponsored by the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA). In all cases, this research support has been in the form of grants awarded competitively after peer review.

Prior to joining Scripps Institution of Oceanography, UCSD, in 1979, I did research at NOAA and NASA laboratories, at the National Center for Atmospheric Research, and at the Courant Institute of Mathematical Sciences at New York University. My current part-time, post-retirement salary at Scripps Institution of Oceanography, UCSD, is funded partly by that organization and partly by my research grants described above. The out-of-pocket expenses that I have incurred in order to be present at this hearing will be reimbursed in part by Scripps Institution of Oceanography, UCSD, and in part by Climate Communication LLC, an organization for which I consult, affiliated with Aspen Global Change Institute, a Colorado nonprofit corporation. Climate Communication LLC is devoted to improving the effective communication of sound climate science. Once again, I emphasize that the views expressed in my written and oral testimony before this Subcommittee are entirely my own, and I am speaking here only as an individual scientist and not as the representative of any of these organizations or any other organization.

The comprehensive Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), published in 2007, authoritatively evaluates climate change science published in the peer-reviewed technical research literature up to about mid-2006. Viewed from the perspective of what is known now, in early 2011, the report is thus inevitably somewhat out of date. I am a Coordinating Lead Author of AR4. This jargon term denotes a scientist who co-headed the writing team for a chapter of AR4. The report AR4 has three major parts, denoted by Working Groups One, Two, and Three. My contribution to AR4 was as part of Working Group One (WG1), which is devoted to the physical science of climate change. The other two working groups are concerned with several other aspects of climate change such as mitigation, adaptation, impacts and vulnerability.

In early 2007, at the time of the publication of WG1 of AR4, the mainstream global community of climate scientists already understood from the most recent research that the latest observations of climate change were disquieting. In the words of a research paper published at the same time as the release of AR4 WG1, a paper for which I am a co-author, "observational data underscore the concerns about global climate change. Previous projections, as summarized by IPCC, have not exaggerated but may in some respects even have underestimated the change" (Rahmstorf et al. 2007).

Now, in 2011, more recent research and newer observations have demonstrated that climate change continues to occur, and in several aspects the magnitude and rapidity of observed changes frequently exceed the estimates of earlier projections, including those of AR4. In addition, the case for attributing much observed recent climate change to human activities is even stronger now than at the time of AR4.

Several recent examples, drawn from many aspects of climate science, but especially emphasizing atmospheric phenomena, support this conclusion. These include temperature, atmospheric moisture content, precipitation, and other aspects of the hydrological cycle.

Motivated by the rapid progress in research, a recent scientific synthesis, *The Copenhagen Diagnosis* (Allison et al. 2009), has assessed recent climate research findings, including:

- Measurements show that the Greenland and Antarctic ice-sheets are losing mass and contributing to sea level rise.
- Arctic sea-ice has melted far beyond the expectations of climate models.
- Global sea level rise may attain or exceed 1 meter by 2100, with a rise of up to 2 meters considered possible.
- In 2008, global carbon dioxide emissions from fossil fuels were about 40% higher than those in 1990.
- At today's global emissions rates, if these rates were to be sustained unchanged, after only about 20 more years, the world will no longer have a reasonable chance of limiting warming to less than 2 degrees Celsius, or 3.6 degrees Fahrenheit, above 19th-century pre-industrial temperature levels, This is a much-discussed goal for a maximum allowable degree of climate change, and this aspirational target has now been formally adopted by the European Union and is supported by many other countries, as expressed, for example, in statements by both the G-8 and G-20 groups of nations.

The Copenhagen Diagnosis also cites research supporting the position that, in order to have a reasonable likelihood of avoiding the risk of dangerous climate disruption, defined by this 2 degree Celsius (or 3.6 degree Fahrenheit) limit, global emissions of greenhouse gases such as carbon dioxide must peak and then start to decline rapidly within the next five to ten years, reaching near zero well within this century.

The Copenhagen Diagnosis is available at www.copenhagendiagnosis.org.

The remainder of my present testimony summarizes the rapid recent progress in climate change scientific research and relates it to recent developments in the politics and public perceptions of climate change.

2. The Intergovernmental Panel on Climate Change (IPCC) and its 2007 report

We can begin by looking back at the last IPCC report and asking some key questions:

1. What is the Intergovernmental Panel on Climate Change, and how does it work?

2. Were the main conclusions in the IPCC Fourth Assessment Report (AR4), published in 2007, correct?

3. How has climate science changed since the scientific papers that were assessed in AR4?

IPCC was founded in 1988. Bolin (2007) has documented the history of IPCC. To date, IPCC has produced four major Assessment Reports (ARs). The average interval between reports is about six years:

1990: First AR (FAR)

1995: Second AR (SAR)

2001: Third AR (TAR)

2007: Fourth AR (AR4)

In 2013, the Fifth AR (AR5) is expected. During the 20 years since the publication of the First Assessment Report, great progress has been made in climate change science. As an example, much more observational data has become available, and computer simulations of the climate system have made great advances in physical comprehensiveness and realism, and also in computational resolution.

The Working Group One (physical science) part of AR4 was written by 152 scientists, called "Lead Authors." 22 of the 152 are called "Coordinating Lead Authors." These 22 are the scientists who led the writing teams for each of the eleven chapters. I was a Coordinating Lead Author for AR4. In this testimony, however, I am speaking as an individual scientist, not representing IPCC or any other organization.

The WG1 portion of the 2007 IPCC report (AR4) is about 1,000 pages long and took three years to write. During the writing, more than 30,000 review comments, from both governments and individuals, were received on three separate drafts of the report. The authors' written responses to every review comment are in the public record. The open and transparent nature of the IPCC process, the multiple stages of peer review, and the credentials of the authors, all contribute to the stature of the report.

The relentless upward trend in the amount ("concentration") of carbon dioxide or CO_2 in the atmosphere continues. In fact, the concentration now is increasing more rapidly than before. Charles David Keeling, who in 1958 began these key observations of atmospheric CO_2 concentrations, died in 2005. However, other scientists are now continuing the meticulous measurements that he undertook, initially made with an instrument that he invented. There is no doubt whatever that the increasing CO_2 concentrations are caused by human activities, primarily by the burning of fossil fuels (coal, oil and natural gas), but also importantly by land use changes, especially agriculture and deforestation.

3. The international scientific congress in Copenhagen in March 2009

There were two noteworthy climate meetings in Copenhagen in 2009. The more famous one, the United Nations Framework Convention on Climate Change (UNFCCC) meeting, was held in Copenhagen in December 2009. This was the 15th Conference of the Parties (COP15). The UNFCCC is the document to which the countries that had ratified it were parties. This document has as its goal avoiding dangerous human-caused interference to the climate system. The United States and virtually every other country of the world is a party to the UNFCCC. The primary scientific input to the COP15 negotiations was, of course, AR4, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2007. This report, and many other recent IPCC documents, are available at www.ipcc.ch and are also published by Cambridge University Press.

However, new scientific developments occur continually. Since the publication of the AR4 IPCC report, new knowledge has emerged that furthers our understanding of climate change, including the impacts of human influence on the climate. To bring this new knowledge together, about nine months before COP15, another international congress, called Climate Change: Global Risks, Challenges and Decisions, was held, also in Copenhagen, from 10-12 March 2009. One must keep in mind that the AR4 IPCC report was published in 2007, and the most recent papers that it assesses were published in 2006.

The Copenhagen congress in March 2009 covered more recent research results, but the conclusions of this meeting did not go through any procedure resembling the long IPCC process of multiple drafts and extensive review. Nor did the March 2009 Copenhagen meeting report have the full participation of many expert authors, as did the IPCC. This fact illustrates the inevitable trade-off between the slow and painstaking IPCC process and faster but less thorough summaries and assessments of recent science.

We now consider some of the key results presented at the March 2009 Copenhagen meeting. Temperature is the single most important climate variable. Let us first consider recent temperature trends. IPCC in 2007 concluded, "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."

The 2007 IPCC Fourth Assessment Report (AR4) described "an unambiguous picture of the ongoing warming of the climate system." This trend is continuing. Small year-to-year differences in global average temperatures are unimportant in evaluating long-term trends. During a warming trend, a given year is not always warmer than all the previous years, because the ongoing warming is sometimes temporarily masked by internal climate variability, a normal and natural phenomenon. For example, 2008 was slightly cooler globally than 2007, in part because a La Niña occurred in 2008 (NASA Goddard Institute for Space Studies, 2009). Such natural events can lead to slight temporary cooling. Solar output was also at its lowest level of the satellite era, another temporary cooling influence.

Quantitatively, the global average near-surface atmospheric temperature in 2008 was only about 0.1 deg C less than in the years immediately preceding it. Such a small difference over such a short time is not statistically significant in evaluating trends. It is noteworthy that 2008, while at the time it may have been the coolest year since 2000, was one of the ten warmest years since instrumental records began in mid-19th century, and the most recent ten-year period is still warmer than the previous ten-year period. The long-term trend is clearly still a warming trend (NASA Goddard Institute for Space Studies, 2009). Its magnitude is about 0.2 degrees Celsius per decade, consistent with IPCC AR4 projections. This is equivalent to about one third of a degree Fahrenheit per decade.

Our knowledge of the causes of this trend has also improved. IPCC said in 2007, "Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations." Science never provides absolute certainty. Here, '*very likely*' is calibrated language used by IPCC to express the degree of scientific uncertainty or the possible range of given scientific findings. In this terminology, used consistently in AR4, "*very likely*" means at least 90% probable.

Thanks to recent research, we have learned that by far the greatest part of the observed century-scale warming is due to human rather than natural factors (Lean and Rind, 2008). These scientists analyzed the role of natural factors (e. g., solar variability, volcanoes) versus human influences (e. g., added man-made greenhouse gases and aerosols) on temperatures since 1889. They found, for example, that the sun contributed only about 10% of surface warming in the last century and a negligible amount in the last quarter century, thus contributing far less than had been estimated in earlier assessments.

Recent research has also clarified our understanding of a warming trend in the atmosphere above the lowest layers near the Earth's surface. By reducing errors in temperature measurements, a warming in the tropical upper troposphere, 10 to 15 kilometers (roughly 6 to 10 miles) above the surface, is now apparent in observations, thus reconciling different measurement data and model simulations (Thorne, 2008). A new method based on wind observations (Allen and Sherwood, 2008) shows a similar warming trend in the upper troposphere, consistent with model results.

The climatic roles of clouds, and of small liquid or solid particles ("aerosols") in the atmosphere, are among the subjects where intensive research is occurring and progress is being made, but only the results of future research can settle several interesting and important scientific questions. AR4 affirmed this conclusion, and it is still true.

In the 2007 IPCC Fourth Assessment Report (AR4), projections were made that future climates would generally have more precipitation at high latitudes and less in the subtropics, where many major deserts exist. However, at that time, no observational studies could be cited defining precipitation trends on a fifty-year time scale. Now such trends have been identified in measurements. For example, Zhang et al. (2007) found that precipitation has been reduced in the subtropics but has increased in middle latitudes, consistent with model projections of human-caused global warming.

Recent research and new observations have decisively settled the question of whether a warming climate will lead to an atmosphere containing more water vapor, and if so, whether the additional water vapor will add to the greenhouse effect, augmenting the warming. The answers to both these questions are yes. Water vapor does become more plentiful in a warmer atmosphere (Dessler et al., 2008). Satellite data show that atmospheric moisture content over the oceans has increased since 1998, with human causes being responsible (Santer at al., 2007).

Recent research has also found that precipitation tends to increase as atmospheric water vapor content increases (Wentz et al., 2007; Allan and Soden, 2008). These conclusions strengthen those of earlier studies.

In the remainder of this portion of my testimony, I briefly summarize several important findings from recent research. Further details, and citations of many of the original papers in the peer-reviewed literature, on which these summary statements are based, may be found in *The Copenhagen Diagnosis* (Allison et al. 2009).

Only a small fraction of the heat gained by the planet in recent decades is stored in the atmosphere. By far the largest portion of heat stored is to be found in the ocean. Recently developed observational advances, such as the deployment of a widespread fleet of thousands of autonomous instrumented floats, have greatly improved our knowledge of ocean heat content. Current estimates indicate that ocean warming is about 50% greater than had been previously reported by the IPCC.

Increased melting of the large polar ice sheets contributes to the observed increase in sea level. Observations of the area of the Greenland ice sheet that has been at the melting point temperature for at least one day during the summer period shows a 50% increase during the period 1979 to 2008. The Greenland region experienced an extremely warm summer in 2007. The whole area of south Greenland reached the melting temperatures during that summer, and the melt season began 10-20 days earlier and lasted up to 60 days longer in south Greenland, compared with Greenland as a whole.

In addition to melting, the large polar ice sheets lose mass by ice discharge, which also depends on regional temperature changes. Satellite measurements of very small changes in gravity have revolutionized the ability to estimate loss of mass from these processes. The Greenland ice sheet has been losing mass at a rate of about 179 Gt/yr since 2003. Here Gt is an abbreviation for gigaton, or one billion metric tons.

One of the most dramatic developments since the last IPCC Report is the rapid reduction in the area of Arctic sea ice in summer. A new minimum in Arctic sea ice was observed only a few months after the publication of AR4. In summer 2007, the minimum area covered by sea ice in the Arctic decreased by about 2 million square kilometers as compared to previous years. In 2008 and subsequently, the decrease has been almost as dramatic. This decreasing ice coverage is important for climate on a larger scale for several reasons, including that an ice-free ocean is far less reflective and so absorbs more heat than an ice-covered ocean. Thus, the loss of Arctic sea ice triggers a strong feedback that amplifies the warming.

The global carbon cycle is in strong disequilibrium because of the input of CO_2 into the atmosphere from fossil fuel combustion and land use change. Total emissions have grown at about 2% per year since 1800. However, fossil fuel emissions have accelerated since 2000 to grow at about 3.4% per year, an observed growth rate that is at or even somewhat beyond the upper edge of the range of growth rates in IPCC scenarios. Total CO_2 emissions are responsible for about two thirds of the growth of all greenhouse gas radiative forcing. Here radiative forcing is a technical term quantifying the effect on the Earth's heat balance.

I shall next comment briefly about some key aspects of the impacts of climate change, treated mainly in WG2 and WG3 of the IPCC reports. The IPCC in its Third Assessment Report (2001) attempted to assess scientific evidence available at the time in terms of "reasons for concern." The resulting visual representation of that synthesis, the so-called "burning embers diagram," shows the increasing risk of various types of climate impacts with an increase in global average temperature. Using the same methodology, the same diagram of reasons for concern has been updated by several authors (Smith et al 2009). Although there inevitably is some subjectivity in any such exercise, the results are provocative and disquieting.

Several conclusions follow from the updated "burning embers diagram" and associated recent findings. First, the risks of climate change impacts now tend to appear at lower global average temperature increases. Second, a 2 deg C (or 3.6 deg F, where deg means degree) limit of warming relative to pre-industrial temperatures, which was widely thought in 2001 to be sufficient to avoid serious risks, now appears to be less adequate. Third, the risks of large-scale discontinuities are now considered to be greater than previously thought.

In summary, although a 2 deg C (or 3.6 deg F) rise in temperature above pre-industrial temperature levels remains the most commonly quoted limit for avoiding dangerous climate change, there is now a serious case to be made that even this level of warming nevertheless carries significant risks of harmful impacts for society and for the environment.

According to the IPCC analysis in AR4, atmospheric CO_2 concentration should not exceed 400 ppm (parts per million by volume) of CO_2 if the global temperature rise is to be kept within 2.0 – 2.4°C. Today, the average CO_2 concentration is about 390 ppm, and is rising by about 2 ppm per year. The 2007 concentration of all greenhouse gases, both CO_2 and non-CO_2 gases, was about 463 ppm in CO_2-equivalents. Adjusting this concentration for the cooling effects of aerosols yields a CO_2-equivalent concentration of 396 ppm. A recent study estimates that a concentration of 450 ppm CO_2-equivalents (including the cooling effect of aerosols) would give only a 50-50 chance of limiting the temperature rise to 2°C or less. In this discussion, the term "CO_2-equivalents" refers to facilitating comparisons by converting the effects of other factors to the equivalent amount of carbon dioxide.

Thus, atmospheric CO_2 concentrations are already at levels predicted to lead to global warming of between 2.0 and 2.4°C. The conclusion from both the IPCC and subsequent analyses is blunt and stark – immediate and dramatic emission reductions of all greenhouse gases are urgently needed if the 2 deg C (or 3.6 deg F) limit is to be respected. This scientific conclusion illustrates a key point, which is that it will be governments that will decide, by actions or inactions, what level of climate change they regard as tolerable. This choice by governments may be affected by risk tolerance, priorities, economics, and other considerations, but in the end it is a choice that humanity as a whole, acting through national governments, will make. Science and scientists will not and should not make that choice. After governments have set a tolerable limit of climate change, however, climate science can then provide valuable information about what steps will be required to keep climate change within that limit.

Humanity is now committing future generations to a strongly altered climate. Even beyond the current century, there are major implications for longer-term climate change. Warmer temperatures and changes in precipitation caused by CO_2 emissions from human activity are largely irreversible on human time scales. Atmospheric temperatures are not expected to decrease for many centuries to millennia, even after human-induced greenhouse gas emissions stop completely (Matthews and Caldeira 2008; Solomon et al. 2009; Eby et al. 2009).

A recent analysis of several decades of data in the western United States suggests that as much as 60% of the hydrological changes in this region are due to human activities. This trend, if sustained, has profound consequences for the future water supply of this already water-stressed part of the world (Barnett et al. 2008).

One complex climate model that had been modified to include recent advances in understanding of the carbon cycle, natural climate factors, and other elements, then produced twice as large a global average temperature increase at the end of the 21st century as it had before the model was modified: 5.2 °C in the new model run compared to 2.4 °C for the older version of the model (Sokolov et al. 2009).

Many recent aspects of observed climate change reveal a more rapid pace than had been foreseen by recent model projections. Thus, recent revisions of projected climate change exceed earlier estimates, and it is increasingly clear that the projections reported in the IPCC Fourth Assessment Report in 2007 may well have underestimated the pace of current climate change. This conclusion cited earlier, by Rahmstorf et al. (2007), which coincidentally appeared at the same time when the WG1 portion of AR4 was published, in February 2007, thus could stand as a conclusion for this entire survey of the results of climate change science:

"Overall, these observational data underscore the concerns about global climate change. Previous projections, as summarized by IPCC, have not exaggerated but may in some respects even have underestimated the change, in particular for sea level."

4. How *The Copenhagen Diagnosis* came to be written

The Copenhagen Diagnosis (Allison et al. 2009) is a report published online in November 2009. It is available for download at www.copenhagendiagnosis.com and www.copenhagendiagnosis.org. A group of 26 climate scientists wrote *The Copenhagen Diagnosis*. All are active researchers. They come from 8 countries and include 3 women and several younger scientists. I am one of the 26 scientists who wrote this report. Our group is private, independent, and unaffiliated with any organization. We speak only for ourselves, not for the Intergovernmental Panel on Climate Change (IPCC) or anyone else.

We are self-selected and self-organized. We have no official leader or formal structure. About half of us are IPCC authors, so we know first-hand what preparing such an assessment entails and what scientific standards it should meet. Our report is firmly based on the more than 200 peer-reviewed papers we cite.

Our aim was to write a readable, short, authoritative report summarizing relevant peer-reviewed climate change research appearing since the cut-off publication date (about mid-2006) for papers assessed in the most recent (2007) IPCC assessment. Like IPCC, we insisted on being policy-relevant but policy-neutral. We thought that such an update was needed to inform the UN climate negotiations in Copenhagen in December 2009, because there has been so much important recent research. It seemed obvious to us that somebody ought to prepare such an update, so we simply decided to accept this responsibility ourselves. The veracity and value of this report thus rests entirely on the scientific credibility of its authors as well as that of the peer-reviewed publications we cite. Any errors or shortcomings in our report are also the sole responsibility of the 26 named authors.

We worked on this document for about a year. Many of us met in Copenhagen in March 2009, at the time of the congress described above, to organize the work and to agree on deadlines, topics, chapter lengths, etc. In deciding who would be in the group of authors, our primary criterion was scientific expertise on one or more of the various topics that we thought needed to be covered. We sought scientists with excellent research reputations, willing and able to work to deadlines, fluent in English, and able to function as part of a writing team. Typically, one author would draft a given chapter, then several others of the group would review and revise it, and finally the entire group would consider the revised draft and reach consensus.

The Climate Change Research Centre at the University of New South Wales in Sydney, Australia contributed some staff support, e.g., for developing the web site. A grant paid essential costs such as printing and travel to our meeting in Copenhagen. Nobody had any influence whatever on the contents of the report other than the 26 authors. We, the authors of *The Copenhagen Diagnosis*, all freely contributed our time and expertise. None of us were paid anything from any source to write this report.

In *The Copenhagen Diagnosis*, the reader is hearing directly from the 26 scientists who wrote it. We made all our own editorial decisions, such as to include special sections of the report, called "boxes." These boxes deal with common misconceptions. We also decided what each of our chapters would be about and how long they would be. In short, we authors enjoyed complete autonomy to design and write our report as we wished.

The Copenhagen Diagnosis is emphatically not an attack on IPCC or a repudiation of the IPCC process or the 2007 IPCC assessment report. We simply considered that the significance of very recent research, and of many climate observations made after the AR4 IPCC assessment was written, together with novel and important improvements in several areas of scientific tools and technology, all deserved to be brought to the attention of the Copenhagen negotiators, the media, governments, corporations and the global public. Our goal was to write in plain English and to make our report accessible to all.

The Copenhagen Diagnosis is about climate change science, not policy. For example, we summarize recent research underpinning the scientific rationale for large and rapid reductions in global greenhouse gas emissions, in order to reduce the likelihood of dangerous man-made climate change. However, we have no political or policy agenda, and we do not speak to the issue of formulating policies to achieve such reductions in emissions. As scientists, when climate change research is relevant to public policy, we consider it important to bring that research to the attention of the wider world. We are convinced that sound science can and should inform wise policy. This conviction led us to write *The Copenhagen Diagnosis*. In this testimony, I also have no political or policy agenda. I am simply summarizing my view of the current state of scientific understanding.

5. Main findings of *The Copenhagen Diagnosis*

According to *The Copenhagen Diagnosis* (Allison et al. 2009), the most significant recent climate change findings are:

Surging greenhouse gas emissions: Global carbon dioxide emissions from fossil fuels in 2008 were nearly 40% higher than those in 1990. Even if global emission rates are stabilized at present-day levels, just 20 more years of emissions would give a 25%

probability that warming exceeds 2 deg C, even with zero emissions after about 2030. Every year of delayed action, to decrease greenhouse gas emissions, increases the chances of exceeding 2 deg C warming. Again, 2 deg C is 3.6 deg F.

Recent global temperatures demonstrate human-induced warming: Over the past 25 years temperatures have increased at a rate of about 0.19 deg C per decade, in very good agreement with predictions based on greenhouse gas increases. Even over the past ten years, despite a decrease in solar forcing, the trend continues to be one of warming. Natural, short-term fluctuations are occurring as usual, but there have been no significant changes in the underlying warming trend.

Acceleration of melting of ice-sheets, glaciers and ice-caps: A wide array of satellite and ice measurements now demonstrate beyond doubt that both the Greenland and Antarctic ice-sheets are losing mass at an increasing rate. Melting of glaciers and ice caps in other parts of the world has also accelerated since 1990.

Rapid Arctic sea-ice decline: Summer melting of Arctic sea-ice has accelerated far beyond the expectations of climate models. The area of sea-ice melt during 2007-2009 was about 40% greater than the average prediction from IPCC AR4 climate models.

Current sea-level rise underestimated: Satellites show recent global average sea-level rise to be about 80% above past IPCC predictions. This acceleration in sea-level rise is consistent with a doubling in contribution from melting of glaciers, ice caps, and the

Greenland and West-Antarctic ice-sheets.

Sea-level predictions revised: By 2100, global sea-level is likely to rise at least twice as much as projected by Working Group 1 of the IPCC AR4. For unmitigated emissions, the rise may well exceed 1 meter. The upper limit has been estimated as about 2 meters sea level rise by 2100. Sea level will continue to rise for centuries after global temperatures have been stabilized, and several meters of sea level rise must be expected over the next few centuries.

Delay in action risks irreversible damage: Several vulnerable elements in the climate system (e.g. continental ice sheets, Amazon rainforest, West African monsoon and others) could be pushed towards abrupt or irreversible change if warming continues in a business-as-usual way throughout this century. The risk of transgressing critical thresholds ("tipping points") increases strongly with ongoing climate change. Thus, waiting for higher levels of scientific certainty could mean that some tipping points will be crossed before they are recognized.

The turning point must come soon: If global warming is to be limited to a maximum of 2 deg C (or 3.6 deg F) above pre-industrial values, global emissions need to peak between now and 2020 and then decline rapidly. To stabilize climate, a decarbonized global society – with near-zero emissions of CO_2 and other long-lived greenhouse gases – needs to be reached well within this century. More specifically, the average annual per-capita emissions will have to shrink to well below 1 metric ton CO_2 by 2050. This is 80 to 95% below the per-capita emissions in developed nations in 2000.

In this testimony, I give only the above brief summary of *The Copenhagen Diagnosis*. The full report is available at www.copenhagendiagnosis.com.

6. COP15 in Copenhagen, December 2009

At the beginning of December 2009, one might have naively anticipated that the increasingly somber and compelling results of climate change science would have led the governments of the world to produce an agreement to rapidly reduce global emissions of greenhouse gases. Indeed, such an agreement at COP15 in Copenhagen in 2009 had been widely expected after COP13 in Bali two years earlier. Many observers had predicted that a binding treaty, with clear and firm targets and timetables and enforcement mechanisms, was achievable. Furthermore, as we have seen, the passage of time had seen a strengthening of the scientific rationale for such an agreement. This is apparent in the conclusions of AR4 as strengthened by subsequent research summarized in *The Copenhagen Diagnosis.*

However, the outcome of the COP15 climate negotiations in Copenhagen in December 2009 disappointed almost everybody. The final "agreement" among a few countries, known as the Copenhagen Accord (http://en.wikipedia.org/wiki/Copenhagen_Accord), was brokered by the US and China at the last minute. This document has no legally binding status and is simply an aspirational statement. It is better than nothing, and one must hope for further progress in the future. However, there is no sign, in this minimal diplomatic result, of the clear need for urgency based on solid climate change science.

Yet many countries have already agreed on the firm aspirational goal of limiting global warming to 2 degrees Celsius (or 3.6 degrees Fahrenheit) above nineteenth-century "pre-industrial" temperatures, in order to have a reasonable chance for avoiding dangerous human-caused climate change.

Setting such a goal is a political decision, as I stressed earlier. However, now that the goal is set, at least by several countries, science can say with confidence that meeting the goal requires that *global* greenhouse gas emissions must peak within the next decade and then decline rapidly. We say that emphatically in the 2009 report *The Copenhagen Diagnosis*, where we also cite the peer-reviewed research on which this statement is firmly based, such as that of Meinshausen et al (2009).

We scientists have been aware of this urgency for more than 30 years. The authoritative IPCC report in 2007 emphasized it. My popular book *The Forgiving Air: Understanding Environmental Change* (Somerville, 2008) cited, "the need to act soon if sensible targets are to be met, the fact that the needed reductions in greenhouse gas emissions will be large, and the fact that both developed and developing countries must be involved."

These results are sensitive to assumptions, of course. Meinshausen et al. (2009) conclude that, "the probability of exceeding 2 deg C rises to 75% if 2020 emissions are not lower than 50 Gt CO2 equiv. (25% above 2000)."

We relied on this paper and others in reaching our conclusion in *The Copenhagen Diagnosis* that, "the required decline in emissions coupled with a growing population will mean that by 2050, annual per capita CO2 emissions very likely will need to be below 1 ton." Obviously, that will be very tough to achieve.

When I say that we scientists have known about the urgency for more than 30 years, I have one especially important scientific research paper in mind, among others. That paper is by Siegenthaler and Oeschger (1978). Here is the conclusion taken from its summary (page 389):

"For a prescribed maximum increase of 50 percent above the preindustrial carbon dioxide level, the production could grow by about 50 percent until the beginning of the next century, but should then decrease rapidly."

So "production" (meaning emissions) has to peak and then quickly decline early in the current (21^{st}) century. This 1978 result came from simple models and the limited data available in the 1970s. We know much more today about the quantitative aspects of this prediction, and the caveats and other details. However, the essential scientific foundation was already clear more than 30 years ago, at least to two insightful Swiss scientists, Siegenthaler and Oeschger. That is the message I wish to emphasize in my testimony here: the need to drastically reduce global greenhouse gas emissions is urgent, and the urgency is scientific, not political.

Mother Nature herself thus imposes a timescale on when emissions need to peak and then begin to decline rapidly. This urgency is therefore not ideological at all, but rather is due to the physics and biogeochemistry of the climate system itself. Diplomats and legislators, as well as heads of state worldwide, are powerless to alter the laws of nature and must face scientific facts and the hard evidence of scientific findings.

Thus, it is profoundly regrettable that what I must characterize as dithering and procrastination at COP15 in Copenhagen continued a year later in December 2010 at COP16 in Cancun, Mexico. The enduring failure to achieve meaningful international agreements, informed by sound climate science, must inevitably have serious consequences for the degree of climate disruption that the Earth will undergo.

7. Public perceptions and the politics of climate change

In late November 2009, at about the same time that *The Copenhagen Diagnosis* was released, a crime was committed in which thousands of emails of prominent climate scientists were illegally obtained from a server at the University of East Anglia in the United Kingdom. These emails, which appear to be authentic, were published online and extensively discussed in the press and the blogosphere.

Extremely serious questions were immediately raised. Is the science of global warming indeed valid, or has it been proven fundamentally incorrect by this episode of emails stolen from a climate research center in England? The short answer is that the hacked emails do not undermine the science in any way.

There is no doubt that the emails have embarrassed several climate scientists. Writing what they thought were private messages to their close colleagues, they expressed themselves in intemperate language. Angered by what they regarded as intolerable harassment by repeated and unreasonable demands from some of their critics, they lashed out and expressed extreme frustration in these private emails to one another.

Edited excerpts from the emails do read poorly, especially out of context, and they might lead some people to conclude that climate research must involve biased, power-hungry, and unprincipled scientists. Following the release of the emails, many in the blogosphere and media, and some politicians, immediately appointed themselves prosecutor, judge and jury. There was little chance to mount a defense in this rush to judgment.

Time has now passed. During the year following the release of the emails, several independent investigations were carried out, and we now have the results of these inquiries. The outcome of all of these investigations has been to exonerate the scientists from accusations of fraud, incompetence, and dishonesty. Many of the specific charges made against the scientists have been shown to be entirely false. For example, cherry-picked words like "trick" turn out to be innocent jargon. In science, a "trick" is not an underhanded tactic to conceal the truth. It is simply a clever way to solve a technical problem, like finding solutions to certain equations. "Trick" here is a jargon term, a word that means one thing to scientists, something else to bridge players, and something altogether different to dog trainers. Context matters.

Much has also been made of unsuccessful demands for temperature data to be released from the research center at East Anglia. In fact, the scientists did resist such demands. Not all the legal issues in question here have yet been completely resolved. They involve freedom of information laws in countries other than the United States, as well as the proprietary restrictions attached to some data by the organizations that originally supplied the data. Nearly all the data in question, however, is freely available from several sources. Several other climate research centers worldwide independently monitor and analyze global temperatures, using essentially the same original data, and their findings closely confirm the ones from the English center. The notion that the main scientific results of modern climate change research might be upset by the release of additional data is not credible.

In my opinion, the most serious charge by far made against the emailing group of climate scientists is that they blocked publication by other scientists with whom they disagreed, and that they prevented the IPCC, the Intergovernmental Panel on Climate Change, from considering the findings of those other scientists in its 2007 assessment report, AR4. Research papers by Soon and Baliunas and by McIntyre and McKitrick were alleged to be in that category.

The facts, however, as brought out in the investigations that have now concluded, are that in these cases, good scientific practice worked exactly as it should. The papers by these authors were indeed published. Other scientists carefully considered them and did further research and published it too. The IPCC cited and discussed all this in its landmark Fourth Assessment Report, published in 2007. This is the relevant passage from page 466 of that report:

> "The 'hockey stick' reconstruction of Mann et al. (1998) has been the subject of several critical studies. Soon and Baliunas (2003) challenged the conclusion that the 20th century was the warmest at a hemispheric average scale. They surveyed regionally diverse proxy climate data, noting evidence for relatively warm (or cold), or alternatively dry (or wet) conditions occurring at any time within pre-defined periods assumed to bracket the so-called 'Medieval Warm Period' (and 'Little Ice Age'). Their qualitative approach precluded any quantitative summary of the evidence at precise times, limiting the value of their review as a basis for comparison of the relative magnitude of mean hemispheric 20th-century warmth (Mann and Jones, 2003; Osborn and Briffa, 2006). Box 6.4 provides more information on the 'Medieval Warm Period'.
>
> "McIntyre and McKitrick (2003) reported that they were unable to replicate the results of Mann et al. (1998). Wahl and Ammann (2007) showed that this was a consequence of differences in the way McIntyre and McKitrick (2003) had

> implemented the method of Mann et al. (1998) and that the original reconstruction could be closely duplicated using the original proxy data. McIntyre and McKitrick (2005a,b) raised further concerns about the details of the Mann et al. (1998) method, principally relating to the independent verification of the reconstruction against 19th-century instrumental temperature data and to the extraction of the dominant modes of variability present in a network of western North American tree ring chronologies, using Principal Components Analysis. The latter may have some theoretical foundation, but Wahl and Amman (2006) also show that the impact on the amplitude of the final reconstruction is very small (~0.05 °C; for further discussion of these issues see also Huybers, 2005; McIntyre and McKitrick, 2005c,d; von Storch and Zorita, 2005)."

It is a standard tactic of many climate "skeptics" or "contrarians" (terms commonly used to denote those who reject central findings of mainstream climate change science) to try to frame this issue in terms of the whole edifice of modern climate science hanging from some slender thread. Thus, if a given scientist uses intemperate language, or a particular measurement is missing from an archive, or a published paper has a minor mistake in it, the whole unstable scientific structure comes tumbling down, or so the skeptics would have people believe.

In fact, climate change science is not at all fragile or vulnerable, and there are multiple lines of evidence in support of every one of its main conclusions. That is what the 2007 IPCC AR4 report says. It remains definitive.

Historians of science tell us that the overwhelming degree of scientific agreement on climate change is rare for such a complex issue. A Galileo does come along every few hundred years to reveal fundamental errors in the prevailing understanding and thus to revolutionize a branch of science. However, almost all the people who think they are a Galileo are simply wrong. Facts matter.

Minor errors have been found in the IPCC reports, though not in the WG1 (physical science) portion of AR4, and IPCC has acknowledged these errors and taken steps to reduce the likelihood of such errors in future reports. Scientists are humans, thus imperfect, and it would be amazing if not a single minor error could be found in a report of some 3,000 pages. It is noteworthy, however, that since the WG1 AR4 report was published in 2007, no reputable scientist has yet been able to point to a major conclusion of this IPCC report, and then point to a persuasive body of peer-reviewed published research that proves that conclusion wrong. *The Copenhagen Diagnosis* has similarly not been challenged successfully. Science can never provide absolute certainty, and any scientific finding is always subject to review and revision on the basis of further research. However, it is highly unlikely that the bedrock conclusions of modern climate science will be proven wrong. Indeed, the most recent research further supports and underscores the fundamental scientific result that manmade climate change is real and serious.

8. A scientific response to climate skeptics or contrarians

Although the expert community is in wide agreement on the basic results of climate change science, as assessed in AR4 and *The Copenhagen Diagnosis*, much confusion exists among the general public and politicians in many countries, as polling data convincingly shows.

In my opinion, many people need to learn more about the nature of junk or fake science, so they will be better equipped to recognize and reject it. There are a number of warning signs that can help identify suspicious claims. One is failure to rely on and cite published research results from peer-reviewed journals. Trustworthy science is not something that appears first on television or the Internet. Reputable scientists first announce the results of their research by peer-reviewed publication in well-regarded scientific journals. Peer review is not a guarantee of excellent science, but the lack of it is a red flag. Peer review is a necessary rather than a sufficient criterion.

Another warning sign is a lack of relevant credentials on the part of the person making assertions, especially education and research experience in the specialized field in question. For example, it is not essential to have earned a Ph. D. degree or to hold a university professorship. It is important, however, that the person be qualified, not in some general broad scientific area, such as physics or chemistry, but in the relevant specialty. Accomplishments and even great distinction in one area of science do not qualify anybody to speak authoritatively in a very different area. We would not ask even an expert cardiologist for advice on, say, dentistry. One should inquire whether the person claiming expertise in some area of climate science has done first-person research on the topic under consideration and published it in reputable peer-reviewed journals. Is the person actively participating in the research area in question, or simply criticizing it from the vantage point of an outsider? One should be suspicious of a lack of detailed familiarity with the specific scientific topic and its research literature. Good science takes account of what is already known and acknowledges and builds on earlier research by others.

Other warning signs include a blatant failure to be objective and to consider all relevant research results, both pro and con a given position. Scientific honesty and integrity require wide-ranging and thorough consideration of all the evidence that might bear on a particular question. Choosing to make selective choices among competing evidence, so as to emphasize those results that support a given position, while ignoring or dismissing any findings that do not support it, is a practice known as "cherry picking" and is a hallmark of poor science or pseudo-science.

Mixing science with ideology or policy or personalities is never justified in research. Scientific validity has nothing to do with political viewpoints. There are no Republican or Democratic thermometers. Whether a given politician agrees or disagrees with a research finding is absolutely unimportant scientifically. Science can usefully inform the making of policy, but only if policy considerations have not infected the science. Similarly, one should always be alert to the risk of bias due to political viewpoints, ideological preferences, or connections with interested parties. All sources of funding, financial interests and other potential reasons for bias should be openly disclosed.

Finally, we must always be alert for any hint of delusions of grandeur on the part of those who would insist that they themselves are correct, while nearly everyone else in the entire field of climate science is badly mistaken. Scientific progress is nearly always incremental, with very few exceptions. Occasionally, an unknown lone genius in a humble position, such as the young Einstein doing theoretical physics while working as a clerk in a patent office, does indeed revolutionize a scientific field, dramatically overthrowing conventional wisdom. However, such events are exceedingly rare, and claims to be such a lone genius deserve the most severe scrutiny. For every authentic Einstein, there must be thousands of outright charlatans, as well as many more ordinary mortals who are simply very badly mistaken.

I have attempted to summarize a number of key points and scientific results in a recently published essay in *Climatic Change* (Somerville 2011), which I paraphrase here:

1. The essential findings of mainstream climate change science are firm. The world is warming. There are many kinds of evidence: air temperatures, ocean temperatures, melting ice, rising sea levels, and much more. Human activities are the main cause. The warming is not natural. It is not due to the sun, for example. We know this because we can measure the effect on the Earth's energy balance of man-made carbon dioxide, and it is much stronger than that of changes in the sun, which we also measure.

2. The greenhouse effect is well understood. It is as real as gravity. The foundations of the science are more than 150 years old. Carbon dioxide in the atmosphere amplifies the natural greenhouse effect and traps heat. We know carbon dioxide is increasing because we measure it. We know the increase is due to human activities like burning fossil fuels because we can analyze the chemical evidence for that.

3. Our climate predictions are coming true. Many observed climate changes, like rising sea level, are occurring at the high end of the predicted changes. Some changes, like melting sea ice, are happening faster than the anticipated worst case. Unless mankind takes strong steps to halt and reverse the rapid global increase of fossil fuel use and the other activities that cause climate change, and does so in a very few years, severe climate change is inevitable. Urgent action is needed if global warming is to be limited to moderate levels.

4. The standard skeptical or contrarian arguments have been refuted many times over in technical papers published in the peer-reviewed scientific research literature. The refutations are now readily available to the broad public and are summarized on many web sites and in many books. For example, natural climate change like ice ages is irrelevant to the current warming. We know why ice ages come and go. That is due to changes in the Earth's orbit around the sun, changes that take thousands of years. The warming that is occurring now, over just a few decades, cannot possibly be caused by such slow-acting processes. But it can be caused by man-made changes in the greenhouse

effect.

5. Science has its own high standards. It does not work by unqualified people making claims on television or the Internet. It works by scientists doing research and publishing it in carefully reviewed research journals. Other scientists examine the research and repeat it and extend it. Valid results are confirmed, and wrong ones are exposed and abandoned. Science is self-correcting. People who are not experts, who are not trained and experienced in this field, who do not do research and publish it following standard scientific practice, are not doing science. When they claim that they are the real experts, they are just plain wrong.

6. The leading scientific organizations of the world, like national academies of science and professional scientific societies, have carefully examined the results of climate science and endorsed these results. It is silly to imagine that thousands of climate scientists worldwide are engaged in a massive conspiracy to fool everybody. The first thing that the world needs to do if it is going to confront the challenge of climate change wisely is to learn about what science has discovered and accept it.

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Mr. WHITFIELD. At this time, Dr. Christy, you are recognized for 5 minutes.

STATEMENT OF JOHN CHRISTY

Mr. CHRISTY. Chairman Whitfield, Ranking Member Rush, and members, thank you for this opportunity to discuss climate change. I am John Christy, Alabama's State climatologist and Professor of Atmospheric Science at the University of Alabama in Huntsville. My research actually involves building climate data sets from scratch to answer questions about what the climate is doing and to test assertions from model theory. In this verbal testimony, I will briefly address six points that are detailed in my written testimony.

One, extreme events. It is popular now to claim extreme events are somehow caused by humans. The earth is very large, the weather is very dynamic, and extreme events will occur somewhere every year. A quick analysis shows that, A, floods in England in 2000 and Australia in 2010 have been exceeded several times in the past; B, snowstorms in the eastern U.S. occur as part of natural circulation processes; and, C, the recent Russian heat wave and related flooding in Pakistan were due to blocking systems which occur without appeal to human causes. Natural, unforced climate variability explains these events.

Two, the underlying temperature trend. An updated analysis of the underlying trend of global atmospheric temperature over the past 32 years, which accounts for volcanos and El Ninos, shows that an atmospheric warming rate of only 9⁄100ths of a degree has occurred per decade. This is the same value published in my 1994 analysis, which covered only 15 years then. This rate is one third of that suggested by climate model theory.

Three, patterns of warming. Continued research on surface temperature changes over land indicates nighttime warming but little daytime change. This is a classic feature that arises from land use change, not greenhouse gas warming.

For the tropical atmospheric temperature, several new studies verify our earlier work that observations and models do not agree about the rate of tropical warming.

Four, climate sensitivity and feedback. New research addresses a question fraught with uncertainty and contention: How sensitive is the climate system to extra greenhouse gases? My colleague, Dr. Roy Spencer, has shown that for time periods for which this quantity can be assessed, the observations indicate the earth has strong negative feedbacks that mitigate warming impulses. No model reproduces these type of feedbacks, and so this is a clue as to why models tend to show more warming than is observed when they add CO_2.

Five, consensus science. Widely publicized reports, purportedly by thousands of scientists, are often misrepresentative of our science and contain overstated confidence in their assertions. Very few scientists actually control the content of these reports, and they rarely represent the full range of scientific opinion and uncertainty that attends our relatively murky science.

I understand the House has approved an amendment to defund the IPCC. I describe our proposal in my written testimony that, should the IPCC be funded by taxpayers, then 10 percent should be set aside for a written report by credentialed scientists who have consistently found the IPCC to have underrepresented critical issues, such as the evidence for low climate sensitivity, the importance in natural unforced variability, and a focus on metrics that are of little value in understanding the greenhouse effect.

And finally, number six, impact of emission control measures. Five years ago, I testified before the Oversight and Investigation Subcommittee chaired by you, Congressman Whitfield. At that time, I calculated the impact of CO_2 emissions if we built 1,000 1.4 gigawatt nuclear power plants, and that they were added by 2020. That is not going to happen. But using the average climate model sensitivity, I demonstrated that global temperatures would change very little. But with the new evidence that the climate is less sensitive to CO_2 increases, the impacts will be even tinier. Developing countries will dominate emissions growth as they seek to rise out of poverty, a goal we cannot and should not subvert, which requires low-cost energy which is today carbon-based.

Thank you. And I will be happy to answer questions at the appropriate time.

Mr. WHITFIELD. Thank you, Dr. Christy.

[The prepared statement of Mr. Christy follows:]

John R. Christy, PhD

The University of Alabama in Huntsville

House Energy and Commerce Committee, Subcommittee on Energy and Power

8 March 2011, One Page Summary

1. It has become popular to claim extreme events are evidence of a human-caused climate change disasters. Actually, the Earth is very large, the weather is very dynamic, and extreme events will occur somewhere every year without appeal to human causes.

2. An updated analysis of the underlying trend in global atmospheric temperature over the past 32 years indicates a warming rate of only +0.09 °C/decade. This rate is one-third of that suggested by climate model theory for the current period.

3. Continued detailed analysis of surface and tropospheric temperature changes verify our earlier work that observations and models influenced by greenhouse gases do not agree regarding the patterns of temperature change in the climate system.

4. New research on the sensitivity of the climate system shows that for time periods for which feedbacks can be assessed, the observations indicate the Earth has strong negative feedbacks that mitigate warming impulses. No model reproduces these types of feedbacks, and thus tend to show a greater response to forcing than is observed.

5. Widely publicized consensus reports by "thousands" of scientists are misrepresentative and contain overstated confidence in their assertions, rarely representing the range of scientific opinion that attends our relatively murky field of climate science.

6. Using the average climate model sensitivity, the net changes in global surface temperature to emission reduction measures by proposed US actions are so small as to be negligible. Developing countries will dominate emissions growth.

Written Statement of John R. Christy

The University of Alabama in Huntsville

Subcommittee on Energy and Power

Committee on Energy and Commerce

8 March 2011

I am John R. Christy, Distinguished Professor of Atmospheric Science, Alabama's State Climatologist and Director of the Earth System Science Center at The University of Alabama in Huntsville. I have served as a Lead Author and Contributing Author of IPCC assessments. It is a privilege for me to offer my view of climate change based on my experience as a climate scientist. My research area might be best described as building climate datasets from scratch to advance our understanding of what the climate is doing and why. This often involves weeks and months of tedious examination of paper records and digitization of data for use computational analysis. I have used traditional surface observations as well as measurements from balloons and satellites to document the climate story. Many of my datasets are used to test hypotheses of climate variability and change. In the following I will address six issues that are part of the discussion of climate change today, some of which will be assisted by the datasets I have built and published.

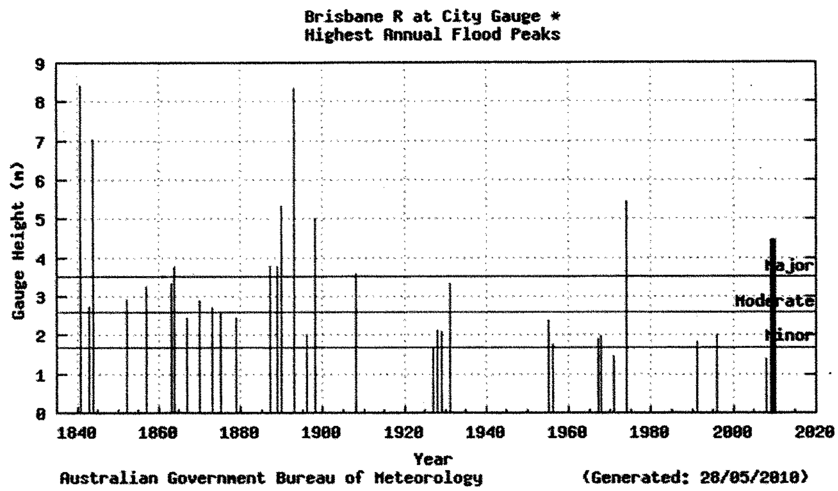
EXTREME EVENTS

Recently it has become popular to try and attribute certain extreme events to human causation. The Earth, however, is very large, the weather is very dynamic, especially at local scales, so that extreme events of one type or another will occur somewhere on the planet in every year. Since there are innumerable ways to define an extreme event (i.e. record high/low temperatures, number of days of a certain quantity, precipitation over 1, 2, 10 ... days, snowfall amounts, etc.) this essentially requires there to be numerous "extreme events" in every year. The following assess some of the recent "extreme events" and explanations that have been offered as to their cause.

Australia

The tragic flooding in the second half of 2010 in NE Australia was examined in two ways, (1) in terms of financial costs and (2) in terms of climate history. First, when one normalizes the flood costs year by year, meaning if one could imagine that the infrastructure now in place was unchanging during the entire study period, the analysis shows there are no long-term trends in damages. In an update of Crompton and McAneney (2008) of normalized disaster losses in Australia which includes an estimate for 2010, they show absolutely no trend since 1966.

Secondly, regarding the recent Australian flooding as a physical event in the context climate history (with the estimated 2010 maximum river height added to the chart below) one sees a relative lull in flooding events after 1900. Only four events reached the moderate category in the past 110 years, while 14 such events were recorded in the 60 years before 1900. Indeed, the recent flood magnitude had been exceeded six times in the last 170 years, twice by almost double the level of flooding as observed in 2010. Such history charts indicate that severe flooding is an extreme event that has occurred from natural, unforced variability.



There is also a suggestion that emergency releases of water from the Wivenhoe Dam upstream of Brisbane caused "more than 80 per cent of the flood in the Brisbane River. … Without this unprecedented and massive release ... the flooding in Brisbane would have been minimal." (*The Australian* 18 Jan 2011.) (See http://rogerpielkejr.blogspot.com/2011/02/flood-disasters-and-human-caused.html where Roger Pielke Jr. discusses extreme events and supplies some of the information used here.)

England Floods

Svensson et al. 2006 discuss the possibility of detecting trends in river floods, noting that much of the findings relate to "changes in atmospheric circulation patterns" such as the North Atlantic Oscillation (i.e. natural, unforced variability) which affects England. For the Thames River, there has been no trend in floods since records began in 1880 (their Fig. 5), though multi-decadal variability indicates a lull in flooding events from 1965 to 1990. The authors caution that analyzing flooding events that start during this lull will create a false positive trend with respect to the full climate record.

Flooding events on the Thames since 1990 are similar to, but generally slightly less than those experienced prior to 1940. One wonders that if there are no long-term increases in flood events in England, how could a single event (Fall 2000) be pinned on human causation as in Pall et al. 2011, while previous, similar events obviously could not? Indeed, on a remarkable point of fact, Pall et al. 2011 did not even examine the actual history of flood data in England to understand where the 2000 event might have fit. As best I can tell, this study compared models with models. Indeed, studies that use climate models to make claims about precipitation events might benefit from the study by Stephens et al. 2010 whose title sums up the issue, "The dreary state of precipitation in global models."

In mainland Europe as well, there is a similar lack of increased flooding (Barredo 2009). Looking at a large, global sample, Svensson et al. found the following.

> *A recent study of trends in long time series of annual maximum river flows at 195 gauging stations worldwide suggests that the majority of these flow records (70%) do not exhibit any statistically significant trends. Trends in the remaining records are almost evenly split between having a positive and a negative direction.*

<u>Russia and Pakistan</u>

An unusual weather situation developed in the summer of 2010 in which Russia experienced a very long stretch of high temperatures while a basin in Pakistan was inundated with flooding rains. NOAA examined the weather pattern and issued this statement indicating this extreme event was a part of the natural cycle of variability (i.e. natural, unforced variability) and unrelated to greenhouse gas forcing.

> "*...greenhouse gas forcing fails to explain the 2010 heat wave over western Russia. The natural process of atmospheric blocking, and the climate impacts induced by such blocking, are the principal cause for this heat wave. It is not known whether, or to what extent, greenhouse gas emissions may affect the frequency or intensity of blocking during summer. It is important to note that observations reveal no trend in a daily frequency of July blocking over the period since 1948, nor is there an appreciable trend in the absolute values of upper tropospheric summertime heights over western Russia for the period since 1900. The indications are that the current blocking event is intrinsic to the natural variability of summer climate in this region, a region which has a climatological vulnerability to blocking and associated heat waves (e.g., 1960, 1972, 1988).*"

Snowfall in the United States

Snowfall in the eastern US reached record levels in 2009-10 and 2010-11 in some locations. NOAA's Climate Scene Investigators committee issued the following statement regarding this, indicating again that natural, unforced variability explains the events.

> *Specifically, they wanted to know if human-induced global warming could have caused the snowstorms due to the fact that a warmer atmosphere holds more water vapor. The CSI Team's analysis indicates that's not likely. They found no evidence — no human "fingerprints" — to implicate our involvement in the snowstorms. If global warming was the culprit, the team would have expected to find a gradual increase in heavy snowstorms in the mid-Atlantic region as temperatures rose during the past century. But historical analysis revealed no such increase in snowfall.*

In some of my own studies I have looked closely at the snowfall records of the Sierra Nevada mountains, which includes data not part of the national archive. Long-term trends in snowfall (and thus water resources) in this part of California are essentially zero, indicating no change in this valuable resource to the state (Christy and Hnilo, 2010.)

Looking at a long record of weather patterns

A project which seeks to generate consistent and systematic weather maps back to 1871 (20th Century Reanalyisis Project, http://www.esrl.noaa.gov/psd/data/20thC_Rean/) has taken a look at the three major indices which are often related to extreme events. As Dr. Gill Campo of the University of Colorado, leader of the study, noted to the *Wall Street Journal* (10 Feb 2011) that "... we were surprised that none of the three major indices of climate variability that we used show a trend of increased circulation going back to 1871." (The three indices were the Pacific Walker Circulation, the North Atlantic Oscillation and the Pacific-North America Oscillation, Compo et al. 2011.) In other words, there appears to be no supporting evidence over this period that human factors have influenced the major circulation patterns which drive the larger-scale extreme events. Again we point to natural, unforced variability as the dominant feature of events that have transpired in the past 140 years.

What this means today should be considered a warning – that the climate system has always had within itself the capability of causing devastating events and these will certainly continue with or without human influence. Thus, societies should plan for their infrastructure projects to be able to withstand the worst that we already know has occurred, and to recognize, in such a dynamical system, that even worse events *should* be expected. In other words, the set of the *measured* extreme events of the small climate history we have, since about 1880, does not represent the full range of extreme events that the climate system can actually generate. The most recent 130 years is simply our current era's small sample of the long history of climate. There will certainly be events in this coming century that exceed the magnitude of extremes measured in the past 130 years in many locations. To put it another way, a large percentage of the worst extremes over the period 1880 to 2100 will occur after 2011 simply by statistical probability without any appeal to human forcing at all. Going further, one would assume that about 10 percent of the record extremes that occur over a thousand-year period ending in 2100 should occur in the 21st century. Are we prepared to deal with events even worse than we've seen so far? Spending resources on creating resiliency to these sure-to-come extremes, particularly drought/flood extremes, seems rather prudent to me.

<u>A sample study of why extreme events are poor metrics for global changes</u>

In the examples above, we don't see alarming increases in extreme events, but we must certainly be ready for more to come as part of nature's variability. I want to illustrate how one might use extreme events to conclude (improperly I believe) that the weather in the USA is becoming less extreme and/or colder.

For each of the 50 states, there are records kept for the extreme high and low temperatures back to the late 19th century. In examining the years in which these extremes occurred (and depending on how one deals with "repeats" of events) we find about 80 percent of the states recorded their hottest temperature prior to 1955. And, about 60 percent of the states experienced their record cold temperatures prior to that date too. One could conclude, if they were so inclined, that the climate of the US is becoming less extreme because the occurrence of state extremes of hot and cold has diminished dramatically since 1955. Since 100 of anything is a fairly large sample (2 values for each of 50 states), this on the surface seems a reasonable conclusion.

Then, one might look at the more recent record of extremes and learn that no state has achieved a record high temperature in the last 15 years (though one state has tied theirs.) However, five states have observed their all-time record low temperature in these past 15 years (plus one tie.) This includes last month's record low of 31°F below zero in Oklahoma, breaking their previous record by a rather remarkable 4°F. If one were so inclined, one could conclude that the weather that people worry about (extreme cold) is getting worse in the US. (Note: this lowering of absolute cold temperature records is nowhere forecast in climate model projections, nor is a significant drop in the occurrence of extreme high temperature records.)

I am not using these statistics to prove the weather in the US is becoming less extreme and/or colder. My point is that extreme events are poor metrics to use for detecting climate change. Indeed, because of their rarity (by definition) using extreme events to bolster a claim about any type of climate change (warming or cooling) runs the risk of setting up the classic "non-falsifiable hypothesis." For example, we were told by the IPCC that "milder winter temperatures will decrease heavy snowstorms" (TAR WG2, 15.2.4.1.2.4). After the winters of 2009-10 and 2010-11, we are told the opposite by advocates of the IPCC position, "Climate Change Makes Major Snowstorms More Likely" (http://www.ucsusa.org/news/press_release/climate-change-makes-snowstorms-more-likely-0506.html).

The non-falsifiable hypotheses works this way, "whatever happens is consistent with my hypothesis." In other words, there is no event that would "falsify" the hypothesis. As such, these assertions cannot be considered science or in anyway informative since the hypothesis' fundamental prediction is "anything may happen." In the example above if winters become milder or they become snowier, the hypothesis stands. This is not science.

As noted above, there are innumerable types of events that can be defined as extreme events – so for the enterprising individual (unencumbered by the scientific method), weather statistics can supply an almost unlimited set of targets in which to discover a "useful" extreme event. Thus, when such an individual observes an unusual event, it may be tempting to define it as a once-for-all extreme metric to "prove" a point about climate change. This works both ways with extremes. If one were prescient enough to have predicted in 1996 that over the next 15 years, five states would break record cold temperatures while zero states would break record high temperatures as evidence for cooling, would that prove CO_2 emissions have no impact on climate? No.

Extreme events happen, and their causes are intricately tied to semi-unstable dynamical situations that can occur out of an environment of natural, unforced variability.

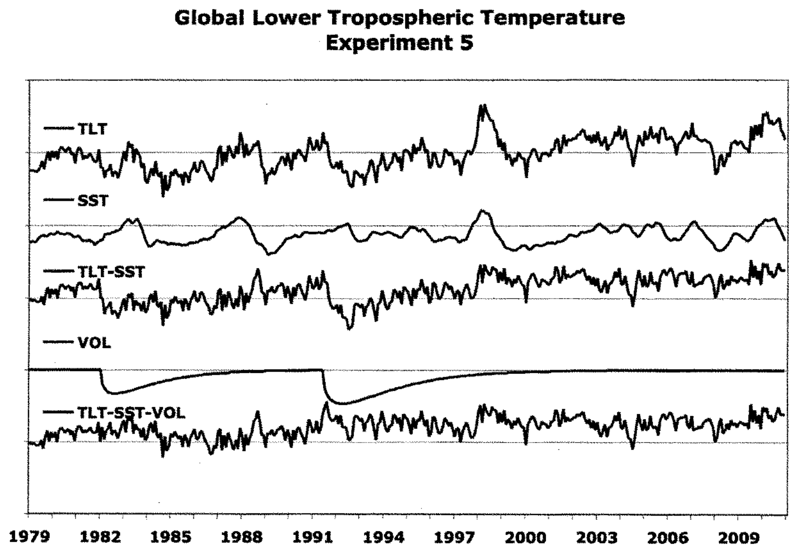
Science checks hypotheses (assertions) by testing specific, falsifiable predictions implied by those hypotheses. The predictions are to be made in a manner that, as much as possible, is blind to the data against which the prediction is evaluated. It is the testable predictions from hypotheses, derived from climate model output, that run into trouble. Before going on, the main point here is that extreme events do not lend themselves as being rigorous metrics for *convicting* human emissions of being guilty of causing them.

THE UNDERLYING TEMPERATURE TREND

As noted earlier, my main research projects deal with building climate datasets from scratch to document what the climate has done and to test assertions and hypotheses about climate change.

In 1994, *Nature* magazine published a study of mine in which we estimated the underlying rate at which the world was warming by removing the impacts of volcanoes and El Niños (Christy and McNider 1994.) This was important to do because in that particular 15-year period (1979-1993) there were some significant volcanic cooling episodes and strong El Niños that convoluted what would have been the underlying trend.

The result of that study indicated the underlying trend for 1979-1993 was +0.09 °C/decade which at the time was one third the rate of warming that should have been occurring according to estimates by climate model simulations.



Above: update of Christy and McNider 1994: Top curve: Monthly global atmospheric temperature anomalies 1979-2010 (TLT). 2nd: (SST) the influence of tropical sea surface temperature variations on the global temperature. 3rd: (TLT-SST) global temperature anomalies without the SST influence. 4th (VOL) The effect of volcanic cooling on global temperatures (El Chichon 1982 and Mt. Pinatubo 1991). Bottom: (TLT-SST-VOL) underlying trend once SST and VOL effects are removed. The average underlying trend of TLT-SST-VOL generated from several parametric variations of the criteria used in these experiments was +0.09 °C/decade. Lines are separated by 1°C.

I have repeated that study for this testimony with data which now cover 32 years as shown above (1979-2010.) In an interesting result, the new underlying trend remains a modest +0.09 C/decade for the global tropospheric temperature, which is still only one third of the average rate the climate models project for the current era (+0.26°C/decade.)

There is no evidence of acceleration in this trend. This evidence strongly suggests that climate model simulations on average are simply too sensitive to increasing greenhouse gases and thus overstate the warming of the climate system (see below under climate sensitivity.) This is an example of a model simulation (i.e. hypothesis) which can provide a "prediction" to test: that "prediction" being the rate at which the Earth's atmosphere should be warming in the current era. In this case, the model-average rate of warming fails the test (see next.)

PATTERNS OF WARMING

Through the years there have been a number of publications which have specifically targeted two aspects of temperature change in which observations and models can be compared. The results of both comparisons suggest there are significant problems with the way climate models represent the processes which govern the atmospheric temperature.

In the first aspect of temperature change, we have shown that the pattern of change at the surface does indeed show warming over land. However, in very detailed analyses of localized areas in the US and Africa we found that this warming is dominated by increases in nighttime temperatures, with little change in daytime temperatures. This pattern of warming is a classic signature of surface development (land cover and land use change) by human activities. The facts that (a) the daytime temperatures do not show significant warming in these studies and (b) the daytime temperature is much more representative of the deep atmospheric temperature where the warming due to the enhanced greenhouse effect should be evident, lead us to conclude that much of the surface temperature warming is related to surface development around the thermometer sites. This type of surface development interacts with complexities of the nighttime boundary layer which leads to warming not related to greenhouse warming (Christy et al. 2006, 2009, see also Walters et al. 2007, Pielke, Sr. 2008.)

The second set of studies investigates one of the clearest signatures or fingerprints of greenhouse gas warming as depicted in climate models. This signature consists of a region of the tropical upper atmosphere which in models is shown to warm at least twice as fast as the surface rate of warming. We, and others, have tested this specific signature, i.e. this hypothesis, against several observational datasets and conclude that this pervasive result from climate models has not been detected in the real atmosphere. In addition, the *global* upper atmosphere is also depicted in models to warm at a rate faster than the surface. Again, we did not find this to be true in observations (Klotzbach et al. 2010.) The following are quotes from three of the recent papers which come to essentially the same conclusion as earlier work published in Christy et al. 2007 and Douglass et al. 2007.

> *Table 2 displays the new per decade linear trend calculations [of difference between global surface and troposphere using model amplification factor] ... over land and ocean. All trends are significant[ly different] at the 95% level. Klotzbach et al. 2010.*
>
> *[Our] result is inconsistent with model projections which show that significant amplification of the modeled surface trends occurs in the modeled tropospheric trends. Christy et al. 2010.*
>
> *Over the interval 1979-2009, model-projected temperature trends are two to four times larger than observed trends in both the lower and*

mid-troposphere and the differences are statistically significant at the 99% level. McKitrick et al 2010.

Again we note that these (and other) studies have taken "predictions" from climate model simulations (model outputs are simply hypotheses), have tested these predictions against observations, and found significant differences.

CLIMATE SENSITIVITY AND FEEDBACKS

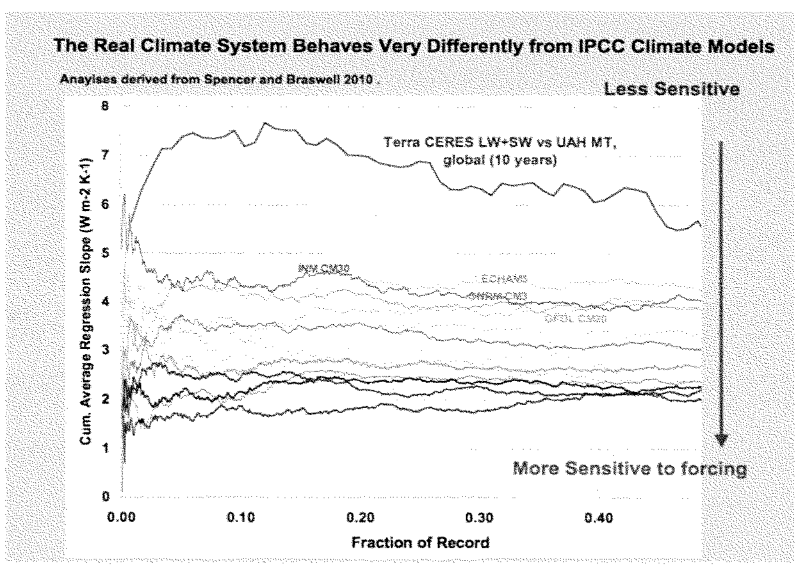
One of the most misunderstood and contentious issues in climate science surrounds the notion of climate sensitivity. Climate sensitivity is a basic variable that seeks to quantify the temperature response of the Earth to a particular forcing, for example answering the question, how much warming can be expected if the warming effect of doubling CO2 acts on the planet? The temperature used in this formulation is nearly always the surface temperature, which is a rather poor metric to serve as a proxy for the total heat content of the climate system, but that is the convention in use today. In any case, it is fairly well agreed that the surface temperature will rise about 1°C as a modest response to a doubling of atmospheric CO2 if the rest of the component processes of the climate system remain independent of this response. This is where the issue becomes uncertain: the complexity and interrelatedness of the various components of the climate system (e.g. clouds) mean they will not sit by independently while CO2 warms the planet a little, but will get into the act too. The fundamental issue in this debate is whether the net response of these interrelated actors will add to the basic CO2 warming (i.e. positive feedbacks) or subtract from the basic CO2 warming (i.e. negative feedbacks.)

Since climate models project a temperature rise on the order of 3 °C for a doubling of CO_2, it is clear that in the models, positive feedbacks come into play to increase the temperature over and above the warming effect of CO_2 alone, which is only about 1°C. However, given such observational results as noted earlier (i.e. warming rates of models being about three times that of observations) one can hypothesize that there must be negative feedbacks in the real world that counteract the positive feedbacks which dominate model processes.

My colleague at UAHuntsville, Dr. Roy Spencer, has searched tediously for a way to calculate climate sensitivity from satellite observations which at the same time would reveal the net response of the feedbacks which is so uncertain today. NASA and NOAA have placed in orbit some terrific assets to answer questions like this. Unfortunately, the best observations to address this issue are only about 10 years in length, which prevents us from directly calculating the sensitivity to 100 years of increasing CO_2. However, the climate sensitivity over shorter periods to natural, unforced variability can be assessed, and this is what Dr. Spencer has done. To put it simply, Spencer tracks large global temperature changes over periods of several weeks. It turns out the global temperature rises and falls by many tenths of a degree over such periods. Spencer is able to measure the amount of heat that accumulates in (departs from) the climate system as the temperature rises (falls) with temperature changes.

When all of the math is done, he finds the real climate system is dominated by negative feedbacks (probably related to cloud variations) that work against changes in temperature once that temperature change has occurred. When this same analysis is applied to climate model output (i.e. apples to apples comparisons), the result is very different, with all models showing positive feedbacks, i.e. helping a warming impulse to warm the atmosphere even more (see figure below.) Thus, the observations and models are again inconsistent. On this time scale in which feedbacks can be assessed, Spencer sees a significant difference between the way the real Earth processes heat and the way models do. This difference is very likely found in the way models treat cloudiness, precipitation and/or heat deposition into the ocean. This appears to offer a strong clue as to why climate models tend to overstate the warming rate of the global atmosphere.

Below: Climate feedback parameter from observations (blue, top line) and IPCC AR4 model simulations (other lines, derived from results in Spencer and Braswell 2010.) Model parameters cluster in a grouping that indicates considerably more sensitivity to forcing than indicated by observations.



The bottom line of this on-going research is that over time periods for which we are able to determine climate sensitivity, the evidence suggests that all models are characterized by feedback processes that are more positive than feedback processes measured in nature.

CONSENSUS SCIENCE

The term "consensus science" will often be appealed to in arguments about climate change. This is a form of "argument from authority." Consensus, however, is a political notion, not a scientific notion. As I testified to the Inter-Academy Council last June, the IPCC and other similar Assessments do not represent for me a consensus of much more than the consensus of those who already agree with a particular consensus. The content of these reports is actually under the control of a relatively small number of individuals - I often refer to them as the "climate establishment" – who through the years, in my opinion, came to act as *gatekeepers* of scientific opinion and information, rather than *brokers*. The voices of those of us who object to various statements and emphases in these assessments are by-in-large dismissed rather than acknowledged.

I've often stated that climate science is a "murky science." We do not have laboratory methods of testing our hypotheses as many other sciences do. As a result, opinion, arguments from authority, dramatic press releases, and notions of consensus tend to pass for science in our field when they should not.

I noticed the House has passed an amendment to de-fund the Intergovernmental Panel on Climate Change (IPCC.) I have a proposal here. If the IPCC activity *is* ultimately funded by US taxpayers, then I propose that ten percent of the funds be allocated to a group of well-credentialed scientists with help from individuals experienced in creating verifiable reports, to produce an assessment that expresses alternative hypotheses that have been (in their view) marginalized, misrepresented or minimized in previous IPCC reports. We know from climategate emails and many other sources of information that the IPCC has had problems with those who take different positions on climate change. Topics to be addresses in this assessment, for example, would include (a) evidence for a low climate sensitivity to increasing greenhouse gases, (b) the role and importance of natural, unforced variability, (c) a rigorous evaluation of climate model output, (d) a thorough discussion of uncertainty, (e) a focus on metrics that most directly relate to the rate of accumulation of heat in the climate system (which, for example, the problematic surface temperature record does not represent), (f) analysis of the many consequences, including benefits, that result from CO2 increases, and (g) the importance that accessible energy has to human health and welfare. What this proposal seeks to accomplish is to provide to the congress and other policymakers a parallel, scientifically-based assessment regarding the state of climate science which addresses issues which here-to-for have been un- or under-represented by previous tax-payer funded, government-directed climate reports.

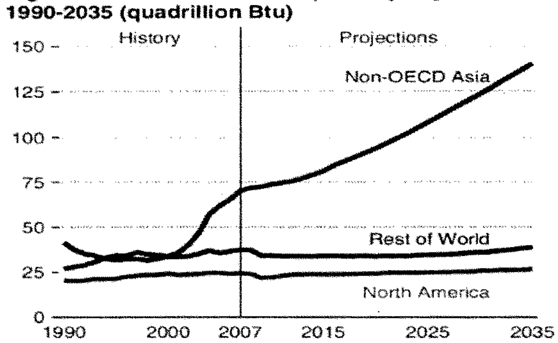
IMPACT OF EMISSION CONTROL MEASURES

The evidence above suggests that climate models overestimate the response of temperature to greenhouse gas increases. Even so, using these climate model simulations we calculate that the impact of legislative actions being considered on the global temperature is essentially imperceptible. These actions will not result in a measurable climate effect that can be attributable or predictable with any level of confidence, especially at the regional level.

When I testified before the Energy and Commerce Oversight and Investigations subcommittee in 2006 I provided information on an imaginary world in which 1,000 1.4 gW nuclear power plants would be built and operated by 2020. This, of course, will not happen. Even so, this Herculean effort would result in at most a 10 percent reduction in global CO2 emissions, and thus exert a tiny impact on whatever the climate is going to do. Indeed, with these most recent estimates of climate sensitivity, the impact of these emission control measures will be even tinier since the climate system doesn't seem to be very sensitive to CO2 emissions. (Note: we have not considered the many positive benefits of higher concentrations of CO2 in the atmosphere, especially for the biological world, nor the tremendous boost to human health, welfare, and security provided by affordable, carbon-based energy. As someone who has lived in a developing country, I can assure the subcommittee that without energy, life is brutal and short.)

Coal use, which generates a major portion of CO2 emissions, will continue to rise as indicated by the Energy Information Administration's chart below. Developing countries in Asia already burn more than twice the coal that North America does, and that discrepancy will continue to expand. The fact our legislative actions will be inconsequential in the grand scheme of things can be seen by noting that these actions attempt to bend the blue, North American curve, which is already fairly flat, down a little. So, downward adjustments to North American coal use will have virtually no effect on global CO2 emissions (or the climate), no matter how sensitive one thinks the climate system might be to the extra CO2 we are putting back into the atmosphere.

Figure 5. World coal consumption by region, 1990-2035 (quadrillion Btu)



International Energy Outlook 2010
Energy Information Agency
http://www.eia.doe.gov/oiaf/ieo/index.html

Thus, if the country deems it necessary to de-carbonize civilization's main energy sources, sound and indeed *compelling* reasons beyond human-induced climate change need to be offered. Climate change alone is a weak leg on which to stand for such a massive undertaking. (I'll not address the fact there is really no demonstrated technology except nuclear that can replace large portions of the carbon-based energy production.)

Thank you for this opportunity to offer my views on climate change.

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Mr. WHITFIELD. Dr. Field, you are recognized for 5 minutes.

STATEMENT OF CHRISTOPHER FIELD

Mr. FIELD. Thank you, Chairman Whitfield, Mr. Rush, and distinguished members of the committee. It is a pleasure to speak with you today. And I want to congratulate you on the initiative to consider climate sciences and its importance for the country and the future.

I am a professor of environmental earth system science at Stanford University and director of the Carnegie Institution's Department of Global Ecology. I have worked on climate change-related issues for the past 25 years. And I want to start with two key foundational points. The first is that climate warming over the last century is unequivocal and primarily human caused. The second is that climate changes are already occurring in the United States and they are projected to grow in the future.

It is important to realize that the world has convened a large number of scientific organizations, several in the United States, coordinated by the U.S. Global Change Research Program, by the National Academy of Sciences, or internationally by the Intergovernmental Panel on Climate Change. And in each of these consortia, there has been an aggressive, comprehensive effort to consolidate views across the spectrum of climate science. We haven't looked at institutions that have been put together to reflect one perspective or another. And when we see as what appears as consensus statements, these are overviews of the positions of the wide range of climate scientists, including the full diversity of positions and the measured statements that come from these assessments are in fact reflecting the entire diversity across the spectrum of legitimate science.

What I would like to do in my comments is focus specifically on relatively recent research on the sensitivity of key sectors in the United States to climate change. My distinguished colleagues who focus more on atmospheric science will talk about where we are headed with the climate and where we have been, but what I want to do is talk about sensitivity that is observed from data, not based on simulations, that takes advantage of the fact that, for example, the U.S. Department of Agriculture has been surveying crop fields very, very carefully over the last more than 100 years. And I want to focus on two important sectors for the United States. The first is yields of agriculture and their sensitivity to climate change; the second is wildfires in the west and its sensitivity to climate change.

By looking at the summary of global agriculture yields over the last 50 years or so, we can see that agriculture is one of the triumphs of human ingenuity. We have been able to increase crop yields by 1 percent to 2 percent per year over many decades, but there is increasing evidence that we are doing this with an anchor or climate change that is pulling us back. By looking at the year-to-year variations in climate change, we can see that for several of the world's major food crops, there has been a negative effect of warming that is occurring on our ability to increase yields, such that for crops including wheat, corn, and barley, we are seeing a decrease globally that means that something like 40 million tons of food production has been foregone as a consequence of the climate changes that have already occurred.

For each of these crops, we see a sensitivity to warming, based on observations, not simulations, of something like 10 percent yield loss for each 1.8 degrees Fahrenheit of warming. In terms of 2002 ag yields, this 40 million tons of foregone productivity represents an economic loss of about $5 billion.

Recently, Wolfgang Schlenker and John Roberts have explored the climate sensitivity of U.S. agriculture using an incredibly detailed data set that has allowed them to, with much higher precision, assess the sensitivity of U.S. crops. And what they find is that for corn, soybeans, and cotton, there is a profound sensitivity to warming such that at a threshold that is about 82 for corn, 84 for soybeans, and about 90 for cotton, you see a very steep drop-off in productivity as temperatures rise above that. There is no question that temperatures are at these thresholds and exceeding them relatively frequently.

With wildfires, we see a pattern where warmer, longer summers increase the probability of wildfires. And what we have seen by summarizing wildfire data is that in the United States a warming of 1.8 Fahrenheit increases on average the area in the west that has burned from 1.3 million acres per year to 4.5 million acres per year. These are profound effects that indicate, based on observations, the deep sensitivity of U.S. activities.

Mr. WHITFIELD. Thank you very much, Dr. Field.

[The prepared statement of Mr. Field follows:]

Summary of Major Points: Christopher B. Field, PhD[1], Carnegie Institution for Science[2], Energy and Commerce Committee, Subcommittee on Energy and Power: "Climate Science and the EPA's Greenhouse Gas Regulations", March 8, 2011

The modern understanding of climate change is based on many lines of robust, independent evidence, providing a foundation of well established conclusions, including the following, from the US Global Change Research Program: *(1) Global warming is unequivocal and primarily human-induced, (2) Climate changes are underway in the United States and are projected to grow, and (3) Widespread climate-related impacts are occurring now and are expected to increase.*

Against these foundations, I want to talk about the observed (not simulated) climate sensitivity of two important processes – US agriculture and wildfires in the Western US.

- Observed yields of corn, soybean, and cotton all have clear temperature thresholds, below which yields are stable and above which yields fall quickly with rising temperatures. A single day of 104°F instead of 84°F reduces corn yields by about 7%. Modest warming over the century is expected to reduce yields by 30-46% below levels that would otherwise occur, and severe warming could reduce yields by 63-82%
- Large wildfires in the Western US are more frequent, last longer, and occur over a longer fire season in years that are unusually warm. Based on observed patterns, a 1.8°F warming would increase the annual area burned from 1.3 million acres (the average for 1970-2003) to 4.5 million acres.

[1] Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect those of the Carnegie Institution for Science or the IPCC

[2] The Carnegie Institution for Science is a not-for-profit organization dedicated to basic research for the benefit of humanity.

Statement of
Christopher B. Field, PhD[3]

Director, Department of Global Ecology
Carnegie Institution for Science[4]
Co-chair, Working Group II of the IPCC

Mailing Address:
Carnegie Institution for Science
260 Panama Street
Stanford, CA 94305

Before the
U.S. House of Representatives
Energy and Commerce Committee
Subcommittee on Energy and Power
"Climate Science and the EPA's Greenhouse Gas Regulations"

10:00 a.m., March 8, 2011
Room 2123, Rayburn House Office Building

[3] Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect those of the Carnegie Institution for Science or the IPCC
[4] The Carnegie Institution for Science is a not-for-profit organization dedicated to basic research for the benefit of humanity.

Climate Science and the EPA's Greenhouse Gas Regulations

Introduction

I thank Chairman Upton, Ranking Member Waxman, Chairman of the Subcommittee Whitfield, Ranking Member of the Subcommittee Rush, and the other Members of the Committee for the opportunity to speak with you today on observed impacts of climate on important processes in our country. My name is Christopher Field. I am director of the Department of Global Ecology at the Carnegie Institution for Science, a not-for-profit organization dedicated to basic research for the benefit of humanity. In addition, I am a professor in the Department of Environmental Earth System Science and the Department of Biology at Stanford University. Since September of 2008, I have served as co-chair of Working Group 2 of the Intergovernmental Panel on Climate Change. Working Group 2 is tasked with assessing scientific information concerning impacts of climate change, options for adaptation to climate changes that cannot be avoided, and vulnerability to climate change.

My personal research focuses on interactions among climate, the carbon cycle, and ecosystem processes, using approaches that range from ecosystem-scale climate manipulations to global climate models. I have published over 200 peer-reviewed papers in leading scientific journals, and was a coordinating lead author on the topic "North America" for the Working Group 2 contribution to the IPCC Fourth Assessment Report. I have served on many committees of the National Research Council and International Scientific Organizations. I am an elected member of the US National Academy of Sciences and the American Academy of Arts and Sciences as well as an elected Fellow of the American Association for the Advancement of Science.

In today's testimony, I will focus on two aspects of observed sensitivity of important processes to climate. The two processes are agricultural yields in the United States and wildfire in the Western United States. The sensitivities I want to discuss today are based on observations and not on simulations. All of the material I will be discussing today is based on publications in peer-reviewed scientific journals or on national or international assessments of thousands of scientific sources.

Robust Foundations of Current Knowledge

The starting point for the material I want to discuss today is a series of robust conclusions from climate science, synthesized in a number of recent major assessments including two 2010 reports from the US National Academy of Sciences, "Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia" (Solomon 2010), and "Advancing the Science of Climate Change" (Matson 2010), the 2009 report from the US Global Change Research Program, "Global Climate Change Impacts in the United States" (Karl et al. 2009) and the Fourth Assessment Report of the IPCC (IPCC 2007a, c, b). These documents provide a scientifically rich picture of a changing climate, the mechanisms that underlie observed and projected changes, impacts of climate change on individuals, ecosystems, economies, and regions, and the costs and benefits of changing practices to decrease the amount of climate change from a business-as-usual scenario.

The following 10 points, quoted from (Karl et al. 2009), form the foundation for any discussion of climate change and its impacts:

"*1. Global warming is unequivocal and primarily human-induced.*
Global temperature has increased over the past 50 years. This observed increase is due primarily to human induced emissions of heat-trapping gases.

2. Climate changes are underway in the United States and are projected to grow.
Climate-related changes are already observed in the United States and its coastal waters. These include increases in heavy downpours, rising temperature and sea level, rapidly retreating glaciers, thawing permafrost, lengthening growing seasons, lengthening ice-free seasons in the ocean and on lakes and rivers, earlier snowmelt, and alterations in river flows. These changes are projected to grow.

3. Widespread climate-related impacts are occurring now and are expected to increase.
Climate changes are already affecting water, energy, transportation, agriculture, ecosystems, and health. These impacts are different from region to region and will grow under projected climate change.

4. Climate change will stress water resources.
Water is an issue in every region, but the nature of the potential impacts varies. Drought, related to reduced precipitation, increased evaporation, and increased water loss from plants, is an important issue in many regions, especially in the West. Floods and water quality problems are likely to be amplified by climate change in most regions. Declines in mountain snowpack are important in the West and Alaska where snowpack provides vital natural water storage.

5. Crop and livestock production will be increasingly challenged.
Many crops show positive responses to elevated carbon dioxide and low levels of warming, but higher levels of warming often negatively affect growth and yields. Increased pests, water stress, diseases, and weather extremes will pose adaptation challenges for crop and livestock production.

6. Coastal areas are at increasing risk from sea-level rise and storm surge.
Sea-level rise and storm surge place many U.S. coastal areas at increasing risk of erosion and flooding, especially along the Atlantic and Gulf Coasts, Pacific Islands, and parts of Alaska. Energy and transportation infrastructure and other property in coastal areas are very likely to be adversely affected.

7. Risks to human health will increase.
Harmful health impacts of climate change are related to increasing heat stress, waterborne diseases, poor air quality, extreme weather events, and diseases transmitted by insects and rodents. Reduced cold stress provides some benefits. Robust public health infrastructure can reduce the potential for negative impacts.

8. Climate change will interact with many social and environmental stresses.

Climate change will combine with pollution, population growth, overuse of resources, urbanization, and other social, economic, and environmental stresses to create larger impacts than from any of these factors alone.

9. Thresholds will be crossed, leading to large changes in climate and ecosystems.
There are a variety of thresholds in the climate system and ecosystems. These thresholds determine, for example, the presence of sea ice and permafrost, and the survival of species, from fish to insect pests, with implications for society. With further climate change, the crossing of additional thresholds is expected.

10. Future climate change and its impacts depend on choices made today.
The amount and rate of future climate change depend primarily on current and future human-caused emissions of heat-trapping gases and airborne particles. Responses involve reducing emissions to limit future warming, and adapting to the changes that are unavoidable."

Recent Results: Observed Responses of the Temperature Sensitivity of US Agriculture

Globally and in the US, advancements in agriculture are among the crowning accomplishments of human ingenuity. Especially over the last century, yields have increased dramatically (Lobell et al. 2009), more than keeping pace with the growth of human population. One recent analysis concludes that agricultural intensification since 1961 has increased yields so much that the area in crops has not needed to change, even as demand has soared (Burney et al. 2010). As a consequence, intensification of agriculture has prevented deforestation that otherwise would have emitted 161 billion tons of carbon to the atmosphere.

Over recent decades, yields of most major crops have increased at 1-2% per year (Lobell and Field 2007), but an increasing body of evidence indicates that obtaining these yield increases is becoming more and more difficult, as climate change acts to resist or reverse yield increases from improvements in management and breeding. Using global records of yield trends in the world's six major food crops since 1961, my colleague David Lobell and I (Lobell and Field 2007) concluded that, at the global scale, effects of warming are already visible, with global yields of wheat, corn, and barley reduced since 1981 by 40 million tons per year below the levels that would occur without the warming. As of 2002 (the last year analyzed in the study), this represents an economic loss of approximately $5 billion per year.

In the United States, the observed temperature sensitivity of three major crops is even more striking. Based on a careful county-by county analysis of patterns of climate and yields of corn, soybeans, and cotton, Schlenker and Roberts (Schlenker and Roberts 2009) concluded that observed yields from all farms and farmers are relatively insensitive to temperature up to a threshold but fall rapidly as temperatures rise above the threshold. For farms in the United States, the temperature threshold is 84°F for corn, 86°F for soybeans, and 90°F for cotton. For corn, a single day at 104°F instead of 84°F reduces observed yields by about 7%. These temperature sensitivities are based on observed responses, including data from all of the US counties that grow cotton and all of the Eastern counties that grow corn or soybeans. These are not simulated responses. They are observed in the aggregate yields of thousands of farms in thousands of locations.

The temperature sensitivity observed by Schlenker and Roberts (Schlenker and Roberts 2009) suggests a challenging future for US agriculture. Unless we can develop varieties with improved heat tolerance, modest warming (based on the IPCC B1 scenario) by the end of the 21st century will reduce yields by 30-46%. With a high estimate of climate change (based on the IPCC A1FI scenario), the loss of yield is 63-82%. These three major crops, in some ways the core of US agriculture, are exquisitely sensitive to warming. This result is very clear. We may be able to breed warming tolerant varieties, and it is possible that some of the yield losses due to warming will be compensated by positive responses to elevated atmospheric CO_2 (Long et al. 2006), but we will be trying to improve yields in a setting where warming is like an anchor pulling us back.

Recent Results: Observed Responses of the Temperature Sensitivity of Wildfires in the Western US

Wildfire is a common threat in the Western US. While historical, low-intensity wildfires can play an important role in sustaining the health of ecosystems (Minnich 1983), large, high-intensity wildfires destroy lives and homes, impact air quality, degrade watersheds, reduce economic activity, and eliminate wildlife habitat. In recent years, suppression costs have been over $1 billion per annum (Littell et al. 2009).

Westerling and colleagues (Westerling et al. 2006) compiled a database of 1166 large wildfires in the US during the period from 1970 to 2003. They observed a large increase in fire frequency, duration, and in the length of the fire season after the mid 1980s. This increase in fire activity was strongly related to warm spring and summer temperatures. Over this period, the length of time from snow-melt in the spring to the first snow-fall in the autumn is a good predictor of the fire risk.

Littell and colleagues (Littell et al. 2009) looked at a longer series of fire records and analyzed the data for relationships with temperature and rainfall. They found that, for most Western ecosystems, climate is a strong predictor of wildfire area burned, with current-year temperature explaining a significant amount of the variability in most regions. The striking feature of these results, based on observations and not simulations is the sensitivity. For most of the West, the annual area burned increases by 200 to over 600% for every 1.8°F of warming (Solomon 2010). It is only in the driest regions, where warming makes it too dry for fire, that there is not a strong positive response. Based on these observed sensitivities, warming of 1.8°F is expected to increase the area burned from 1.3 million acres per year (the 1970-2003 average) to 4.5 million acres (Solomon 2010).

Conclusion

Many lines of robust, independent evidence support the conclusion that the climate has been warming over the past century and that human emissions of heat-trapping gases are very likely responsible for much of the warming since the middle of the last century (IPCC 2007d). We are already seeing a wide range of impacts of these climate changes (IPCC 2007e). Although there is scientific uncertainty about the amount of future warming, it is very clear that, unless emissions of heat-trapping gases decrease dramatically, the planet will warm substantially in coming decades. New data on sensitivities, here I have discussed US agriculture and wildfire, emphasize the magnitude of the risk for the United States. Based on observations, not simulations, the sensitivities to warming of both agriculture and wildfire are more than sufficient to cause pervasive regional harm, with even modest warming.

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IPCC. 2007e. Summary for Policymakers. Pages 7-22 *in* M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson, editors. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

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Mr. WHITFIELD. And Dr. Pielke, you are recognized for your 5-minute opening statement.

STATEMENT OF ROGER PIELKE

Mr. PIELKE. Thank you. I have worked throughout my career to improve environmental issues, including air quality, by conducting research, teaching, and also providing scientifically rigorous information to policymakers. At the State level, I served two terms on the Colorado Air Quality Control Commission, where we developed the oxygenated fuels program through reduce carbon dioxide emissions from vehicles, promulgated regulations to mandate strict controls on wood and coal burning in residential fireplaces and stoves, and on asbestos concentrations in the air.

In my testimony today and in more detail in my written testimony, I have four main points.

First, research has shown that a focus on just carbon dioxide and a few other greenhouse gases as the dominant human force on climate is too narrow and misses other important influences.

Two, the phrases global warming and climate change are not the same. Global warming is a subset of climate change.

Three, the prediction or projection of reasonable weather including extremes decades into the future is far more difficult than commonly assumed. As well, the attribution of a string of events to a particular subset of climate force scenes is scientifically incomplete if the research ignores other relevant human and natural causes of extreme weather events.

And, four, the climate science assessments of the IPCC and CCSP, as well as the various statements issued by the AGU, AMS, and NRC are completed by a small subset of climate scientists who are often the same individuals.

Decisions about government regulation are ultimately legal, administrative, legislative, and political decisions. As such, they can be informed by scientific considerations but they are not determined by them. In my testimony, I seek to share my perspectives on the science of climate based on my work in this field over the past four decades.

First, the production of multi-decadal climate predictions of reasonable impacts whose skill cannot be verified until decades from now is not a robust scientific approach. Models themselves are hypotheses. The steps of hypotheses written with respect to climate predictions are, first, make a prediction; quantitatively the prediction with real-world observations, that is test the hypothesis; and, three, communicate the assessment of the scale of the prediction.

There is no way to test that a hypothesis with a multi-decadal global climate model forecast for decades from now as step two as a verification of the skill of these forecasts is not possible until decades pass.

There has also been a misunderstanding of the relationship between global warming and climate variability and longer term change. Global warming is typically defined as an increase in the global average surface temperature. A better metric is the global annual average heat content measured in Joules. Global warming involves the accumulation of heat and Joules within the components of the climate system. This accumulation is dominating by the heating and cooling within the upper layers of the ocean.

Climate change, in contrast, is any multi-decadal or longer alteration in one or more physical, chemical, and/or biological components of the climate system. Climate change involves, for example, changes in fauna and flora, snow cover, and so forth, which persists for decades and longer. Climate variability can then be defined as changes which occur on shorter time periods.

With respect to climate change. In 2009, 18 fellows of the American Geophysical Union accepted an invitation to join me in a paper where we discuss three different mutually exclusive hypotheses with respect to the climate system.

Hypothesis 1. Human influence on climate variability and change is of minimal importance, and natural causes dominate climate variations and changes on all time scales. In coming decades, the human influence will continue to be minimal.

Hypothesis 2a. Although the natural causes of climate variations and changes are undoubtedly important and human influences are significant and involve a diverse range of first-order climate forcings, including but not limited to the human input of carbon dioxide. Most, if not all, of these human influences on regional and global climate will continue to be of concern for the coming decades.

Hypothesis 2b. Although the natural causes of climate variation and change are undoubtedly important, the human influences are significant and dominated by the emissions in the atmosphere of greenhouse gases, the most important of which is carbon dioxide. The adverse effect of these gasses on regional and global climate constitutes the primary climate issue for the coming decades.

Hypothesis 2b, the one with the CO_2 dominance, is the IPCC perspective. In our EOS paper we concluded, however, that only hypothesis A has not been refuted. Hypotheses 1 and 2b are inaccurate characterizations of the climate system.

In our 2009 paper, we concluded, in addition to greenhouse gas emissions, the other first order forcings are important to understand the earth's climate. These forcings are spatially heterogeneous and include effects of aerosols on clouds and associated precipitation, the use of aerosol deposition, and reactive carbon in the roles of land use and land cover change. Among their effect is the role in altering atmospheric and ocean circulations away from what they would be in a natural climate system. As with CO_2, the length of time that they affect the climate or estimated on multi-decadal time scales are longer.

We concluded, therefore, the cost benefit analysis regarding the mitigation of carbon dioxide and other greenhouse gases need to be considered along with other human climate forces in a broader environmental context, as well with respect to the role on the climate system.

Unfortunately, the 2007 IPCC assessment did not significantly acknowledge the importance of these and other human climate forcings in altering regional and global climate and their effects on predictability at the regional scale.

A major conclusion indicated from these studies is that regional atmospheric and ocean circulation features produce extreme events, not a global annual average surface temperature anomaly. It is the multi-decadal change and the statistics of these circulation features in response——

Mr. WHITFIELD. You can complete.

Mr. PIELKE. In response to natural and human forcings and feedbacks which must be skillfully predicted, this level of predictive scale has not been achieved even in hindcasts of past decades.

And my last point is policymakers and the public rarely encounter this broader view of the climate system, in part, due to the limited number of scientists who are leading climate assessments. As just one example, I present my experience with the first CCS report, and my experience is documented in a public comment.

In the executive summary of that report, I stated: The processes for completing the CCS report excluded valid scientific perspectives under the charge of the committee. The editor of the report systematically excluded a range of views on the issues of understanding reconciling lower atmospheric temperature trends.

Future assessment committees need to appoint members with a diversity of views who do not have a significant conflict of interest with respect to their own work. Such committees should be chaired by individuals committed to the presentation of a diversity of perspectives and unwilling to engage in strong-arm tactics to enforce a narrow perspective. Any such committee should be charged with summarizing all relevant literature, even if inconvenient or which presents a view not held by certain members of the committee.

Finally, I have proposed a new approach in the climate committee based on a bottom-up resource-based perspective. There are five broad areas that we can use to define a need for this assessment.

Mr. WHITFIELD. OK. Thanks.

[The prepared statement of Mr. Pielke follows:]

<u>Testimony to the Subcommittee on Energy and Power entitled "Climate Science and EPA's Greenhouse Gas Regulation</u>

<u>Roger A. Pielke Sr.</u>
<u>University of Colorado at Boulder and Colorado State University</u>
8 March 2011

I have worked throughout my career to improve environmental conditions, including air quality, by conducting research, teaching, and also by providing scientifically rigorous information to policymakers.

For example, at the local level, I worked with the National Wildlife Federation to prevent a ski area from building in a pristine area of southwest Colorado. I also served on a local board of the Nature Conservancy and was on a committee in Fort Collins, Colorado that mandated that the permit to construct and operate a brewery near the city require the burning of natural gas rather than coal.

At the state level, I served two terms on the Colorado Air Quality Control Commission where we developed the oxygenated fuels program to reduce atmospheric CO emissions from vehicles, promulgated regulations to mandate strict controls on wood and coal burning in residential fireplaces and stoves, and on asbestos concentrations in the air. I also served on Governor Romer's Blue Ribbon Committee to develop approaches to reduce diesel emissions into the atmosphere. I was also a member of a National Research Council committee that recommended rejecting an attempt to exempt certain locations such as Fairbanks Alaska from the national CO health standard.[1] I also served on a National Research Council to communicate major concerns related to overgrazing, which includes an increase in dust emissions into the atmosphere.[2]

I have taught graduate classes and advised numerous graduate students in air pollution, modeling, weather and forecasting and climate at the University of Virginia, Colorado State University, the University of Arizona, and the University of Colorado in Boulder. My full academic record is available a:
http://cires.colorado.edu/science/groups/pielke/

In my testimony today I have four main points:

1. **Research has shown that a focus on just carbon dioxide and a few other greenhouse gases as the dominant human influence on climate is too narrow, and misses other important human influences.**

[1]National Research Council, 2003: Managing carbon monoxide pollution in meteorological and topographical problem areas. The National Academies Press, Washington, DC, 196 pp.

[2]Committee on Scholarly Communication with the People's Republic of China, 1992: Grasslands and grassland sciences in Northern China, Office of International Affairs, National Research Council, National Academy Press, Washington, D.C., 214 pp.

2. **The phrases "global warming" and "climate change" are not the same. Global warming is a subset of climate change.**

3. **The prediction (or projection) of regional weather, including extremes, decades into the future is far more difficult than commonly assumed. In addition, the attribution of extreme events to a particular subset of climate forcings is scientifically incomplete if the research ignores other relevant human and natural causes of extreme weather events.**

4. **The climate science assessments of the IPCC and CCSP, as well as the various statements issued by the AGU, AMS, and NRC, are completed by a small subset of climate scientists who are often the same individuals in each case.**

Decisions about government regulation are ultimately legal, administrative, legislative, and political decisions. As such they can be informed by scientific considerations, but they are not determined by them. In my testimony, I seek to share my perspectives on the science of climate based on my work in this field over the past four decades.

I elaborate on each of the four conclusions below.

The production of multi-decadal climate predictions of regional impacts, whose skill cannot be verified until decades from now, is not a robust scientific approach. Models themselves are hypotheses. The steps of hypothesis written with respect to climate predictions are

1. *Make a Prediction*
2. *Quantitatively Compare the Prediction With Real World Observations [i.e. Test the Hypothesis]*
3. *Communicate The Assessment of the Skill of the Prediction*

There is no way to test hypotheses with the multi-decadal global climate model forecasts for decades from now, as step 2 as a verification of the skill of these forecasts, is not possible until the decades pass.

There has also been a misunderstanding of the relationship between global warming and climate variability and longer-term change.

Global Warming is typically defined as an increase in the global average surface temperature. A better metric is the global annual average heat content measured in Joules. Global warming involves the accumulation of heat in Joules within the components of the climate system. This accumulation is dominated by the heating and cooling within the upper layers of the oceans.

Climate Change is any multi-decadal or longer alteration in one or more physical, chemical and/or biological component of the climate system.

The climate system is illustrated in the figure below from the NRC (2005).

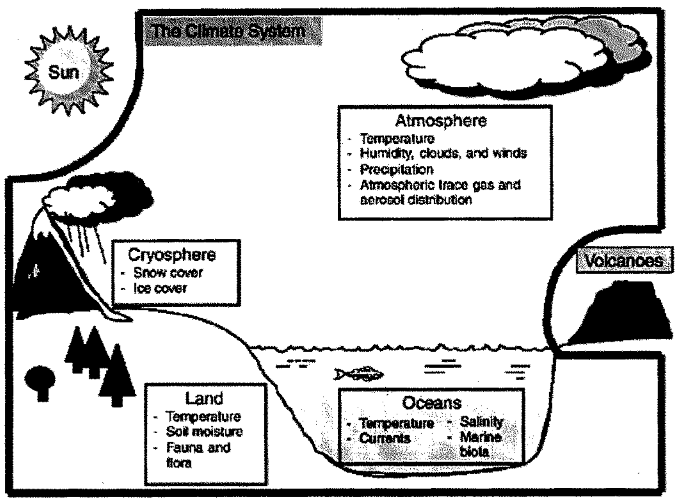

Figure caption: The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes to the land surface are considered external to the climate system. Source: National Research Council, 2005: Radiative forcing of climate change: Expanding the concept and addressing uncertainties. Committee on Radiative Forcing Effects on Climate Change, Climate Research Committee, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C., 208 pp

Climate change includes, for example, changes in fauna and flora, snow cover, etc. which persist for decades and longer. Climate variability can then be defined as changes which occur on shorter time periods.

The use of a global annual average surface temperature anomaly as the metric to diagnose global warming is inaccurate and contains significant uncertainties and several systematic biases.[3]

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[3]Pielke Sr., R.A., C. Davey, D. Niyogi, S. Fall, J. Steinweg-Woods, K. Hubbard, X. Lin, M. Cai, Y.-K. Lim, H. Li, J. Nielsen-Gammon, K. Gallo, R. Hale, R. Mahmood, S. Foster, R.T. McNider, and P. Blanken,

The current best estimate of the rate of global warming from 2005 to mid-2010 is **a rate of 0.425** of that reported by Jim Hansen which he based on a multi-decadal climate model prediction for the period 1993 to 2003 (and presumably would be an even higher rate now).[4] This is still a relatively short time period and fits within the variability of the multi-decadal global model prediction, but it is a primary global warming metric that should be elevated in its prominence.

With respect to climate change, in 2009, 18 Fellows of the American Geophysical Union accepted an invitation to join me in a paper where we discussed three different mutually exclusive hypotheses with respect to the climate system:[5]

Hypothesis 1: Human influence on climate variability and change is of minimal importance, and natural causes dominate climate variations and changes on all time scales. In coming decades, the human influence will continue to be minimal.

Hypothesis 2a: Although the natural causes of climate variations and changes are undoubtedly important, the human influences are significant and involve a diverse range of first-order climate forcings, including, but not limited to, the human input of carbon dioxide (CO_2). Most, if not all, of these human influences on regional and global climate will continue to be of concern during the coming decades.

Hypothesis 2b: Although the natural causes of climate variations and changes are undoubtedly important, the human influences are significant and are dominated by the emissions into the atmosphere of greenhouse gases, the most important of which is CO_2. The adverse impact of these gases on regional and global climate constitutes the primary climate issue for the coming decades.

Hypothesis 2b is the IPCC perspective. In our EOS paper, we concluded that only **Hypothesis 2a** has not been refuted. **Hypotheses 1 and 2b** are inaccurate characterizations of the climate system.

2007: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Res., 112, D24S08, doi:10.1029/2006JD008229. Klotzbach, P.J., R.A. Pielke Sr., R.A. Pielke Jr., J.R. Christy, and R.T. McNider, 2009: An alternative explanation for differential temperature trends at the surface and in the lower troposphere. J. Geophys. Res., 114, D21102, doi:10.1029/2009JD011841.

[4]Expressed as a global annual average in heat content change in Joules – from Update Of Preliminary Upper Ocean Heat Data Analysis By Josh Willis – "An Unpublished Update" - http://pielkeclimatesci.wordpress.com/2011/02/13/update-of-preliminary-upper-ocean-heat-data-analysis-by-josh-willis-%e2%80%93-%e2%80%9can-unpublished-update%e2%80%9d/

[5]Pielke Sr., R., K. Beven, G. Brasseur, J. Calvert, M. Chahine, R. Dickerson, D. Entekhabi, E. Foufoula-Georgiou, H. Gupta, V. Gupta, W. Krajewski, E. Philip Krider, W. K.M. Lau, J. McDonnell, W. Rossow, J. Schaake, J. Smith, S. Sorooshian, and E. Wood, 2009: Climate change: The need to consider human forcings besides greenhouse gases. Eos, Vol. 90, No. 45, 10 November 2009, 413. Copyright (2009) American Geophysical Union

In our 2009 paper we wrote

> *"In addition to greenhouse gas emissions, other first-order human climate forcings are important to understanding the future behavior of Earth's climate. These forcings are spatially heterogeneous and include the effect of aerosols on clouds and associated precipitation [e.g., Rosenfeld et al., 2008], the influence of aerosol deposition (e.g., black carbon (soot) [Flanner et al. 2007] and reactive nitrogen [Galloway et al., 2004]), and the role of changes in land use/land cover [e.g., Takata et al., 2009]. Among their effects is their role in altering atmospheric and ocean circulation features away from what they would be in the natural climate system [NRC, 2005]. As with CO2, the lengths of time that they affect the climate are estimated to be on multidecadal time scales and longer."*

We concluded that

> *"Therefore, the cost- benefit analyses regarding the mitigation of CO2 and other greenhouse gases need to be considered along with the other human climate forcings in a broader environmental context, as well as with respect to their role in the climate system"*

and

> *"The evidence predominantly suggests that humans are significantly altering the global environment, and thus climate, in a variety of diverse ways beyond the effects of human emissions of greenhouse gases, including CO2. Unfortunately, the 2007 Intergovernmental Panel on Climate Change (IPCC) assessment did not sufficiently acknowledge the importance of these other human climate forcings in altering regional and global climate and their effects on predictability at the regional scale."*

This broader view is supported by several broad-based multi-author assessments.[6]

In 2005 the National Research Council concluded,

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[6]Kabat, P., Claussen, M., Dirmeyer, P.A., J.H.C. Gash, L. Bravo de Guenni, M. Meybeck, R.A. Pielke Sr., C.J. Vorosmarty, R.W.A. Hutjes, and S. Lutkemeier, Editors, 2004: Vegetation, water, humans and the climate: A new perspective on an interactive system. Springer, Berlin, Global Change - The IGBP Series, 566 pp.
McAlpine, C.A., W.F. Laurance, J.G. Ryan, L. Seabrook, J.I. Syktus, A.E. Etter, P.M. Fearnside, P. Dargusch, and R.A. Pielke Sr. 2010: More than CO2: A broader picture for managing climate change and variability to avoid ecosystem collapse. Current Opinion in Environmental Sustainability, 2:334-336, DOI10.1016/j.cosust.2010.10.001.
National Research Council, 2005: Radiative forcing of climate change: Expanding the concept and addressing uncertainties. Committee on Radiative Forcing Effects on Climate Change, Climate Research Committee, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C., 208 pp.

"....the traditional global mean TOA radiative forcing concept has some important limitations, which have come increasingly to light over the past decade. The concept is inadequate for some forcing agents, such as absorbing aerosols and land-use changes, that may have regional climate impacts much greater than would be predicted from TOA radiative forcing. Also, it diagnoses only one measure of climate change—global mean surface temperature response—while offering little information on regional climate change or precipitation."

"Regional variations in radiative forcing may have important regional and global climatic implications that are not resolved by the concept of global mean radiative forcing. Tropospheric aerosols and landscape changes have particularly heterogeneous forcings. To date, there have been only limited studies of regional radiative forcing and response. Indeed, it is not clear how best to diagnose a regional forcing and response in the observational record; regional forcings can lead to global climate responses, while global forcings can be associated with regional climate responses. Regional diabatic heating can also cause atmospheric teleconnections that influence regional climate thousands of kilometers away from the point of forcing. Improving societally relevant projections of regional climate impacts will require a better understanding of the magnitudes of regional forcings and the associated climate responses."

"Several types of forcings—most notably aerosols, land-use and land-cover change, and modifications to biogeochemistry—impact the climate system in nonradiative ways, in particular by modifying the hydrological cycle and vegetation dynamics. Aerosols exert a forcing on the hydrological cycle by modifying cloud condensation nuclei, ice nuclei, precipitation efficiency, and the ratio between solar direct and diffuse radiation received. Other nonradiative forcings modify the biological components of the climate system by changing the fluxes of trace gases and heat between vegetation, soils, and the atmosphere and by modifying the amount and types of vegetation. No metrics for quantifying such nonradiative forcings have been accepted. Nonradiative forcings have eventual radiative impacts, so one option would be to quantify these radiative impacts. However, this approach may not convey appropriately the impacts of nonradiative forcings on societally relevant climate variables such as precipitation or ecosystem function. Any new metrics must also be able to characterize the regional structure in nonradiative forcing and climate response."

In an invited multi-authored paper to an American Geophysical Union Monograph on "Complexity and Extreme Events in Geosciences. we report,[7]

[7]Roger A. Pielke Sr., Rob Wilby, Dev Niyogi, Faisal Hossain, Koji Dairuku, Jimmy Adegoke, George Kallos Tim Seastedt and Katie Suding, 2011: Dealing with Complexity and Extreme Events Using a Bottom-up, Resource-based Vulnerability perspective. Surja Sharma Editor, under review.

"...that global multi-decadal predictions are unable to skillfully simulate major atmospheric circulation features such the Pacific Decadal Oscillation [PDO], the North Atlantic Oscillation [NAO], El Niño and La Niña, and the South Asian monsoon (Pielke, 2010; Annamalai et al., 2007). However, these large scale atmospheric/ocean climate features determine the particular weather pattern for a region (e.g. Otterman et al 2002; Chase et al 2006). Proposed decadal prediction efforts seek to address some of these deficiencies but are still under development (Hurrell et al 2010)."

It is these regional atmospheric and ocean circulation features which produce extreme weather events, not a global annual average surface temperature anomaly. We also concluded that

"There is sometimes an incorrect assumption that although global climate models cannot predict future climate change as an initial value problem, they can predict future climate statistics as a boundary value problem (Palmer et al 2008). With respect to weather patterns, for the downscaling regional (and global) models to add value over and beyond what is available from the historical, recent paleo-record, and worse case sequence of days, however, they must be able to skillfully predict the changes in the regional weather statistics. There is only value for predicting climate change if they could skillfully predict the changes in the statistics of the weather and other aspects of the climate system. There is no evidence, however, that the models can predict changes in these climate statistics even in hindcast. As highlighted in Dessai et al. (2009) the finer and time space based downscaled information can be "misconstrued as accurate", but the ability to get this finer scale information does not necessarily translate into increased confidence in the downscaled scenario (Wilby 2010)."

As just one example, we have published recently on the role of land use change, by itself, as a possible explanation of an increase in extreme precipitation in certain regions.[8] Recent studies reported in Nature ignored this possibility.[9]

As we wrote in Pielke Sr. et al (2011) [cited earlier],

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[8]Our papers on this subject, under the leadership of Faisal Hossain, include
Hossain, F., I. Jeyachandran, and R.A. Pielke Sr., 2009: Have large dams altered extreme precipitation patterns during the last Century? Eos, Vol. 90, No. 48, 453-454. Copyright (2009) American Geophysical Union.
Degu, A. M., F. Hossain, D. Niyogi, R. Pielke Sr., J. M. Shepherd, N. Voisin, and T. Chronis, 2011: The influence of large dams on surrounding climate and precipitation patterns. Geophys. Res. Lett., 38, doi:10.1029/2010GL046482, in press.
Hossain, F., I. Jeyachandran, and R.A. Pielke Sr., 2010: Dam safety effects due to human alteration of extreme precipitation. Water Resources Research, 46, W03301, doi:10.1029/2009WR007704.
[9]Na Seung-Ki Min, Xuebin Zhang, Francis W. Zwiers and Gabriele C. Hegerl: 2011: Human contribution to more-intense precipitation extremes. Nature. 17 February 2011.
Pardeep Pall, ToluAina, Dáithí A. Stone, Peter A. Stott, Toru Nozawa, Arno G. J. Hilberts, Dag Lohmann, Myles R. Allen Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000 Nature470, 382-385 (16 February 2011) doi:10.1038/nature09762 Letter

"Quantitative predictions of extremes by climate models are highly uncertainty due to: the choice of model(s); unknown future changes in radiative and other climate forcing (by anthropogenic emissions, land-surface modifications and natural (e.g. solar, volcanoes); and random, internal variability of climate.

When taking all of these factors into account it is hardly surprising that detection of robust anthropogenic signals in regional climate predictions is seldom possible within decision-making time-scales of a few decades. For example, Ziegler et al. (2005) find that time-series of 50-350 years are required to detect plausible trends in annual precipitation, evaporation and discharge in the Missouri, Ohio, and Upper Mississippi River basins. Likewise, Wilby (2006) showed that, under widely assumed climate change scenarios, expected trends in UK summer river flows are seldom detectable within typical planning horizons (i.e., by the 2020s). Again, depending on the climate model and underlying uncertainty of the regional projections, emergence time-scales for US tropical cyclone losses range between 120 and 550 years (Crompton et al., 2011)."

Policymakers and the public rarely encounter this broader view of the climate system, in part due to the limited number of scientists who are leading climate assessments. As just one example, I present my experiences with the first CCSP report, from which I resigned with my experiences documented in a public comment[10]

In the executive summary of that report, I wrote

"The process for completing the CCSP Report excluded valid scientific perspectives under the charge of the Committee. The Editor of the Report systematically excluded a range of views on the issue of understanding and reconciling lower atmospheric temperature trends.

The Executive Summary of the CCSP Report ignores critical scientific issues and makes unbalanced conclusions concerning our current understanding of temperature trends.

The CCSP Report entitled, "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences", therefore, while containing useful new information on temperature trends failed to adequately evaluate the diversity of scientific issues as tasked in the charge to the Committee. Instead, the Editor and the majority of the members of the Committee intended to focus almost exclusively on seeking to remove the discrepancy noted in the NRC (2000) report between surface and tropospheric temperature trends.

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[10]Pielke Sr., Roger A., 2005: Public Comment on CCSP Report "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences". 88 pp including appendices

The process that produced the report was highly political, with the Editor taking the lead in suppressing my perspectives, most egregiously demonstrated by the last-minute substitution of a new Chapter 6 for the one I had carefully led preparation of and on which I was close to reaching a final consensus. Anyone interested in the production of comprehensive assessments of climate science should be troubled by the process which I document below in great detail that led to the replacement of the Chapter that I was serving as Convening Lead Author.

Future assessment Committees need to appoint members with a diversity of views and who do not have a significant conflict of interest with respect to their own work. Such Committees should be chaired by individuals committed to the presentation of a diversity of perspectives and unwilling to engage in strong-arm tactics to enforce a narrow perspective. Any such committee should be charged with summarizing all relevant literature, even if inconvenient, or which presents a view not held by certain members of the Committee."

Finally, I have proposed a new approach in the climate community based on a bottom-up, resource-based perspective. There are five broad areas that we can use to define the need for these vulnerability assessments: *water, food, energy, human health* and *ecosystem function*. Each sector is critical to societal well-being. The vulnerability concept requires the determination of the major threats to these resources from extreme events including climate, but also from other social and environmental pressures. After these threats are identified for each resource, relative risks can be compared in order to shape the preferred mitigation/adaptation strategy. The questions to be asked for each key resource are:

1. Why is this resource important? How is it used? To what stakeholders is it valuable?

2. What are the key environmental and social variables that influence this resource?

3. What is the sensitivity of this resource to changes in each of these key variables? (This may include but is not limited to, the sensitivity of the resource to climate variations and change on short (days), medium (seasons), and long (multi-decadal) time scales).

4. What changes (thresholds) in these key variables would have to occur to result in a negative (or positive) outcome for this resource?

5. What are the best estimates of the probabilities for these changes to occur? What tools are available to quantify the effect of these changes? Can these estimates be skillfully predicted?

6. What actions (adaptation/mitigation) can be undertaken in order to minimize or eliminate the negative consequences of these changes (or to optimize a positive response)?

7. What are specific recommendations for policymakers and other stakeholders?

Mr. WHITFIELD. Dr. Zwiers, you are recognized for 5 minutes.

STATEMENT OF FRANCIS ZWIERS

Mr. ZWIERS. Thank you, Chairman. Thank you, Mr. Rush. Thank you, committee members. I am privileged as a Canadian to be able to speak to this body. It is truly an honor to be able to do so.

I have trained as a statistician, I have spent all of my career applying the tools of statistics to problems in climate research, and I have held various positions in climate research enterprises. I am currently a professor at the University of Victoria.

There is a growing body of literature available that examines both the observed changes in temperature and precipitation extremes. These are events that, of course, do happen all the time. A 100-year event at a particular location is expected to recur at that location once every 100 years. The question that we are posing to ourselves in this literature is whether or not humans influencing the climate system are tilting the odds and are increasing the likelihood of an event from a one-in-100-year event to perhaps a more frequent event. And this is the kind of evidence that the literature seems to be turning up. The literature shows that extreme warm temperatures seem to becoming more likely over time and extreme cold temperatures seem to be becoming less likely over time, and very intense precipitation is becoming more likely. And these are phenomena that we are generally observing at operational meteorological observing stations basically throughout the world where the data are available.

These are changes that are expected with an overall warming climate. We have observed the shift to warmer temperatures. We understand a lot about the causes of those rises. The warming climate leads to increases in the likelihood of extreme warm temperatures. It leads to decreases in the likelihood of extreme cold temperatures. We have observed both of those phenomena. It leads to increases in the amount of water vapor that is held by the free atmosphere, something that has also been observed, and that creates conditions that would allow more intense precipitation events to occur, something that we are beginning to see in observations as well.

Climate models simulate extreme events, and climate models simulate changes in extreme events that correspond more or less to changes that have been observed, and those models are run with historical increases in greenhouse gases and changes in other forcing factors. Changes in the amount of aerosol that is present in the atmosphere, for example, another product of fossil fuel combustion.

Statistical analysis of the observations finds evidence that these signals that are anticipated by climate models are present in the observations. We find this evidence with high confidence in the case of temperature extremes and with somewhat lower confidence in the case of precipitation extremes, but in both cases, it would be difficult to explain observed changes with natural climate variability alone. The most plausible explanation for observed changes in temperature extremes and observed changes in precipitation extremes is human influence on the climate system and human-induced increase in greenhouse gases in the atmosphere.

With regard to temperature, we are beginning to be confident enough so that we can cautiously attempt to estimate changes in waiting times for rare events. You could think of the 20-year extreme temperature event. In the case of cold temperature events that were expected to recur about once every 20 years in the 1960s, we see that by the end of the 20th century these events were recurring roughly two times as frequently, they became roughly 10-year events, and we are able to attribute that change and probability of likelihood in extreme cold temperature events to increasing greenhouse gas concentrations.

Similar results are available for warm temperature extremes. In the case of precipitation, the odds of extreme events has appeared to increase, but it is generally too soon to quantify scientifically the extent to which those odds have changed. So we have evidence that indicates that human influence on the climate system is tilting the odds towards more intense precipitation events, but at this stage, we are not able to say by how much.

A few events have been studied in detail. One that has been studied in detail was the European 2003 heat wave, which was an event that took 40,000 lives. It is very likely that human influence on climate increased the odds of that event by a factor of at least two. In the case of the U.K. flooding in the fall of 2000, it is also very likely that human influence has increased the odds of flooding. The best estimate is the risk was doubled.

So these kinds of events have significant impacts. Heat waves cause death. Flooding cause death, damage, and enormous economic impacts. Even seemingly benign changes can have negative impacts. If you think of the reduced intensity of cold extremes in wintertime, this has been linked to forest bark beetle outbreaks throughout western North America which have devastated forest industries in western North America as an impact of climate change over the last several decades.

The available studies are subject to uncertainties, and therefore do not provide the final word on the question of whether and by how much increasing greenhouse gas concentrations has affected the frequency and intensity of extreme weather events, but they provide sufficient evidence, I believe, to indicate that human influence is having an effect on high impact events to put people and their livelihood at risk and provide an additional piece of information for taking action on greenhouse gas emissions. Thank you.

Mr. WHITFIELD. Thank you, Dr. Zwiers.

[The prepared statement of Mr. Zwiers follows:]

Testimony for House Committee on Energy and Commerce
Subcommittee on Energy and Power
hearing entitled
"Climate Science and EPA's Greenhouse Gas Regulations"

Francis W. Zwiers

8 March 2011

Summary

Observational studies show that warm temperature extremes have become hotter since the mid 20th century, cold temperature extremes have moderated, and precipitation extremes have intensified over broad areas of the world where suitable observations are gathered. There is a firm physical basis for the expectation that increasing greenhouse gas concentrations in the atmosphere should lead to such changes, and recent research that compares observations with changes predicted by climate models shows that the effects of increasing greenhouse gas concentrations provides a more plausible explanation for the observed changes in temperature and precipitation extremes than other possibilities, such as natural climate variations. While these studies do not provide the final word on the question of whether, and by how much, increasing greenhouse gas concentrations have affected the frequency and intensity of extreme climate and weather events, they suggests that human influence is now affecting the frequency and intensity of high impact events that put people and their livelihoods at risk. Moreover, studies of two specific events (the European 2003 heat wave, and flooding in the UK in the autumn of 2000) have shown that the odds of those events had been increased substantially relative to the world that would have been in the absence of human induced increases in atmospheric greenhouse gases. The approaches used in these studies are applicable to other events, and to the prediction of long- and short-term changes in the risk of damaging climate events.

Biographical Information

I am a Canadian citizen who was born in the Netherlands and immigrated to Canada with my parents as a small child. I am married with three children and currently live in Victoria, BC. I was trained as a statistician but have spent most of my professional career in climate science, primarily at Environment Canada where I have served as a Research Scientist, Chief of the Canadian Centre for Climate Modelling and Analysis, and ultimately Director of the Climate Research Division which has about 120 staff. Recently, I have taken a position at the University of Victoria as the Director of the Pacific Climate Impacts Consortium, which is a regional climate service that serves public and private stakeholders as well as the general public in the Pacific and Yukon region of Canada. I have served the IPCC in a number of capacities over my career, including as a Lead Author of Chapter 12 of the IPCC WG1 contribution to the Third Assessment Report Report (Mitchell et al., 2001), a Coordinating Lead Author of Chapter 9 of the IPCC WG1 contribution to the Fourth Assessment Report (Hegerl et al., 2007), and currently as a member of the IPCC Bureau for WG1.

Introduction

As noted in the recent U.S. Climate Change Science Program Synthesis and Assessment Product 3.3 (CCSP, 2008) "Extremes are a natural part of even a stable climate system and have associated costs ... and benefits. For example, extremes are essential in some systems to keep insect pests under control. While hurricanes cause significant disruption, including death, injury, and damage, they also provide needed rainfall to certain areas, and some tropical plant communities depend on hurricane winds toppling tall trees, allowing more sunlight to rejuvenate low-growing trees. But on balance, because systems have adapted to their historical range of extremes, the majority of events outside this range have primarily negative impacts."[i] Recently we have seen a spate of extreme climate and weather events that have drawn intense media interest, including this winter's intense storms affecting the US and Canadian eastern seaboard, similarly extreme winter storms last year, the Russian heat wave and Pakistani flooding of summer 2010, the extraordinary Australian flooding event of this past January. These events have certainly tested our ability to cope with weather and climate variations, have had significant negative impacts, and pose the question as to whether human influence on the climate system has played a role. While the research required to answer this question specifically in the context of recent events is yet to be completed, two new papers in *Nature* (Min et al., 2011; Pall et al., 2011) have presented evidence that changes in the intensity of extreme precipitation since the middle of the 20th century may be linked to human induced global warming, and that in at least in one instance, that human influence on climate had likely substantially increased the risk of flooding.

The observed intensification of precipitation extremes, and observed changes in temperature extremes, are occurring in the context of a climate that has warmed markedly over the past century. Since this change in the basic state of the climate system affects extremes, I first briefly review some of the available information on global warming. I then consider research on changes in temperature and precipitation extremes specifically that I and my colleagues have undertaken. It should be noted that the types of events that we have considered are the simplest imaginable – heavy 1-day and 5-day precipitation accumulations, and extreme warm or cold temperatures. An important reason for this simple approach is that reliable data, gathered operationally by meteorological services in many countries, are available to define such events, assess whether they are changing in intensity or frequency, and if possible, assess causes of observed changes. While this makes the science at least somewhat tractable, it has only allowed us to begin to scratch the surface of a complex web of questions; there is a great need to better understand the complex combinations of factors that trigger impacts in humans and ecosystems (Hegerl et al., 2011) and to understand how, and why, dynamically energetic phenomena such as tornadoes and hurricanes are changing and are likely to change in the future.

Warming of the climate system

The global surface temperature record is the most thoroughly studied and scrutinized observational record used in climate research. Compiling this record is a massive undertaking that involves the assembly, quality control and adjustment of observations from thousands of locations and that are obtained with a variety of technologies. Several groups (UEA CRU/Hadley Centre, NASA GISS, NOAA NCDC, etc) independently maintain compilations of surface temperature (Brohan et al., 2006; Hansen et al., 2006; Smith et al., 2008). Differences between compilations reflect uncertainty due to incomplete global coverage, differences in approaches that are used for gridding, adjustment uncertainties, etc. The record is continually updated as new observations become available, historical data are recovered and transcribed to electronic form, errors in data entry, station location and identification, processing, etc., are identified and corrected, and adjustments techniques are improved[ii,iii]. Figure 1 shows that despite the different methods in the way they collect and process data to calculate the global-average temperature, there is agreement on temperature trends from decade to decade (Figure 1) and they all agree global-average temperature has increased over the past century. Differences between global-average temperature anomalies estimated from the different compilations are consistent with published uncertainty estimates that accompany each of the compilations.

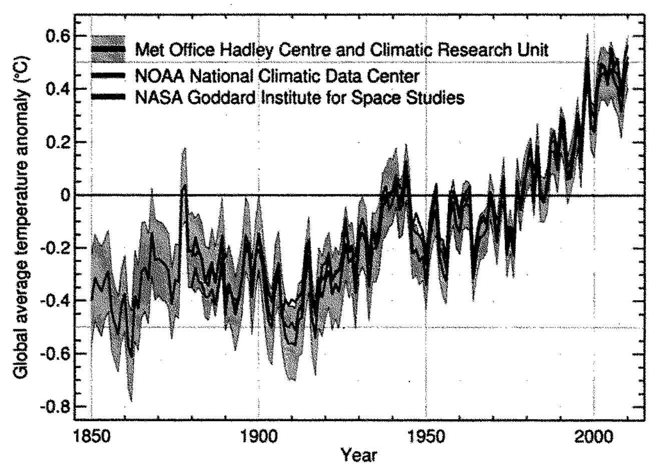

Figure 1: Estimated global-average surface temperature anomalies based on three data sets. The three data sets are: Met Office-CRU (black), produced by the Met Office Hadley Centre in collaboration with the Climatic Research Unit at the University of East Anglia; NCDC (red) produced by the National Climate Data Center; and NASA GISS (blue) produced by the Goddard Institute for Space Studies at NASA. The grey shaded area shows the approximate 95% confidence range for the Met Office-CRU data. The true global average is expected to lie outside this range around 5% of the time. Courtesy Peter Stott, Met Office Hadley Centre.

Warming over the past century is unequivocal (IPCC, 2007). This is evident not just from the surface temperature record (e.g., Figure 1), but also from observations of other parts of the climate system – information that is gathered independently of the surface temperature record using different methods and instruments from those that are used to monitor surface temperature. For example, the free atmosphere, as monitored by satellites, is warming in a manner that is consistent with surface warming (Figure 2). In addition, a recent survey of 10 key climate indicators published in the 2009 *State* *of the Climate* report (Arndt et al., 2010)[iv], and based on the findings of 300 scientists from 160 research groups in 48 countries, all point to the same finding that the world is warming. The indicators include increases in atmospheric water vapour content, reductions in snow cover extent, glacier mass balance and Arctic sea ice extent (see also Min et al., 2008), warming in the interior of the global oceans leading to increases in ocean heat content, and rising sea level due to ocean warming and the melting land ice.

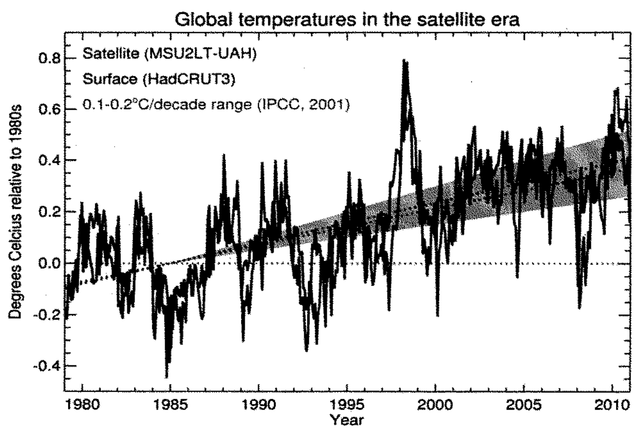

Figure 2: Monthly global mean surface temperature anomalies estimated from HadCRUT3 (blue) and global mean lower tropospheric air temperature anomalies estimated from the University of Alabama MSU2LT record (red) relative to 1980-1989 for 1979 to the present. The trends for this period are shown in dotted blue and red lines respectively, and show warming over the period of about 0.15°C per decade. Also shown is the warming range projected by the IPCC in its Third Assessment Report (IPCC, 2001). Figure courtesy Myles Allen, University of Oxford.

Figure 2 also shows the prediction that was made by the IPCC in 2001 that the decade of the 2000s would be 0.1-0.2°C warmer than the 1990s, primarily because of the influence of rising greenhouse gases. The fact that this prediction has turned out to be correct provides independent confirmation that most of the observed warming on global and continental scales can be ascribed, with a high level of scientific certainty, to increases in greenhouse gas concentrations in the atmosphere. If the upswing in temperatures from the 1970s to the 1990s had been entirely due to internally-generated variability, there would have been no reason to predict a continued warming.

The effect of greenhouse gas induced warming is modulated to some extent by other influences on the climate system, including that of aerosols, volcanic activity, and solar activity (Hegerl et al., 1997; Tett et al., 1999; Huntingford et al., 2006; Hegerl et al., 2007) as well as natural internal variability. It is acknowledged that there have likely also been influences from regionally important forcing agents, such as land use change (Portmann et al., 2009) and some types of aerosols (including black carbon – soot; Jones et al., 2011); some of which may have regional cooling influences, but the science has not yet been able to quantify the extent to which these factors have affected regional temperatures. Against this backdrop of natural variability and possible regional influences, it is not surprising that warming should be less evident at some times than others, or that it should be less evident in some regions, such as in the US "warming hole" (Kunkel et al., 2006; Portmann et al., 2009; Christidis et al., 2010).

That there should be a warming effect is an unassailable fact of science. Human use of fossil fuels and the land surface have lead to an increase in the atmospheric concentration of CO_2 from about 280 ppmv prior to industrialization to approximately 390 ppmv today (GAW, 2010). Concentrations continue to rise at a rate of about 2 ppmv per year. CO_2 is a gas that is transparent to sunlight, and thus its presence in the atmosphere does not impede the flow of energy into the Earth system. Sunlight, which powers the Earth system, is either reflected back to space (by clouds, reflective aerosols, or the Earth's surface), or absorbed and converted to heat. In order to maintain a constant temperature, the Earth must, in turn, radiate the heat that is produced from sunlight back to space. However, higher levels of CO_2 and other greenhouse gases in the atmospheric make it more difficult for heat to exit the system because these gases not fully transparent to infrared (heat) radiation. This inevitably leads to a warming, the magnitude of which depends upon various "feedback" processes. Science has been aware of this warming effect, which is now well evident in observations, since the 19^{th} century (Fourier, 1824; Arrhenius, 1896; Harries et al., 2001).

Extreme Temperature and Precipitation Events

While observed changes in global-average temperature may not seem to be particularly harmful, it is increasingly apparent that neither the observed warming over the past century of approximately 0.75°C globally (Trenberth et al., 2007), nor the projected warming of approximately 2-4°C or more for the end of the current century (Meehl et al., 2007), is without serious impact. It has often been stated that those impacts will make themselves felt most acutely through extreme climate and weather events because such events evidently stress the coping capacity of human and natural systems. From an ecosystem perspective, extreme events may initiate responses to gradual background changes that are delayed by inertia (e.g., Jentsch and Beierkuhnlein, 2008).

Changes in extreme temperature and the intensification of extreme precipitation events are natural consequences of a warming climate. A warmer climate would inevitably have more intense warm temperature extremes than the present climate, including longer and more intense heat waves, and less intense cold temperature extremes. Further, a warmer atmosphere can, and does, hold more water vapour, which has been detected in data (Santer et al., 2007; Willett et al., 2007; Arndt et al., 2010), and which implies that more moisture is available to form precipitation in extreme events and to provide additional energy to further intensify such events[v]. Many of these expected changes have been observed, and in some instances, are beginning to be linked to human induced warming of the climate system.

A number of studies (e.g., Christidis et al., 2005, 2010; Zwiers et al., 2011) have now used various types of detection and attribution methods to determine whether the changes in temperature extremes predicted by climate models in response to historical greenhouse gas increases and other forcings are detectable in observations of extreme temperatures. This research demonstrates that this is indeed the case, both globally and in many regions, and suggests that human influence has substantially increased the frequency of rare warm events globally (such as the 20-year warm extreme in daily maximum or minimum temperature) and substantially decreased the frequency of rare cold events (such as the 20-year cold extreme in daily maximum or minimum temperature) (Zwiers et al., 2011).

While demonstrating that human influence from increasing greenhouse gas concentrations has influenced temperature extremes on large scales is a useful advance that provides information about the impact of global warming, this alone does not answer the very frequently asked question about whether a specific event, such as the extended European heat wave of 2003 that caused approximately 40,000 deaths (García-Herrera et al., 2010), was due to human influence on the climate system. The clear answer to this question, and one that is underscored by the Meehl et al. (2009) study of the occurrence of record breaking temperatures, is that individual extreme events cannot be ascribed to human influence on the climate system in the sense that the event could not have occurred if it were not for human influence. It is, however, possible to assess how human influence on climate may be "loading the weather dice", making some events more likely, and others less likely. In the case of the European heat wave event, Stott et al. (2004) estimated that human influence had very likely at least doubled the probability of an event similar to that which occurred compared to the world that would have been if human activities had not increased greenhouse gas concentrations. Numerous factors can affect the occurrence of an extreme warm event in a given location, so answering the question, what was the role of human influence on climate in this event, requires specific research. Showing that one heat wave was made more likely by human influence does not mean this would apply to all heat waves.

Heavy and extreme precipitation events have also received a considerable amount of study. Heavy precipitation has contributed an increasing fraction of total precipitation over the regions for which good instrumental records are available (Groisman et al., 2005; Alexander et al, 2006), and particularly over the US (Karl and Knight, 1998; Kunkel et al., 2007; Peterson et al., 2008; Gleason et al., 2008), indicating an intensification of precipitation extremes. Direct examination of precipitation extremes, such as the largest annual 1-day accumulation, or the largest annual 5-day accumulation, also shows that extreme precipitation has been intensifying over most parts of the world for which suitable records are available (Alexander et al., 2006; Min et al., 2011, Figures 3, 4), with an increase in the likelihood of a typical 2-year event of about 7 percent over the 49 year period from 1951 to 1999.

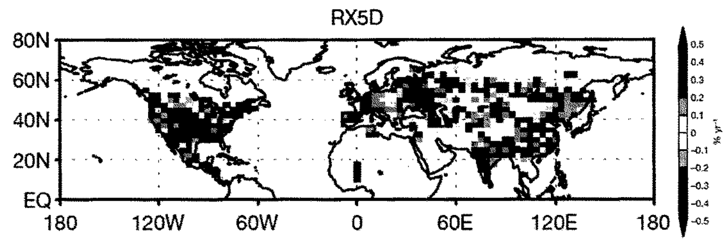

Figure 3: Geographical distribution of trends of extreme precipitation indices (PI) during 1951–99 for 5-day precipitation accumulations. Annual extremes of non-overlapping 5-day accumulations were fitted to the Generalized Extreme Value distribution which was then inverted to map the extremes onto a 0-100% probability scale. Blue colours indicate intensification of extreme precipitation, which is observed at about 2/3rds of locations. From Min et al. (2011).

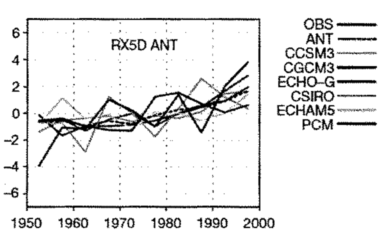

Figure 4: Time series of five-year mean area-averaged PI anomalies in percent for 5-day annual extreme precipitation anomalies over Northern Hemisphere land during 1951–99. Black solid line represents observations and the dashed line represents the multi-model mean for the models indicated in the legend. Model simulations where run with anthropogenic forcings. Coloured lines indicate results for individual model averages (see Supplementary Table 1 of Min et al. (2011) for the list of climate model simulations and Supplementary Fig. 2 of Min et al. (2011) for time series of individual simulations). Each time series is represented as anomalies with respect to its 1951–99 mean.

Climate scientists have long argued that an intensification of extreme precipitation is an expected consequence of human influence on the climate system (e.g., see Allen and Ingram, 2002; Trenberth et al., 2003). Indeed, models do intensify extreme precipitation in response to increasing greenhouse gas concentrations and Min et al. (2011) recently showed, using an ensemble of models, that the observed large-scale increase in heavy precipitation cannot be explained by climate variability, and is most likely due to human influence on climate. However, as with extreme temperature events, place and event based research is required to determine whether increasing greenhouse gas concentrations have altered the odds of a given type of event. Pall et al. (2011) demonstrate a suitable approach, and show that human influence from increased greenhouse gas contributions had substantially increased the odds of flooding in England and Wales in the autumn of year 2000 as compared to the world that would have been if greenhouse gas concentrations had remained at pre-industrial levels (Figure 5).

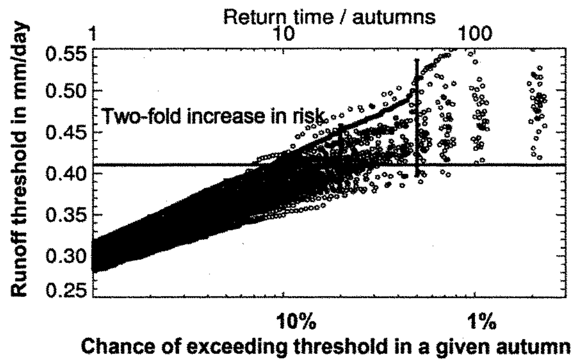

Figure 5: Change in occurrence frequency of daily river runoff for England and Wales in autumn 2000. Occurrence frequency curves of runoff (circles) synthesized from all precipitation simulations in A2000 (blue) and A2000N climates (green). A2000 climates are obtained using an atmospheric climate model run with observed year 2000 atmospheric composition (greenhouse gases and aerosols) and observed autumn 2000 sea-surface temperatures. A2000N climates are obtained using the preindustrial atmospheric composition and observed sea surface temperatures from which sea-surface temperature changes attributed to anthropogenic forcing had been removed. Four global coupled climate models (HadCM3, GFDLR30, NCARPCM1 and MIROC3.2) were used to estimate attributed sea-surface temperature changes. Top axis is equivalent return time. Horizontal lines mark the highest autumn 2000 runoff synthesized from ERA-40 precipitation (0.41 mm). Bars represent 5–95% confidence intervals. Note that 'chances' on the lower x-axis are provided to give an informal interpretation of the technical term 'return time' but do not account for the impact of multiple events occurring in a single season.After Pall et al. (2011, Supplementary Fig. 3a).

The weather events that do most damage are very often those that are most difficult to predict: we can, however, assess the impact of an external factor like human influence on climate on the odds of a weather event occurring, even if we cannot predict when it will occur (if you load a dice to double the odds of a six, you still cannot predict precisely the result of any particular roll). Hence the fact that seasonal forecasting of extreme weather is clearly very difficult does not prevent us from assessing the role of long-term drivers in extreme weather risk or attempting to predict seasonal variations in risk. El-Nino, for example, strongly influences both temperature and precipitation extremes globally (Kenyon and Hegerl, 2008, 2010; see Figure 6), and can alter the likelihood of rare damaging precipitation events by more than a factor of 4 in some parts of the US, particularly in the southwest (Zhang et al., 2010). Any human influence on extreme weather risk combines with these episodic variations and the chance fluctuations that are inevitable when dealing with rare events: hence we should not assume that, if human influence is making a particular event more likely on average, it will necessarily do so every year.

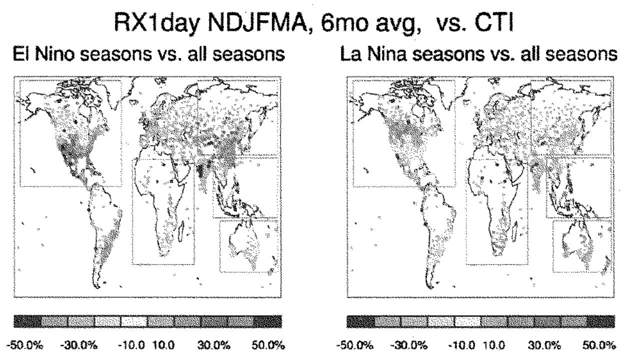

Figure 6: Impact of El-Nino (left) and La-Nina (right) on the intensity of the largest precipitation event monthly in the November to April half of the year. Based on station data from the GHCN (Global Historical Climate Network) for 1949-2003. Courtesy G. Hegerl. From Kenyon and Hegerl (2010).

The recent studies on temperature and precipitation extremes discussed in this statement are far from being the final word on the question of whether, and by how much, increasing greenhouse gas concentrations have affected the frequency and intensity of extreme climate and weather events. However, the "smoking gun" evidence from these studies suggests that human influence is now affecting the frequency and intensity of high impact events that put people and their livelihoods at risk. While assessments of the abilities of climate models to simulate temperature and precipitation extremes (e.g., Kharin et al., 2007) are sobering, there is a firm physical basis for the expectation that increasing greenhouse gases will intensify warm temperature extremes, moderate cold temperature extremes, and intensify extreme damaging precipitation events. Note that moderating cold temperature extremes are not necessarily a benefit – e.g., they have been identified as a key factor in the ongoing devastation of western North American forests by forest beetles (see CCSP, 2008, Box 1.2). Recent research, such as that cited above, shows that these effects on climate are becoming evident in operationally gathered and reported meteorological data – scientific data that are not affected by changes in reporting policy or the intensity of media interest. While some people and regions may expect to benefit in the short term from climate change, the evidence is emerging that others, including citizens of the United States, may already be being harmed by extreme weather events that have been made more likely by human influence on climate.

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Notes

[i] CCSP (2008), pp 1-2.

[ii] The adjustment of instrumental records to remove non-climatic artefacts from, for example, instrument changes, is unavoidable if the record is to be useful for monitoring long term change. This is so both for the "insitu" instrumental record (e.g., surface temperature observations obtained with thermometers), and for satellite records, which much necessarily be constructed by piecing together readings from sequences of relatively short-lived instruments.

[iii] Corrections to errors in the CRUTEM3 dataset identified through scrutiny of CRU software and emails have virtually no impact on trends in either global-average surface temperature or global-average land surface air temperature. See http://hadobs.metoffice/com/crutem3/jan_2010_update.html for details.

[iv] See also http://www.noaanews.noaa.gov/stories2010/20100728_stateoftheclimate.html.

[v] The condensation of water vapour into precipitation releases the heat that was used initially to evaporate this water into the atmosphere. Therefore, if there is more condensation in a given event, more of this "latent" heat is released, imparting more energy to the storm.

Mr. WHITFIELD. Dr. Nadelhoffer, you are recognized for 5 minutes.

STATEMENT OF KNUTE NADELHOFFER

Mr. NADELHOFFER. Thank you, Chairman Whitfield, Ranking Member Rush, and other members of the committee. It is a true pleasure and honor to be testifying before you, and I very much appreciate the opportunity. My name is Knute Nadelhoffer. I am a researcher and professor of ecology. I am not a climatologist or a climate scientist, but I study the effects of all kinds of factors as they affect arctic and arctic ecosystems and tempered forests.

I worked for 20 years as a researcher in Woods Hall, Massachusetts, at the marine biological laboratory, and for the past 8 years I have been a professor at the University of Michigan in Ann Arbor.

I am also the director of a major field station near the center of the Great Lakes Basin. Our field station, the University of Michigan biological station, is over 100 years old. It attracts researchers from around the world who have been recording distributions of plants and animals, ecosystem properties, and interactions between humans and their environments for over a century.

That field station is in the middle of the largest freshwater system in the world. Twenty percent of the world's surface freshwater is in the Great Lakes Basin. Our economy, the economy of the eight States and Canadian provinces that surround the Great Lakes are the third or fourth largest economy in the world, and in our region we interact intimately with our natural resources to sustain our economy and our culture. So we pay very close attention to what happens around us.

Measurements at my field station and others across the Great Lakes region are providing knowledge and insights into changes in ecosystems associated with the changes in climates that we have heard about.

Climate change is real. You have heard that from others on the panel. The fact that there is a consensus is minor in my view. The evidence is what drives our conclusions, and science is an evidentiary-based process. The evidence is strong and overwhelming. We can measure its effects in the Great Lakes region, and we know that the change is primarily driven by increases in greenhouse gases. In fact, even the skeptics call these gases greenhouse gases. We can thank them for warming the planet as much as it is. Excursions that we are now encountering and experience are likely to drive our planet to a warmer state. They have, in fact.

In the Arctic, where I have worked for 20 years on the north slope of Alaska, we see changes, changes in vegetation. There is now more shrub cover in the Arctic, but more importantly, summer ice cover has decreased by 30 percent in the satellite records since 1978. Less summer sea ice means less reflection of heat back into space and more absorption of heat by the ocean. This has huge implications for global climate, as our climate scientists will tell you.

Not only is the Arctic warming but the Great Lakes region is warming—in the north by 4 degrees Fahrenheit; in the southern part of the Great Lakes region by 1 degree since 1978.

Stunning is the fact that Lake Superior has warmed by 4½ degrees in the past 30 years. That is a lot of joules. That is a lot of energy. Lake Superior is a big thermometer. It is the deepest lake and the largest lake in the Western Hemisphere, second largest in the world, and it is warming at a rate that no one thought it would.

Ice cover is decreasing on the Great Lakes. It varies year to year, but over decades we can see that the ice cover is lower. That affects our climate. That affects evaporation from the lakes.

In the Great Lakes itself, in the region, total annual precipitation has been relatively constant over the past 50 years, but major storm events have increased by a factor of two, and those major storms tend to come in the springtime, late winter; and they are balanced by droughts in the summer, and we feel it. Our coastal cities, small cities, like South Haven on the west coast of Michigan, and larger cities like Milwaukee on the east coast of Wisconsin, have storm sewer systems that are now compromised. They were built 50 years ago, and they can't handle the floods. So we are paying a cost in terms of infrastructure.

We are experiencing more late-winter, early-spring storms, more summer droughts and heat events. Not only does this compromise our infrastructure, but it can degrade drinking water quality, lead to the export of nutrient sediments into our lakes, exacerbating dead zones. It delays planting in springtime and stresses crops in the summer.

We have heard about the heat tolerances of corn and soybeans, which are major crops in the Midwest. It stresses them for us, making them more vulnerable to pests, and jeopardizing a $40 billion forest products industry. It reduces summer swim flow and groundwater recharge and threatens our tourist and recreation industry which is a part of our culture.

Business-as-usual scenarios of various greenhouse gas emissions will exacerbate these trends, compromising our environment and the economy and culture and water of this resource-rich region.

Thank you very much for listening to me. I look forward to questions.

Mr. WHITFIELD. Thank you very much.

[The prepared statement of Dr. Nadelhoffer follows:]

Testimony of Dr. Knute Nadelhoffer, PhD
Director, University of Michigan Biological Station
Professor, Department of Ecology and Evolutionary Biology

"Climate Science and EPA's Greenhouse Gas Regulations"

Subcommittee on Energy and Power,
House Committee on Energy and Commerce
U.S. House of Representatives

Tuesday, March 8, 2011

Chairman Whitfield, Ranking Member Rush, and members of the Committee, thank you for inviting me to testify on this very important matter. My name is Prof. Knute Nadelhoffer and I am the Director of the University of Michigan Biological Station in Pellston Michigan, a field station near the geographic center of the Great Lakes Basin which hosts researchers from around the world who study ecosystems and their constituent organisms across the upper Great Lakes region. I am also a Professor in the Department of Ecology and Environment at the University of Michigan in Ann Arbor with 30 years of research experience. I will address the current and expected ecological impacts of climate change, with a particular emphasis on the Great Lakes basin - a region that holds approximately 20% of the world's surface fresh water, and is a large industrial-agricultural region highly dependent upon services and products provided by natural systems.

My expertise is in arctic tundra and north temperate forest ecology and biogeochemistry. I have worked in North American and European forests since my graduate studies in the late 1970s and have conducted research in the Arctic (mostly on Alaska's North Slope) since the mid-1980s. Overall, I have over 30 years of research experience studying ecology and nutrient cycling in the field in forest and tundra environments.

I now direct the University of Michigan Biological Station– a century-old field station located near the center of the Great Lakes basin, south of the Mackinac Straits, with access to the watersheds and shorelines of Lakes Michigan, Huron and Superior. Teams of researchers (biologists, chemists, atmospheric scientists, and others) from around the world work at the Michigan Biological Station to understand the functioning of land, air, and water systems, and how they interact with humans. Measurements and research results from over a century of work at my field station and others across the Great Lakes region are providing a comprehensive picture of changes in climate and associated changes in natural systems during this period. As a result of my colleagues and my own research, in both the Great Lakes Basin and the Arctic, I am very aware of climate change impacts on environments and ecosystems in northern regions.

INTRODUCTION

We know the climate is changing. It is real, it is happening, and the impacts are becoming clearer the more we observe and study plant and animal distributions, nutrient cycles, atmospheric chemistry, and long-term, large-scale weather and climate patterns. The United States has become both warmer and wetter over the past century. In the Great Lakes region, total annual precipitation (rain plus snow) has been relatively constant during the past 50 or so years. However, the seasonality and intensity of precipitation events has changed dramatically over this period. More of our rain now falls as storms in late winter and spring, leading to early season floods that often exceed the capacities of storm-water handling systems of our coastal towns and cities, and which delay farmer access to fields. Overall, heavy downpours and major floods are becoming more common. Heat waves have increased in both frequency and duration. Spring is arriving earlier and winter, later. Winter ice cover in all five Great Lakes, although highly variable from year to year, has decreased dramatically in past decades. This is consistent with steady decreases in summer ice cover extent and thickness recorded by satellite observations of the Arctic Ocean. These changes adversely impact people, wildlife, natural ecosystems and agricultural productivity.

These basic facts are well documented both within the scientific literature, and elsewhere. More importantly, the science has become essentially irrefutable on this point -- rising concentrations of greenhouse gases (mainly carbon dioxide, methane, and nitrous oxide) in the atmosphere, resulting from fossil fuel combustion and other human activities, are the primary drivers of these recent changes in the climate system. There are no other viable, science-based explanations for the effects we are seeing.

Our best research shows that we cannot ignore what the science is telling us about these changes any longer. This sentiment is supported by nearly 149 (as of March 5) scientists from Michigan who have signed a letter appended to my testimony. This is just the most recent, and regionally significant, endorsement of the IPCC assessments, the fourth of which, published in 2007, involved over 500 expert lead authors (including 5 from Michigan) and more than 2000 reviewers (myself included). Congress, likewise, should support efforts to limit human-caused climate change, namely fossil fuel emissions, in order to protect our nation's interests and sustain the natural and agricultural systems on which we depend for food, fiber, clean air, and clean water. Stabilizing the climate, by limiting and eventually reducing greenhouse gas emissions, will help maintain these and other "ecosystem services," which together contribute to our quality of life and economy.

The Great Lakes Region

Within the eight states of the Midwest region – Illinois, Wisconsin, Indiana, Ohio, Iowa, Minnesota, Missouri, and Michigan – lies the largest group of freshwater lakes in the country and the world. These lakes provide clean, fresh drinking water to tens of millions of people. Long accustomed to utilizing this unique natural resource for shipping and manufacturing purposes, the Midwest produces 40% of the US industrial output and provides 30% of the US foreign agricultural exports. A recent analysis by the Michigan Sea Grant showed that more than 1.5 million jobs, which generate $62 billion in wages, are directly connected to the Great Lakes. The largest sectors include manufacturing (almost 950 thousand jobs), tourism and recreation (over 215 thousand jobs), shipping (118 thousand jobs), and agriculture/fishing/food production (118 thousand jobs).

Much of my research has focused on the region around Lake Michigan, encompassing the states of Illinois, Indiana, Michigan and Wisconsin. This region is experiencing profound ecological changes due to climate change including changes in precipitation and temperature that alter plant growing conditions, wildlife habitats and entire ecosystems. Observed climate change effects in the region include increases in temperatures – 4°F (2.2°C) in the North and 1°F (.6°C) in the South (Easterling & Karl

2001). Growing seasons have advanced by nearly a week over the past 50 years. Lake Superior is warming at an alarming rate; Average water temperature increased by 4.5 °F from 1979 to 2006, or approximately 0.2 °F per year during this 28-year interval (Austin & Coleman, 2007). This largest body of fresh water in North America is feeling the impacts of a warming climate, and is serving as key indicator of changes that are already occurring across the region. Given the huge volume of water in this lake, the energy required to raise temperatures this quickly is stunning. Similar trends are observable in smaller lakes, where we measure decreasing lengths of winter ice cover, more evaporation from lakes, longer periods of "stratification", and warmer summer water temperatures. Warmer water temperatures, together with more intense spring rains and flooding which deliver more sediments and nutrient loadings to our lakes, lead to more oxygen depletion in deep waters, fish kills, nutrient enrichment, and greater variation in water levels. Warmer waters also tend to favor invasive species adapted to warmer conditions. As a result, highly valued, cold-water species such as trout and small mouth bass are at risk of being replaced in many of our waters over the short-term, and most certainly as we progress through the 21st century.

Additionally, higher winter temperatures have allowed destructive invasive terrestrial species like the kudzu plant and plant pests such as the gypsy moth and Hemlock wooly adelgid to spread northward and eastward. Summers and winters have been wetter than average for the last three decades, the wettest period in more than 100 years. The Midwest has experienced two record-breaking floods in the past 15 years and heavy downpours are now twice as frequent as they were a century ago.

These changes are not meaningless or benign. They will likely accelerate into the future if we continue on our current emissions path. Of particular concern are heavier and more frequent winter and spring precipitation events that lead to increased spring flooding. Hotter and drier summers stress plants, animals and livestock, decrease production of key crops, and lead to severe heat waves and poor air quality in cities. Early season flooding and hotter, drier summers are also increasing insect and waterborne diseases. Future effects of climatic warming and changes in seasonality of precipitation on water levels in the Great Lakes are not well understood. However, there is potential to impact recreation, shipping, and potable water, all of which are key economic drivers in the upper Midwest.

About $3.4 billion and 60,000 jobs rely on the movement of goods within the Great Lakes-St. Lawrence shipping route annually (Easterling & Karl 2001). Lower water levels along the system could jeopardize this relatively inexpensive and effective method of transporting manufactured goods. If water levels drop significantly, dredging may be the only alternative to salvage this system. It is estimated that between 7.5 and 12.5 million cubic yards would need to be dredged annually at a cost of $85-142 million (Great Lakes Regional Assessment Group 2000). System connectivity is predicted to become 25% impaired, causing a loss of $850 million annually (Easterling & Karl 2001). Increased incidences of drought will likely place an additional stress on the water conveyance system. For example, a 1988 Midwest drought cost the region over $49 billion, in part because river commercial shipping had to be replaced by more expensive railroad transport due to the Mississippi River's reduced water levels (Easterling & Karl 2001).

The Great Lakes region also stands in the middle of important transitions between prairie and woodlands, and central and northern forests. Forestry is an integral part of the economic structure in the Midwest. Over 90% of public and private forestland is used for commercial forestry, resulting in economic activity valued at $41.6 billion (Great Lakes Regional Assessment

Group 2000). The sector employs 200,000 people and produces $27 billion in forest products.

Depending on the pace of climate change, we stand to see substantial changes and shifts in the habitats and abundance of trees, plants, animals and insects around Lake Michigan. Mammals and other species are increasing their ranges northward, and forests and other systems are becoming more vulnerable to invasive diseases and defoliating insects. Many of the economically valuable timber species – aspen, jack pine, red pine, and white pine – may be lost due to warming of the climate (Easterling & Karl 2001; Hellman, Nadelhoffer & others, 2010). The pine-aspen pulping/wood fiber industry may be eliminated entirely as the forested landscape shifts toward oak and hickory species.

In addition there will likely be a decrease in "good" or desirable species (e.g. bats that eat insects considered a pest by farmers) and an increase in "bad" species (eg aggressive invasive species such as kudzu). As plant species shift and change, or disappear, so to do the insect and animal species that depend on them.

Agriculture is particularly susceptible to the negative impacts of current and projected climate change trends in the region, including substantial crop losses due to weeds and pests, as well as changing precipitation and temperature patterns. This means that farmers will lose money and prices for food paid by consumers will rise at a time when costs are rising dramatically. A big concern in the region is drought-like conditions resulting from elevated temperatures, which increase levels of evaporation, contributing to decreases in soil moisture and reductions in lake and river levels. Although longer growing seasons provide potential for increased crop yields, increases in heat waves, floods, droughts, insects, and weeds will present increasing challenges to managing crops, livestock, and forests.

Potentially negative impacts are expected to the $5.7 billion dairy industry, since milk production by dairy cows is temperature sensitive and declines when temperatures advance beyond a certain threshold (Great Lakes Regional Assessment Group 2000). Research also indicates that soybean yields could decline in Illinois as much 55% by the end of this century given the current pace of temperature increases. Weed induced losses for corn could increase 22% in the Great Lakes states, and for soybeans losses could be 35%. This is not a minor concern, given the tremendous economic importance of agriculture to the Lake Michigan states.

The region is well-known to outdoor recreation enthusiasts. Already, ski resorts and businesses profiting from winter activities such as snow-mobiling and ice-fishing are feeling impacts of shorter winters and more frequent winter thaws. Portions of the industry are likely to suffer because of climate change. For example, the distribution of prominent game and other bird species (e.g. waterfowl, warblers, perching bird species) may be altered, affecting hunting and bird-watching. In Michigan, Minnesota and Wisconsin alone, $4.7 billion was spent in 1996 on hunting, and bird-watching generates $668 million in retail sales and supports 18,000 jobs.

CONCLUSION

Climate change is impacting the Great Lakes region now, more so than in many other areas of the country. Future changes will be greater than those we have experienced thus far, unless we act to stabilize and reduce GHG emissions. We cannot hide from these changes. As a scientist I cannot ignore what solid and rigorous research is telling me every day. If we care about the future economy and environment of the Great Lakes – this amazing natural resource that is unique in the US and the world, that supports the livelihoods of millions of people and generates billions in economic activity, we must start now to stabilize atmospheric greenhouse gas emissions – not only carbon dioxide, but also methane, nitrous oxide, and ozone. We cannot just hope to adapt to the dramatic changes that are upon us and that will increase in coming decades if we do not act to mitigate and reduce emissions.

In light of all of the scientific facts relating to climate change, Michigan scientists have overwhelmingly voiced their support for strong federal policies to reduce fossil fuel emissions. Science is not a partisan endeavor. It provides us with the best information available about how the earth and regions such as the Great Lakes basin are responding to the inexorable and unprecedented (in human time-scale) increases in atmospheric greenhouse gases. We ask that Congress support sound legislative and regulatory policies to limit harmful greenhouse gas emissions that threaten our health, welfare, environment and our economy.

Thank you.

Mr. WHITFIELD. And, Dr. Roberts, you are recognized for 5 minutes.

STATEMENT OF DONALD ROBERTS

Mr. ROBERTS. Thank you, Chairman Whitfield, Ranking Member Rush, and members of the committee for the opportunity to be here this morning.

I am a retired professor emeritus of tropical public health. I follow closely the debate on claims of public health harm from climate change. There are parallels in claims about climate change and regulatory controls of carbon dioxide and claims about insecticides and human health. The arguments for government interventions in both topic areas rests on fearful claims, doomsday predictions of devastating consequences in the absence of regulatory intervention, and in my mind, this is fear messaging.

Thirty-nine years ago, the EPA took a political position to ban a famous insecticide, DDT. Global public health leaders at that time repeatedly and firmly warned that a ban would cause return of devastating diseases and millions and millions of deaths. In 1972, in spite of those warnings, the EPA banned DDT. The public health community was right, and the results of that decision have been devastating.

I raise the issue of this famous insecticide because it is an excellent example of the harm that arises when politics and ideology trump science. Poor people in malaria countries are paying every day for an EPA decision taken 4 decades ago. As supporting documentation, I am submitting for the record recent statements by Ministers of Health of Namibia and Guyana, as well as a recent peer-reviewed paper I coauthored confirming an ideological agenda which is, regrettably, supported by the EPA.

As I document in written testimony, those who campaigned to reduce CO_2 emissions through EPA regulatory controls are striving to show climate change is a source of harm to public health. Claims of such harm are necessary for fear messaging. These claims are reflected in many attempts to attribute all sorts of increases in malaria, dengue, and other diseases to global warming. Again, I offer documentation of this in written testimony.

However, attempts by climate change advocates to link those diseases to climate change have been vigorously rebutted. While climate can affect disease rates, there is most assuredly no simple relationship between climate and public health. The truth is those diseases are under control of many complex and dominant factors, with condition of human poverty and man's own effort to control them being most important.

As evidence to back up this statement, I would point to the different conditions of public health on the border of Mexico and Texas. I could also point to the differences in insect-borne disease rates on the border areas between Mozambique and South Africa. Both those cases show how, under the same climatic conditions and same geography, divergent public health outcomes are achieved thanks to differing poverty rates and man's efforts in disease control.

Growing publicity about climate change and asthma shows an effort to prove climate change harms public health are unabated. In written testimony, I review a recent well-publicized paper on this topic. My area of expertise is in tropical public health, but I review this paper as a scientist and a taxpayer, and I question the political agenda of highlighting climate change as an asthma problem. If we accept that it will worsen asthma, the question that arises is, what should we do about it? How are we to improve the health and welfare of those suffering from asthma? The whole body of asthma science points to conditions of poverty being dominant risk factors for asthma. Thus, if we want to reduce asthma problems, then, first, our goal is to improve our economy and eliminate conditions of poverty. It is a mistake to believe that greater EPA control over carbon dioxide will make the slightest difference for asthma sufferers. To the contrary, I believe that with greater EPA control, economic growth will suffer and we will be a poorer Nation as a result.

Let us disabuse ourselves of the idea, if it is out there, that EPA controlling CO_2 will improve health outcomes in the U.S. Or elsewhere. I fear, based on outcomes of past EPA decisions, that greater EPA control over our lives and economy could indeed worsen our health outcomes and, most assuredly, worsen our economy.

Thank you, and I welcome questions.

Mr. WHITFIELD. Thanks, Dr. Roberts.

[The prepared statement of Mr. Roberts follows:]

Written testimony submitted by Professor Donald Roberts to the House of Representatives Energy and Power Subcommittee Hearing: "Climate Science and EPA's Greenhouse Gas Regulations." March 8th, 2011, 10am.

I want to thank the House Energy and Power Subcommittee for the opportunity to speak today. It is an honor to address such a distinguished body of U.S. Representatives.

Introduction

I have given public testimony before and want to begin my comments with an observation from past appearances in hearings. It seems to me those duly selected to represent our citizens seek nothing more from those who testify than truthful and, hopefully, unbiased assessments on the issues of our times. I see this in the microcosm of my wife's elected duties as Vice Mayor of Clifton Forge, VA. While there are magnitudes of difference in responsibilities she has versus the weighty responsibilities you ladies and gentlemen of the U.S. House of Representatives carry, the fundamental need for truth and facts is the same. It has been my experience however, instead of truth and facts, and more often than not, you get carefully crafted and highly qualified assessments representing one ideological perspective or another.

In this context, I want you to know I am a retired research scientist. My opinions do not represent those of my previous employer, the Department of Defense, or the U.S. Government. I am not salaried or funded for my work. I have no active research program that requires my allegiance to some ideological perspective for future funding. Likewise, no corporate interests or nongovernmental group with an ideological agenda pay for my work. This is not to say, however, that I am without convictions. My promise to you is that I can document the truth of my statements. For me, to a considerable extent truth is what is demonstrable, replicable, and consistent across studies.

Science, Climate and Disease

I am here today because I follow closely the evolving debate on claims of public health harm from climate change. My previous testimony in the US Senate[1] on this topic remains relevant and I will not repeat those arguments here, nor will I repeat the excellent scholarship of scientists such as Dr. Paul Reiter who have published so ably on the topic of climate change and insect-borne diseases[2]. This

[1] Testimony by Prof. Donald Roberts, Senate Committee on Environment and Public Works, Hearing, "Examining the Human Health Impacts of Global Warming," October 23, 2007, Available at: http://epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=10a2d911-9404-4145-bfa4-6f5c105ad287

[2] Reiter, Paul, "Climate Change and Mosquito Borne Disease," *Environ Health Perspect*, **109**, Suppl. 1, March 2001.

topic interests me because of parallels in EPA and environmental advocate's claims about climate change and CO_2 regulatory controls and their claims about insecticides and human health. The arguments for government interventions in both topic areas rest on fearful claims, doomsday and fearful predictions of devastating consequences in absence of regulatory intervention. Consider the following statements from a recent Senate hearing:

> "If Congress slashed EPA's funding, concentrations of harmful pollution would increase from current levels," Jackson told the Senate Environment and Public Works Committee yesterday. "The result would be more asthma attacks, more missed school and work days, more heart attacks, more cancer cases, more premature deaths."[3]

The assumptions underlying these predictions are many. One outstanding assumption of this message of fear is that EPA regulations measurably reduce indices of asthma and heart attacks, and cancer and premature deaths. I have reviewed the history of the EPA budget. It has gone up and down during its 41-year history. I know of no increased pollution during years of low budgets. Likewise I know of no marked reductions of asthma, cancer of other health indices during years of budget increases. Jackson's claims are typical fear tactics that have become a hallmark of the environmental movement.

Putting issues of EPA budget aside, I want to introduce my technical comments with a quote from a recent Associated Press article with a lead statement "none of EPA's actions is as controversial as its rules on global warming."[4] In my opinion, this is wrong.

Almost forty years ago EPA banned DDT in the United States. Its action against DDT was extraordinarily controversial, and still is. As activists advanced fearful claims against DDT, the EPA was warned, over and over again, a ban would destroy critically important disease control programs and millions upon millions of poor people in developing countries would die as consequence. Leaders of the World Health and Pan American Health Organizations, and even the U.S. Surgeon

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[3] Kim Chipman and Jim Snyder - EPA Carbon Rules Would Be Blocked Under U.S. Bill Readied by Republicans. Bloomberg. Mar 3, 2011 12:00 AM ET (http://www.bloomberg.com/news/2011-03-02/epa-chief-jackson-urges-u-s-lawmaker-not-to-slash-her-agency-s-funding.html)

[4] DINA CAPPIELLO, 4 Dems join GOP fight to block EPA climate rules, Associated Press - Thu Mar 3, 8:12 pm ET (http://news.yahoo.com/s/ap/us_epa_global_warming)

> Full context of the quote is: None of the EPA's actions is as controversial as its rules on global warming, which Republicans and some Democrats say will raise energy costs and cause job losses in an already fragile economy. The Obama administration counters that controlling global warming pollution is necessary based on scientific evidence that it is threatening public health and the environment. The EPA also says the rules will ultimately yield more health and economic benefits than costs, much like many other Clean Air Act regulations.

General warned against the ban. The EPA banned DDT anyway, and the doomsday predictions of those public health leaders proved prescient[5].

Today, we are engulfed in controversy whether EPA should be allowed to regulate our energy industry on basis of its ideological agenda. Repeatedly we have heard their messages of fear, yet most people oppose government intrusions that risk higher costs of energy or loss of jobs in the energy sector. Perhaps a take home message for our environmentalist colleagues is 'people are tired of the fear tactics.' Regardless, the national debate continues and the EPA and others continue to focus on messages of fear and misinformation to achieve their goals. On the international level, the environmental sector, headed by the United Nations Environment Programme (UNEP), is working for global elimination of DDT by 2020. As with our national energy debate, fear tactics and ideological zeal characterize UNEP's work. Again, as with our national debate, UNEP's work and determination to achieve DDT elimination by 2020 starkly pits the needs of hundreds of millions of poor people in developing countries against an ideological agenda. As I will explain below, UNEP shows scant regard for people living in poor countries at risk from insect-borne diseases in its march toward another environmental victory.

Some in this room will be incensed by my characterization of UNEP's actions against DDT or EPA's actions to regulate the energy industry as ideological. I use the term because EPA was warned over and over again that a DDT ban would sentence untold millions to death and disease. EPA banned DDT for most uses anyway. The impact of this decision on global disease control was devastating and is still being felt today. In the current debate, government is being warned yet again not to enact regulatory controls. Putting aside those warnings is a function of ideology, and it goes far beyond what science can justify or defend, particularly in this time of high unemployment and a troubled economy. The unintended consequences of a major ideological agenda can be devastating.

Climate Change and Asthma

Practically every facet of what I describe in research and advocacy against insecticides has a counterpart in climate change research and advocacy. For purposes of illustrating some counterparts in climate science, I will focus attention on a recent paper currently receiving a lot of attention on climate change and asthma[6]. I have reviewed the paper and offer no serious criticisms. Authors present estimates of time for beginning of the seasonal pollen season (aeroallergen season) and time it ends with the first frost, so the data really are not measures of warming since changes do not provide a measure of actual warming, just changes in

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[5] Further details can be found in Donald Roberts & Richard Tren, The Excellent Powder, DDT's Political and Scientific History, Dog Ear Publishing, IN, April 2010, pp 452

[6] Ziska, L., Kowlton, K., Rogers, C., et. al., "Recent warming by latitude associated with increased length of ragweed pollen season in central North America," *Proc Nat Acad Sci*, Feb 22, 2011, doi: 10.1073/pnas.1014107108

beginning and ending of the pollen season. I will leave it to subject matter experts to deal with any technical issues in this paper. I will restrict my deliberations to those of a lay reader.

The paper suggests numbers of days of aeroallergen seasons might be extended in northern latitudes as a consequence of seasonal changes. To some this might suggest authors have documented warming temperatures as the cause of those changes. Warming temperatures might or might not be involved, I don't know; but authors only present data on the beginning and end of the aeroallergen season by latitude and day of year. The authors fail to point out that the range of confidence intervals were greatest in the more northern and more southern latitudes. This means there should be least confidence in estimates for length of aeroallergen seasons at those latitudes than in mid-level latitudes. The data also show aeroallergen seasons became shorter in southern latitudes, but still range of confidence intervals were larger for the extreme latitudes, thus there were less accurate. Although authors discuss their data in context of surface temperatures and warming, they actually present no data on surface temperatures and degree of actual warming (unless it is included in the supporting information, which I have not examined). The only way I can explain this is that authors consider measurements of first and last days of the aeroallergen season as reliable surrogates for actual warming as might be measured by continuous recordings of surface temperatures. Personally, I am not at all convinced one is an accurate surrogate for the other. No data are presented on whether lengthening of the aeroallergen season increases numbers of asthma cases and the authors do not claim it does.

Authors were appropriately careful about that; but the reason for caution is the incidence of asthma is actually greater in the Northeast and Midwest and less in the south. The logical conclusion from the north-south distributions of asthma cases is warm temperatures and long aeroallergen seasons are not major determinants for incidence of asthma cases.[7] If this interpretation is correct, then it is not easy to understand what the exact significance of their findings really is. In brief, I think the point is this; at some latitudes under some seasonal weather conditions, the allergy season will be longer in other years and, over time, the season may actually increase in length. Yet, the data in this report do not constitute an observation on a long-term climate change trend—and I don't think the authors claim otherwise. In fact, I think the scientists have shown an appropriate level of care in their interpretations and conclusions.

As I have emphasized in this written testimony, I am interested in parallels in messages of fear by ideological campaigns against DDT and those for regulating $C0_2$ emissions. On the DDT issue, it was always the receptivity of popular media to any and all reports of potential harms from DDT exposures that brought about public

[7] CDC. Akinbami, L.J., et al., Asthma Prevalence, Health Care Use, and Mortality: United States, 2005–2009 National Health Statistics Report. January 12, 2011. (http://www.cdc.gov/nchs/data/nhsr/nhsr032.pdf).

fear of the insecticide. That fear persists and is continually exacerbated by media coverage, even today. In my review of this paper I see a similar receptivity of the popular press. Consider that one article about this paper actually infers the work suggests global warming is spurring asthma[8] (does this mean it is causing an increase in numbers of cases? How else can this headline be interpreted?). That report was picked up and repeated on the website stopglobalwarming.org.[9] Nevertheless, brief check on the Internet and other sources will show broad, high-visibility coverage of this rather modest paper. Such coverage is out of context because the paper does not describe a long-term trend (it covers few years), it is not definitive, it requires replication, and the findings must eventually be proven as consistent across multiple studies. In other words, it is just a preliminary report, which suggests some possible associations, nothing more. It is not the last word on this subject.

In this paper, it is worth noting that the paper lists twenty authors. It was published in Proceedings of the National Academy of Sciences. Of the twenty authors, five are affiliated with major environmental science programs. The first author is with the Crop Systems and Global Change Laboratory of the USDA in Beltsville, Maryland. The second author is with the Health and Environment Program of the Natural Resources Defense Council. Later authors are mostly affiliated with asthma centers throughout the U.S. One author, Johnathan Patz, is known for attempts to attribute increasing rates of dengue and malaria to global warming. Of the authors, more than one, e.g., Knowlton, Ziska, and Patz, seem firmly or loosely associated with the NRDC. The NRDC is an activist organization that has a long history of campaigning against DDT and for reductions of CO_2 emissions.

Those who zealously campaign to reduce CO_2 emissions have long recognized a need to establish climate change as a source of harm to public health. Climate change as a threat to public health is, after all, the ultimate message of fear. This need is reflected in the many attempts to attribute all sorts of increases in malaria, dengue and other diseases to global warming. As documented in the DDT story, scientists and other public health professionals engaged in the control of those devastating diseases already know the tragic consequences of allowing misrepresentations in science to fester and grow, unchallenged by professionals within the discipline. As a consequence, attempts by climate change advocates to link those diseases to global warming have been effectively rebutted. The truth is, the range and intensities of those diseases are under control of many complex and dominant factors, such as the conditions of human poverty and man's own efforts to control them. The bitter truth about malaria and dengue in the Americas is the increases are largely products of environmental campaigns to stop the use of public health insecticides.

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[8] Naik, G. Wall Street Journal 3may2007. Global warming may be spurring allergy, asthma. (http://www.mindfully.org/Air/2007/Warming-Allergy-Asthma3may07.htm)

[9] http://www.stopglobalwarming.org/news/global-warming-may-be-spurring-allergy-asthma/

Unintended Consequences: Environmentalism and Insect-borne diseases

A stark example of an unintended consequence relates to the catastrophic harm caused by the ideological war waged against DDT. A close look at options for controlling dengue virus infections (an insect-borne disease also known a break bone fever and, in some cases, life threatening dengue hemorrhagic fever) will show even the causal observer the disease is currently out of control. A closer look will show we have few options for effective preventive measures for reducing disease rates. Dengue is ranked as a global pandemic and is rampant in humid tropical regions of the Americas. For example, in 2010,

> Brazil recorded 999,688 cases of dengue in 2010, more than triple of last year cases, while deaths totaled 572, more than double in 2009, according to figures released Monday.[10]

But this devastating burden of disease was not always there. I lived and conducted research in Brazil through most of the 1970s. There were no cases of dengue because populations of the mosquito responsible for the disease had been eradicated in the 1950s and 1960s and Brazil was dengue-free. There were rare mosquito re-infestations, but public health teams quickly eliminated them with a magical tool, DDT. A re-infestation occurred while I was there in the mid-1970s, but this time the Brazilians did not mount an effective response. In that time frame, similar re-infestations were occurring in other countries. By the mid-1970s the efforts to deal with new infestations were being ramped down. The reason had nothing to do with the EPA had, it was due to fear tactics anti-DDT campaigners had employed in years before the EPA came into existence.

The United States had signed an international agreement to use DDT to eradicate *Aedes aegypti*, the vector of dengue and yellow fever. In 1964 Congress funded the eradication program. Then in 1969, an Executive Order was signed to stop all domestic uses of DDT. *Aedes aegypti* just happens to be a mosquito tied to the domestic environment--so that was that! The 1969 action against DDT was driven by ideology, not science. The U.S. abandoned its eradication program the same year. Prominent tropical medicine specialists protested, but to no avail. At that point other countries knew their own programs would inevitably fail because the U.S. was a major trading partner, so importations of the mosquito would be a continuous problem. Thus, by the mid-1970s, eradication programs of the Americas began to collapse and the mosquito began its inexorable return to all its old haunts in Central and South America.

Once dengue-free countries of Central and South America continue to experience increasing numbers of dengue infections each year. Since those increases can loosely be correlated with some warming of temperatures, climate

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[10] Brazil, dengue cases on the rise. Posted March 1, 2011. Latin America. Current Events and News (http://latinamericacurrentevents.com/brazil-dengue-cases-rise/)

change advocates have claimed the increases are due to warming temperatures.[11] Their claims ignore the historical record of why dengue is there, how current trends reflect a continuum of the mosquito re-occupying a vast geographical range, how outbreaks are dependent on human introductions of different dengue viruses, and ignore how those tropical climates have always been broadly supportive of enormous increases in the disease regardless of any small changes in ambient temperatures. In the end, it is man's control efforts or lack of control efforts that are determinants of dengue outbreaks, not the hyped changes in temperature and rainfall.

I have used this example to demonstrate real-world damage of messages of fear from environmental campaigns. As noted above, in 2010 Brazil suffered a burden of one million cases of dengue and hundreds of deaths. The United States just went through a major scare with swine flu, our total count of cases for 2009-2010 was about 42,000.[12] Just imagine if there had been a million cases. Further imagine the infections would be continuing and a million or more would occur every year. That burden of disease is what Brazil faces with dengue fever, and their problem is, at least in part, an unintended consequence of an old regulatory action. The 1969 decision against DDT constituted a disastrous rush to judgment. The judgment was based on messages of fear; it was political and not scientifically justified.

Perhaps some in this room may not know the EPA actually came into existence as a vehicle to enact a ban on DDT, and other insecticides. The ban was hailed by the anti-insecticide campaign as a great victory and it solidified EPA's ideological agenda for decades to come. To achieve a ban, the EPA Administrator set aside the scientific evidence from months of scientific hearings. Likewise, the Administrator set aside the presiding judge's carefully considered opinion that, based on sworn scientific testimony, a ban was not warranted. Two months later the Administrator signed the ban. The ban was EPA's first major regulatory action and the decision was entirely political. To this day, the EPA has never been compelled to present scientific evidence justifying the Administrator's decision. The EPA continues an international activist agenda against DDT and against national malaria control programs that need DDT to protect life and health of vulnerable populations. As evidence of this, I am attaching in the Annex a document showing direct financial contributions of US and EPA funds to the Stockholm Convention for elimination of persistent organic pollutants which includes special activities for DDT elimination.

Although I will return to this subject later, for now I want to sum up comments about EPA's actions against DDT in the following way:

[11] Valente, M. Climate change fuels spread of dengue fever. March 19, 2007. Inter Press Service Journalism and Communication for Global Change. (http://ipsnews.net/news.asp?idnews=36994)

[12] CDC. 2009 H1N1 flue U.S. situation update. (http://www.cdc.gov/h1n1flu/updates/us/)

From decades of study and debate, it is my firm conviction the ideological foundations of the EPA rest on the graves of millions of babies, children and pregnant women living at risk from disease in poor, malaria endemic countries. The victims died as a consequence of fear tactics of environmental campaigns and of EPA's ban on DDT and its continuing national and international advocacy against that insecticide.

Contributions of Science to Campaigns of Fear

Messages of fear are a key component of environmental campaigns, and it is useful to examine how science contributes to those messages.

Funding for research shapes science. Levels of funding set the stage for growth, stagnation, or decline of a scientific community. Steady and substantial research funding for a given area of enquiry promotes the growth of the scientific discipline. Additionally, continuous and adequate funding gives time for growth of ideological leanings within a science community. These simple concepts are important for understanding rapid growth in claims about the significance of climate change, especially as it relates to public health.

I was an active researcher in the 1980s, during years when there were increasing funds being made available for global warming/public health research. I was lured by the prospect of new funding opportunities and began conducting research into possible impact of warming temperatures on malaria. I compiled some rather large data sets and I started examining relationships between climate and malaria. I soon discovered that those large data sets equipped me to find almost any correlation or statistical association I wanted. I was alarmed and dug deeper. I found actual determinants for changes in malaria incidence were not changes in climate, but changes in what governments were doing to control the disease. This was true for both positive and negative directions of disease incidence. I abandoned those enquiries but my record of publications and professional presentations reflects that brief time of flirting with the global warming subject. In fact, those initial enquiries eventually led to a paper I published in Emerging Infectious Diseases in 1993, which laid out the relationships I am referring to.

Since the 1980s the flow of funding into the subject area of linkages between global warming (now known as climate change) and public health has changed from a trickle to an ongoing flash flood of money. For this reason, expect no diminution in frequency of claims or of decreases in the messaging of fear.

All too often fear messaging has its roots in misrepresentations of science in peer-reviewed literature, so it is worthwhile contemplating how misrepresentations find their way into that literature. In the 1960s and 1970s there were many instances of misrepresentations of DDT science. Many pro-DDT scientists protested; but most did not. However, the real imbalance in the flow of information during those years was not from scientists failing to correct the scientific record, the imbalance was in the popular press' full-hearted receptivity to messages of DDT being a dangerous poison. To a very significant extent, the same sort of biased messaging occurs in current struggles over scary claims about climate change. With DDT, the popular media embraced the messages of fear even though billions of people had been heavily exposed to DDT, to include millions in the U.S., without any documentation or demonstration of meaningful harm.

False "facts," erroneous data, flawed analyses, and biased interpretations are present in every discipline of science. All too often scientists do not purposefully work to expose the falsehoods that clutter scientific thinking. Understanding such failings in the process of science is important to understanding why the anti-insecticide campaigns and why current campaigns over regulatory control of CO_2 often get strong media coverage, with none going to those who blow the whistle over misrepresentations of science.

People reasonably expect scientists to have integrity and to be honest in published work. Yet, the task of enforcing truth in published papers is nobody's responsibility. As a consequence, dishonest papers are not rare. Even more common, however, are highly biased publications with ideological motives. Opposed to a dishonest paper with knowingly fraudulent data, analyses, or interpretations, a paper with ideological motivations presents the author's beliefs opposed to an unbiased and objective analysis of research. In science, the only defense against fraudulent and highly biased papers is the peer-review process. Unfortunately, that too can be manipulated and often falls short. Yet, peer-review is the gold standard. Research presented in any other venue will not really count as validated and peer-reviewed discovery.

Although unfortunate, it is a fact, many scientists do not bother to refute or even respond to false or highly biased publications. This, as expressed in the following quote, leaves the modern process of discovery wanting:

> "If we do not penalize false statements in error, we open up the way, don't you see, for false statements by intention. And of course a false statement of fact, made deliberately, is the most serious crime a scientist can commit. (Snow, 1934, p. 273)"[13]

More often than not, respondents who do write comments and objections to problems in published research do so in defense of their own studies.

The reason the science community is so seemingly tolerant of misrepresentations of science is because of the highly competitive nature of research. Ultimately, the first priority of a research scientist is his or her own research, not policing the literature. Most scientists are fully engaged in the process of discovery. If successful in their pursuit they receive the personal benefits of peer recognition (perhaps even public recognition) plus a professional benefit of

[13] Claus, G., Bolander, J. 1977. *Ecological sanity.* David McKay Company, Inc., New York. 592pp (page 478).

improved chances for more research support and other forms of career advancement. Failure in their quest will do just the opposite. There is almost no reward for exposing malfeasance of fellow scientists. To the contrary, false and biased reports are a great and wasteful distraction. Even more unfortunate is that within this milieu of problems one finds perhaps the biggest problem of all. This problem revolves around those scientists who opt for a shortcut to success. The shortcut is created by existence of well-funded ideological agendas.

Research data, analyses, and interpretations that can be used to advantage of an ideological agenda will be grabbed by activists within the movement and will be trumpeted in blogs, websites, and the popular press. It is precisely at this point that the popular press becomes a pivotal player in deciding what elements of discovery are presented to the public. Thus, what bloggers and the popular press will or will not write about is critically important. And as the history of struggles to preserve DDT for malaria reveals, the fear tactics and heavy funding of anti-DDT campaigns enjoy much more receptivity than do scientists who object to false and biased reports. After all, it is the scary story that seems to win. So scientists who get support from an ideological movement and get their research promoted in the popular press can enjoy quick recognition and rapid career progression. It seems fair to conclude, other than in cases of stupidity or incompetence, there can be rewards for misrepresentations of science. The rewards of shaping ones paper according to dictates of ideology are perhaps the single best explanation for what is happening today in climate change science.

I have tried to identify some pitfalls of research involved in what can be identified as strong ideological agendas. However, none of my views here should be taken as an inference I want cuts in research funding. I don't. However, I think there are huge inequities and those inequities fast track us toward harmful public policy decisions. Let me frame this issue first with comments about the anti-insecticides ideology. We have 40 years of anti-DDT campaigning. As a consequence, disease control programs stalled and some were completely stopped. Those programs were highly effective, so when they were stalled or stopped the diseases came roaring back. I have already described what happened with dengue in the Americas. Over time, but in the background to those devastating developments, the scientific community underwent huge growth in funded research to show potential links between DDT (or other insecticides) and every conceivable sort of harm. Furthermore, this growth in funded research is a global phenomenon. On the flip side of this issue, research funding for discovery of new insecticides declined and is almost non-existent today, especially for new public health insecticides. These facts define a huge problem. Billions spent to find any possible link between insecticides and harm to human health, millions in propaganda to demonize insecticides, and millions more to advocate against their use; but almost nothing for discovery of a true DDT replacement. This inequity has a history of almost 40 years and its cost can be calculated in millions and millions of human deaths.

Contemporary and Historic Lessons

I have explored and explained the important parallels between climate change activism and activism against public health insecticides. Though the EPA's decision to ban DDT for most uses was taken nearly 40 years ago, the battle to preserve this life-saving chemical for malaria control continues today. As we hold this hearing, the attempts of some malarial countries to source, import and use DDT are being thwarted by global environmental agencies and ongoing anti-insecticides activism.

As Annexes to this testimony, I have included copies of an opinion piece by Namibia's Minister of Health, Dr. Richard Nchabi Kamwi and a newspaper interview with Guyana's Minister of Health, Dr. Leslie Ramsammy. Both these Ministers of Health explain in their respective pieces that their malaria control programs require DDT and that global attempts to limit access will undermine their efforts to save lives.

Dr. Kamwi writes:

> Public-health insecticides save lives just as medicines or vaccines do. If there were coordinated campaigns against life-saving medicines, there would be a global outcry. Unfortunately because of the stigma associated with insecticides and DDT in particular, we are often left to defend these life-saving chemicals alone. If we are to achieve our goals of malaria elimination though, we are going to need a more robust and global effort to defend the tools we need to get there.[14]

Dr. Ramsammy is quoted as follows:

> "Guyana would only need about two to thee tonnes of DDT annually for a few years to completely eliminate malaria...there is only one company and it will not produce that small amount for Guyana and even then if they did how would it get around the regulations surrounding the shipping restrictions...virtually there is a ban on DDT,"[15]

More recently, Dr. Ramsammy stated:

> "I support the non-use of DDT for agricultural purposes but not the elimination as a vector control chemical and I would say that until I die. I don't believe we have any justification in terms of the number of deaths globally and the morbidity due to these diseases,"[16]

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[14] Kamwi, R.N. "Free the fight against malaria," Wall Street Journal Europe, Nov. 8, 2010

[15] Narine, V, "The knock-out punch," Guyana Chronicle Online, Jan 20, 2011

[16] Knews, "Health Minister Calls for use of DDT to fight vectors," Kaiteur News Online, March 7, 2011.

As Ministers of Health, both Drs Kamwi and Ramsammy are responsible for the health and welfare of the citizens of their countries. Based on the overwhelming scientific evidence of safety and effectiveness, these Ministers have concluded that DDT should be used. However lives in their countries are being endangered not because of the use of man-made chemicals, but by the lack of man-made chemicals. What I describe here is a triumph of fear-based activism over science and reason. Ultimately, as I describe below, it is a triumph of environmental bureaucracies over the lives of poor people in poor countries.

I attach in the Annex a research paper that I co-authored and which was recently published in the peer-reviewed journal *Research and Reports in Tropical Medicine*. This paper describes the way the UN Environment Program and its financial mechanism, the Global Environment Facility (GEF) along with environmental health units of the Pan American Health Organization (PAHO) and World Health Organization (WHO) misrepresented and manipulated malaria control data. These data manipulations, which could just as accurately be described as scientific malfeasance, were undertaken so as to attempt to prove that malaria control is possible without public health insecticides. Those of us who are experts in tropical public health know that malaria cannot be controlled without the use of public health insecticides, like DDT. At a cost of around $14 million, UNEP and GEF ran experiments in Mexico and seven Central American countries to try to prove that malaria could be controlled with interventions they describe as 'environmentally sound.' These 'sound' interventions included screening houses, planting trees around houses and clearing potential breeding sites.

As with most scientific experiments, UNEP and GEF set up demonstration areas where their interventions would be used and control areas where there would be no interventions. As my research paper describes, at the end of the UNEP/GEF experiments there was no difference in malaria rates between the demonstration areas and the controls. The 'environmentally sound' interventions achieved nothing. Interestingly, malaria cases as a whole were reduced, though not through any of the UNEP/GEF interventions, rather through widespread use of malaria medicines as part of ongoing Ministry of Health programs. UNEP and GEF claimed the reductions in malaria rates were a result of their project, instead of reporting they were due to the widespread use of malaria treatments (a form of malaria control known as pharmacosuppression).

I have included this example in my testimony as just one example of how the UN's lead environmental program has misled the public and has manipulated data for the singular goal of removing DDT from use in malaria control programs. UNEP cannot claim to know that its agenda will not cost lives. Scientists such as myself and many others, to include Ministers of Health, are on public record explaining this to UNEP officials on numerous occasions and in different venues. Yet UNEP is pressing ahead with its agenda and it has the power to do so. It has the power to do so because we have given UNEP this power and regrettably the United States continues to fund its work (as documented in the Annex).

I hope that this example will give the US House of Representatives occasion to pause and seriously consider the long-term consequences of handing greater powers over to the EPA, particularly if it is under the guise of improving human health and wellbeing. I suggest to you that all the great advances and improvement in air and water quality for which this agency might rightfully take credit, on balance, pale in comparison to the enormous devastation and loss of life, perhaps as unintended or perhaps as intended consequences, this agency caused by its political actions against DDT and the agency's continuous advocacy to prevent use of DDT in disease control programs. I am of the opinion that no further funding or authority should be allocated to the EPA without a thorough public audit of past decisions and rulings, beginning with their ruling on DDT.

Conclusion

As I have explained, my area of expertise is in tropical public health. However as a scientist and as a taxpayer, I have to question the political agenda behind highlighting the effect of climate change on asthma. If we are to accept that climate change will worsen asthma, the question that arises is what should we do about it? How are we to improve the health and welfare of those suffering from asthma? The whole body of asthma science points to conditions of poverty being a dominant risk factor for asthma.

If we are going to seriously try and reduce asthma as a public health problem, then our first goal should be to improve our economy and, to the maximum extent possible, try to eliminate conditions of poverty. I believe we are fundamentally mistaken if we believe for one minute that greater EPA control over CO_2 will make the slightest difference to asthma sufferers. In fact I believe that with greater EPA control over CO_2, it is likely that economic growth will suffer and we will be poorer as a nation. I have observed in my many years of scientific research, in both rich and poor countries, the rich countries can afford to deal with public health problems. Let us disabuse ourselves of the idea, if it is out there, that EPA controlling CO_2 will improve health outcomes in the US or elsewhere. I fear, based on outcomes of past EPA decisions, that greater EPA control over our lives and economy could indeed worsen our health outcomes, and most assuredly worsen or economy.

ANNEX 1

1. Stockholm Convention Financial Report – UNEP/POPS/COP.5/34. Page 13
2. Kamwi, Richard Nchabi, "Free the Fight Against Malaria," Wall Street Journal Europe, November 8, 2010
3. The 'Knock-Out' Punch, Vanessa Narine | 20 Jan 2011, Guyana Chronicle Online
4. Health Minister calls for use of DDT to fight vectors 07 Mar 2011 Kaieteur News Online

UNITED NATIONS

UNEP/POPS/COP.5/34

Stockholm Convention on Persistent Organic Pollutants

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Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants
Fifth meeting

Geneva, 25–29 April 2011
Item 6 of the provisional agenda*
Programme of work and adoption of the budget

Financial report and review of the staffing situation in the Secretariat

Country	*Pledge*	*Payment*	*Remarks*
Contributions 2010			
CORSA, Mexico	800	800	PEN magazine
Germany	EUR 30 000	37 890	Technical assistance on new POPs in Nigeria
LITO S.A., Colombia	1 500	1 500	PEN magazine
Netherlands	EUR 40 000	53 600	POPs activities 2010
Netherlands	EUR 40 000	34 264	POPs activities 2010-2011
Netherlands	EUR 120 000	116 336	POPs activities 2010-2011
Norway	NKr 2 900 000	447 531	Technical assistance projects for 2010
Norway	NKr 170 000	26 984	Travel support to developing countries
Sweden (KEMI)	SKr 1 000 000	68 681	GMP project (1st instalment)
Sweden (KEMI)	SKr 660 000	90 659	Alternatives to DDT
United States Environmental Protection Agency	10 000	10 000	International public health pesticides workshop
Subtotal 2010		***888 246***	
Total income		**9 500 621**	
Committed pledges during 2010 (not deposited)			
India		1 000	Launch of Global Alliance for alternatives to DDT
European Community grant		27 200	Toolkit activities (final) (EUR 20,000)
Germany		65 000	Synergy projects between Stockholm and Rotterdam conventions (EUR 50,000); deposit
Norway		192 800	Small-grant projects with Basel, Rotterdam and Stockholm convention regional centres (NKr 1,130,000)
Norway		22 200	Safe Planet Campaign (NKr 130,000)
Sweden		22 200	POPRC-6 participant travel (SKr 150,000)
Trédi International, France		8 000	Launch of PCBs Elimination Network
United States		400 000	Support for POPs activities
Total pledges		738 400	

THE WALL STREET JOURNAL.
EUROPE
Monday, November 8, 2010

Free the Fight Against Malaria

By Richard Nchabi Kamwi

This week southern African countries commemorate Malaria Week, with events to increase awareness of a disease that continues to claim lives and stunt development in Africa, Asia and Latin America. Coincidentally, and perhaps ironically, an expert committee convened by the Stockholm Convention on Persistent Organic Pollutants is also meeting this week, in Geneva, to discuss dichlorodiphenyltrichloroethane or DDT, an anti-malaria insecticide that has been saving lives since 1945. The Geneva meeting, thousands of miles from any malaria-spreading mosquito, could have important implications for disease control and development in poor countries.

Namibia is a party to the Stockholm Convention, which laudably seeks to remove harmful pollutants from the environment. As DDT is essential for malaria control, it is the only chemical classified as a "persistent organic pollutant" that can still be used. Yet my country and others working to eradicate malaria still face ongoing pressure from anti-insecticide activists, and in recent years the manufacturers of DDT have dwindled to only one, a state-owned factory in India. Regrettably the secretariat of the Stockholm Convention envisages halting all production of DDT in just seven years. Yet there is no true replacement for DDT, and malaria-inflicted countries will continue to need it for the foreseeable future.

> *Stop putting the sensibilities of anti-insecticide activists ahead of human lives.*

Malaria is a disease that we should not have to live with, and happily most developed nations eradicated it in the 1950s, mostly thanks to the targeted use of DDT.

Namibia together with seven countries in the Southern African Development Community has been designated for malaria elimination over the coming five years. As part of a phased intervention to roll back malaria from the south to the north, Namibia, Botswana, South Africa and Swaziland are on track to eliminate the disease by building a comprehensive, evidence-based approach that includes using bednets, improving diagnosis, and making available safe, effective treatment. But the cornerstone of this highly successful campaign is the spraying of small amounts of insecticide, including DDT, inside houses.

There are several reasons to defend DDT and ensure we have ongoing supplies. First, DDT is safe for humans and the environment. Since the 1940s thousands of scientific studies have investigated potential harm to human health from DDT. Almost all these studies are weak, inconclusive or contradictory; in other words there is no evidence of harm. On the other hand there is well-documented evidence of its great public-health benefits. As Minister of Health, I have to evaluate the full body of scientific evidence and balance risks. With regard to DDT and malaria, any rational balancing of risks will favor DDT.

As for the environment, DDT produces no environmental contamination when sprayed in small quantities inside. Yet even if there were some concerns about environmental harm, we would still place greater value on human life.

Second, DDT is essential for managing insecticide resistance. There are few alternative insecticides suitable for malaria control and approved by the World Health Organization. None equal the efficacy of DDT nor do they work in the same way as DDT, which primarily stops mosquitoes from even entering houses. The well-documented experience of a number of countries in southern Africa is instructive in this regard. For example, South Africa in 1995 switched from DDT to deltamethrine, a pyrethroid. But the malaria-carrying *Anopheles funestus* mosquito proved resistant to deltamethrine early on, and the resultant increases in fatalities due to malaria necessitated the reintroduction of DDT, which continues to be used.

Third, failing to protect DDT, secure supplies and defend our right to use it will mean that the global community puts the sensibilities of anti-insecticide activists and the agendas of the Stockholm Convention Secretariat ahead of the lives of poor people in malarial countries. This will set a worrying and damaging precedent and would be grossly unjust.

In general, ministries of health work with limited budgets and have many competing demands. Public-health insecticides save lives just as medicines or vaccines do. If there were coordinated campaigns against life-saving medicines, there would be a global outcry. Unfortunately because of the stigma associated with insecticides and DDT in particular, we are often left to defend these life-saving chemicals alone. If we are to achieve our goals of malaria elimination though, we are going to need a more robust and global effort to defend the tools we need to get there.

I have long labored to control this complex and challenging disease in Namibia. My staff understands the strengths and weakness of different malaria-control methods. Drawing on this knowledge and experience, I call on the international community to act against those who seek to eliminate or restrict our freedom to use DDT. First and foremost, we must protect the health and welfare of those who are at risk of disease and death from malaria.

Mr. Kamwi is the minister of Health and Social Services in Namibia and chairperson of the South African Development Community's Malaria Elimination Eight (E8) group of countries.

The 'Knock-Out' Punch

Vanessa Narine | 20 Jan 2011
Guyana Chronicle Online

In the last 20 years there have been at least 20 million deaths because of malaria, one million deaths annually, and 250 million cases of fever cause by malaria each year across the globe.

Last year alone the world saw a new picture - globally over 800 million cases of malaria were recorded and in Guyana alone the incidence of malaria climbed to 17,000 cases.

While locally this was a decrease from the 100,000 cases seen in the 1990's, it was an increase from 2009's 10,000 cases.It is in this context that Health Minister Dr. Leslie Ramsammy contends that Guyana - and the world over - needs the 'knock out punch' to eliminate the malaria scourge that plagues the health sector.

Guyana needs DDT (dichlorodiphenyltrichloroethane).

"Unlike in the 50's and the 60's we do not have the knock out punch we need...we have been making progress in reducing malaria yes, but we can never have complete elimination without DDT," he said.

Ramsammy said using alternative methods to address malaria will only "stagger" an opponent, which has the potential to return stronger and deadlier to inflict major losses on a country - tragically too that loss includes the loss of lives in the millions.

Past Success

In the 1940's malaria was rampant, particularly on the coast, at which time DDT was introduced by an Italian Doctor George Giglioli.

He first headed the Demerara Bauxite Company, Ltd., a subsidiary of the Aluminum Company of America (ALCOA).

The company offered medical services to its employees and the surrounding population through a hospital in Mackenzie, Region 10 (Upper Demerara/ Berbice) and Giglioli was integrally involved in the delivery of these services.

In his autobiography, 'Demerara Doctor: Confessions and Reminiscences of a Self-Taught Physician', Giglioli noted that malaria proved a much more intractable problem, compared to other diseases.

According to the book, between 50 and 75 per cent of all those who sought treatment at the hospital were suffering from malaria in the 1940's.

"The mosquitoes that carried the disease bred prolifically around Mackenzie following the May-July rainy season; there was no practical way to get rid of them or their breeding ponds. The only way to control the disease was through a prolonged course of the unpopular, bitter-tasting drug quinine," the book read.

In 1936, he was asked by Booker's, the country's largest sugar producer, to head a laboratory in Georgetown the company was setting up to conduct systematic medical surveys and improve health conditions on all the sugar estates in the country.

"This was exactly the kind of development I had hoped for when I accepted the job with Davsons," he wrote.

In 1939, another malaria milestone was achieved: a Malaria Research Unit was established with funds from the Colonial Government, the Rockefeller Foundation, and the British Guiana Sugar Producers' Association, and Dr. Giglioli was selected to head it.

Giglioli came to be recognised as a valuable a resource and in August 1942 he obliged to accept the appointment of Government Malariologist.

The following year, three distinguished British scientists made an unscheduled visit to Guyana when their flight from Trinidad to Washington, D.C., was delayed for several days.

One of the scientists, Dr. Alexander King, talked about the new insecticide DDT, which the Allies (in the Second World War) were using as a 'secret weapon' to protect their troops from malaria.

A month later, the first 500-pound consignment was on its way to Guyana. The preliminary work needed for the field experiment, Giglioli's detailed mosquito and malaria surveys, had already been done.

The trials expanded into a large-scale control program in 1946 and into a countrywide campaign in 1947.

By 1951, malaria and its principal carrier had been completely eliminated from the coastal areas, including Georgetown, by means of a highly focused house spraying campaign.

In the interior, where settlements were widely scattered and difficult to get to, it was impossible to completely eliminate the disease. The mosquito lived in the forest there, not in houses.

To date there is no malaria on Guyana's coastal plains, as is the situation in the

Caribbean, most parts of the US, Europe and parts of Asia, among other territories. This work was also promoted by the late Janet Jagan who served as Health Minister. Ramsammy noted that when the People's Progressive Party lost power in 1964, it handed over a country where there was no malaria on the coast.

"This was one of the legacies of the administration under Dr. Cheddi Jagan...when we emerged into independence the PPP gave a country over that had no malaria," the Health Minister said.

However, with time and change, DDT's continued use was not to be.

In 1962, American biologist Rachel Carson wrote Silent Spring. The book cataloged the environmental impacts of indiscriminate DDT use in the United States of America (USA) and questioned the logic of releasing large amounts of chemicals into the environment without fully understanding their effects on the environment or human health. The book suggested that DDT and other pesticides cause cancer and that their agricultural use was a threat to wildlife, particularly birds.

The book produced a large public outcry that led to a 1972 ban in the US and the use of DDT was subsequently banned.

Under the Stockholm Convention on Persistent Organic Pollutants (POPs), which are chemicals capable of affecting human health and the environment far away from the regions where they are used and released, the production and use of DDT in vector control is 'restricted'.

Review

However, the Health Minister made it clear that while a 'ban' on DDT is not implicitly stated, a ban virtually exists because of the regulations governing, in particular, its production and shipping.

He pointed out that there is currently only one producer of DDT, a company in India which only produces based on relatively large demands.

"Guyana would only need about two to thee tonnes of DDT annually for a few years to completely eliminate malaria...there is only one company and it will not produce that small amount for Guyana and even then if they did how would it get around the regulations surrounding the shipping restrictions...virtually there is a ban on DDT," Ramsammy said.

To this end, he called for a review of the perceptions surrounding the use of DDT, pointing out that the non-use of DDT was based on the effects its use had in the agricultural sector - since DDT had a dual purpose, for agriculture and for vector control.

The Health Minister noted that there is not sound evidence which indicates that DDT as a vector control method is a hazard.

"There is no evidence that DDT in vector control led to mass deaths," Ramsammy posited.

He agreed that the use of DDT in the agricultural sector will have negative impacts; that the positives will outweigh the benefits and indicated his support for this position. "There is no one doubting that we should not use DDT in agriculture," the Health Minister said, "We are not talking about using it in the fields where it will get into the water and foods. We are talking about protection from mosquitoes."

However, Ramsammy stressed that in the agriculture sector there are affordable and accessible alternatives which can be used, for example gramoxzone.

He noted that chemicals like gramoxzone do not stay in the environment as long as DDT, when used in agriculture, hence is not included in the Stockholm Convention and its use is permitted.

On the other hand though, there are negative impacts of gramoxzone - an absolute prerequisite in agriculture sectors across the world - but over the years methods have been developed to control those effects.

For example, persons handling the chemical must wear certain gear to protect themselves and there is evidence to prove that people's fertility can be affected by gramoxzone.

Ramsammy "It is a balancing act with the negatives and the positives...there can be do doubt that DDT has biological effects and there are no chemicals that are without such effects, whether it is at an environmental level or at an individual level."

DDT - A Different Story

The Health Minister said since the virtual ban on DDT a number of powerful insecticides have been developed, but they are costly and are inaccessible to most populations.

"What we have are very expensive alternatives to DDT...either we make these more affordable or push to have those insecticides that have shown to be extremely effective," he said.

A point for concern, he highlighted is that the current treatments for malaria, in particular the Pyrethroids, is slowly becoming ineffective, since the mosquitoes are developing a resistance to the drug.

"We have not even reached the stage where we can make one of the alternatives more affordable and it is already showing resistance," Ramsammy said.

The Health Minister stated that for the millions that are dying and the losses caused by malaria, the world over is missing an opportunity to use a product, which can be safely use in the small quantities that are needed.

"The world has done the right thing in identifying the dangers, but in the process of doing that we have neglected to consider that there could be good use of DDT," he said.

Ramsammy stressed that with DDT Guyana can be free of malaria is as little as three years. "It seems an unwise decision not to consider wider use of DDT in a controlled manner," he said.

In this light, Ramsammy proposed that the World Health Organisation (WHO) and the United Nations (UN) ensure the restricted production of DDT.

"The proposal is that there is a global entity responsible for the procurement and distribution of DDT...the distribution will only be made to those countries with a high disease burden for malaria...this way we ensure that it is not abused. We know where it is going and who is getting it, we can monitor it," he opined.

The Health Minister said the Millennium Development Goal (MDG) target, relative to malaria, is attainable, but the alternatives - biological control, fogging, bed nets and treatment (all good once used in the right setting) - are not enough to completely eliminate malaria.

However, Ramsammy said vector control via DDT; plus the combination of good medicines for treatment, better trained health care workers in diagnosing malaria, among other things; will give Guyana a chance to eliminate the malaria scourge.

"There will always be an up and down problem...it will be a yo-yo effect, something we will see for decades to come with the potential to cause us many losses," Ramsammy said.

According to him, malaria has in the past, and will continue to: be a major contributing factor to the death toll; be the cause of disability; be the cause of impoverishment in families and within communities; impact national economies; and impact productivity, expressly it mining and forestry sectors.

"The cumulative effect of what malaria has done globally and then look back at 100 years of DDT use in vector control, before is was less accessible, the negative impacts do not come close to the devastation we saw in just the last 20 years...you cannot equate the negative impacts of DDT in vector control and what we have seen in the last two decades," Ramsammy said.

The Health Minister stressed that no method outside of vector control has ever led to elimination of malaria.

"Everywhere we don't have malaria, if you go back in history, one would see that there was malaria in that area, but it was eliminated through vector control. It was eliminated through DDT," Ramsammy said.

The Health Minister maintained that unless the "knock-our punch" is considered malaria will continue to plague Guyana - continue to plague nations across the globe.

"As long as it is there it will always come back strong...unless we make use of that knock out punch we will be constantly dealing with malaria in a yo-yo way, down and up, down and up...this is a tragedy because if I had DDT today, 2011, Guyana would have been malaria free," the Health Minister said.

Health Minister calls for use of DDT to fight vectors

07 Mar 2011

Kaieteur News Online

Guyana is adopting strategies that fully utilises biological methods as a control strategy for vectors thus the use of BTI (Bacillus Thuringiensis Israelensis) is one that should be more widely utilised in Guyana.

This is according to Minister of Health, Dr Leslie Ramsammy, who recently commended the work that is being done through the efforts of the Canadian International Development Agency (CIDA), the Pan American Health Organisation (PAHO), the Ministry of Health, and professionals of other entities, along with communities in the pilot work currently being undertaken in this regard in Mahdia and Bush Lot.

However, the Minister observed that the work, although commendable, is proceeding at snail's pace, a pace that "is not deserving" of a matter of such serious magnitude.

According to him, biological control using BTI can be used in many local communities and is a unique way of engaging the community in vector control.

He lamented though that "more than a year after we started that project, many of the people working on that project must be reminded that this project is still an ongoing one in Guyana. I am disappointed and I want to say publicly on behalf of the people who live in our villages that we are depriving them of a unique way of addressing the problem through biological control."

The Minister noted that Guyana and too many countries in this Region have made poor use of residual spraying capacity that exist, even as he noted that access to expensive chemical for residual spraying is a constraint.

"I would hope that our use of residual spraying is improved. I believe that we are failing our people all those who have died of vector borne diseases. We have access to very effective chemical that we have made no use of over the years."

In addition, the Minister shared his conviction that the elimination of DDT (Dichloro-Diphenyl-Trichloroethane) has been too early. DDT is a well-known synthetic pesticide which has been banned for agricultural purposes, but there is still limited controversial use in disease vector control.

"I support the non-use of DDT for agricultural purposes but not the elimination as a vector control chemical and I would say that until I die. I don't believe we have any justification in terms of the number of deaths globally and the morbidity due to these diseases," the Minister added.

He underscored too that the use of chemicals locally has been one that is full of "pot holes. The flirtation has been so long that the prospective courting partners are getting too old for flirtation."

He further pointed out that fogging and the use of appropriate chemicals to control the mosquito populations is still an effective tool, adding that "our hesitation in the use of fogging bewilders me."

As a result, he noted that the Ministry of Health is poised to build the fogging capacity of all Local Government entities, insisting that it (fogging) is an exercise that cannot be handled from the Ministry but rather it has to be a capacity that is built into the Municipalities and other such entities as part of their governance mandate.

"It is an obligation to our citizens and while the Ministry is trying at this time to do some fogging exercise it is believed that the Municipalities and the Regional Governments and the Neighbourhood Democratic Councils are failing our people by not aggressively taking on this role."

While the Municipalities and the Local Governments have not taken up this role, Minister Ramsammy noted that the Ministry has an obligation to "fill the vacuum. We cannot stand by and not do anything.

While we will continue to appeal to the authorities to do their job we must take a more robust approach," Minister Ramsammy insisted.

He noted though that the responsibility does not only lie with the Ministry's Vector Control Unit but also other departments including the Environmental Health Unit, which according to him has been weak in its efforts and sometimes "behave as though this is not a role for them to play. It is a role for all of us."

The public also has a role to play, the Minister stressed.

Annex 2

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EXPERT OPINION

International advocacy against DDT and other public health insecticides for malaria control

Donald R Roberts[1]
Richard Tren[2]

[1]Uniformed Services University of the Health Sciences, Bethesda, MD, USA; [2]Africa Fighting Malaria, Washington, DC, USA

Abstract: A new international effort to control/eradicate malaria is accompanied by suggestions that malaria can be controlled without the use of dichloro-diphenyl-trichloroethane (DDT) and other insecticides. We review the underlying science of claims publicized by the Global Environment Facility (GEF), the United Nations Environment Programme, and the Stockholm Convention Secretariat (the Secretariat). Their claims stem from a $14 million GEF project that was conducted from 2003 to 2008 in Mexico and seven countries of Central America. Objectives, experimental design, analyses, and project accomplishments are described. So-called environmentally sound interventions (GEF interventions) that excluded insecticides were implemented in demonstration areas in eight countries. Efficacy of interventions was evaluated by comparing malaria rates in demonstration areas (n = 202) with those in control areas (n = 51), all in high malaria risk areas. There were no statistically significant reductions in malaria rates in demonstration areas compared with controls. This was true across all eight countries. Broad use of antimalarial drugs was the primary method of malaria suppression in the eight countries, but this method was not a GEF intervention. Ultimately statistics favoring efficacy of "environmentally sound" methods of malaria control were obtained by comparing malaria cases in demonstration areas for 2004 with cases in 2007, and we explain why these comparisons are not valid. In conclusion, claims that GEF interventions effectively reduced malaria in Mexico and seven countries of Central America are not supported by existing data or the results of epidemiological analyses. The claims are being used to justify the Secretariat's plan to eliminate DDT production by 2017. DDT is still needed for effective control of malaria, and its elimination could have significant consequences for people in malaria endemic countries.

Keywords: DDT, malaria control, Mexico, Central America, insecticides

Introduction

There has been a gradual awakening to the return, or for some, the continuation of malaria as a major public health issue in developing countries. This awakening has brought about a new emphasis on the control of this terrible disease.

The global malaria eradication program of the 1950s and 1960s demonstrated that malaria can be controlled, and in some regions, eradicated. Indoor residual spraying with (dichloro-diphenyl-trichloroethane) DDT was a major component of that program, which freed almost a billion people of endemic malaria. Lessons were learned that have application to what is happening today. One important lesson was that while program achievements were remarkable, the program was vulnerable to ideological opposition. It was opposed, eventually stalled, and then largely destroyed by, among other things, campaigners who opposed use of DDT and other insecticides. Anti-DDT

Correspondence: Donald R Roberts
118 First St, Clifton Forge,
Virginia 24422, USA
Tel +1 540 862 2998
Fax +1 202 375 7821
Email droberts@usuhs.mil

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propaganda penetrated to the very heart of the global malaria eradication program. In a 1969 meeting of the World Health Organization (WHO) Committee on Programme and Budget, the Netherlands delegation voiced concerns about DDT by stating "... DDT, when broken down to DDD or DDE, was toxic to man, other mammals and also to birds and fish".[1] This is just one of many examples of claims against DDT that were expressed in many forums of the global program. However, public health professionals of that era understood that DDT sprayed on inner walls of houses posed no meaningful threat to wildlife. It was equally well known that residents of hundreds of millions of sprayed houses had suffered no definable harm, while benefiting greatly from reduced threats from disease-spreading insects. Many historical events of the eradication program, to include false claims against DDT and the impact of anti-DDT campaigning, have already been described and documented.[2]

Today's renewed global push to control and perhaps eliminate malaria was reviewed in a recent series of informative papers.[3–6] The papers were remarkably mute on how renewed global efforts to control or eliminate malaria are once again being challenged by campaigns against insecticides. Continued opposition to public health insecticides should be no surprise because the movement against the use of insecticides has grown enormously since the 1960s. Lead agencies include the United Nations Environment Programme (UNEP), the Stockholm Convention Secretariat (the Secretariat), and the Global Environment Facility (GEF). The latter two are the newest of the bureaucracies that oppose insecticides for public health, with GEF gaining control over anti-DDT funding in 2001 and the Stockholm Convention coming into force in 2004. These agencies' opposition to DDT and other public health insecticides is supported by hundreds of millions of dollars being generated by the GEF and partners under the rubrics of improving methods and approaches to the control of malaria while achieving DDT elimination. The GEF has provided grants of $8.8 billion, and has attracted cofinancing from partner organizations in the amount of $38.7 billion.[7] According to a 2009 GEF report, since May 2001 "GEF has committed US$360 million to projects in the POPs [persistent organic pollutants] focal area and leveraged some US$440 million in co-financing, bringing the total value of the GEF POPs portfolio to US$800 million".[8] The GEF has invested $22 million into six projects researching alternatives to DDT for vector control.[8] Their fund-generating capacity is exemplified by the Secretariat's projected 2007 budget of $150 million for stopping DDT production by 2017.[9]

Several malarial countries in sub-Saharan Africa and elsewhere currently use DDT to control malaria, and use it to great effect.[10] It still has considerable value for malaria control, and endemic countries are calling for continued freedom to use DDT.[11,12] However, this freedom for the National Malaria Control Programs (NMCPs) to use DDT is threatened by the Secretariat's plan for total elimination of DDT in 2020. An urgent push to meet these deadlines perhaps explains why the UNEP, WHO, and GEF issued a joint press release in May 2009 announcing a "rejuvenated international effort to combat malaria with an incremental reduction of reliance on the synthetic pesticide DDT".[13] The rejuvenated international effort embodies the global program "Demonstrating and Scaling-up of Sustainable Alternatives to DDT in Vector Management" (Global DSSA program), which consists of 10 GEF projects, in 40 countries, to test nonchemical methods to control malaria, at an estimated cost of $78.3 million.[14] The program is supposed to be building on the results achieved from the "Regional Program of Action and Demonstration of Sustainable Alternatives to DDT for Malaria Vector Control in Mexico and Central America" (the GEF project), which evaluated DDT alternatives in Mexico and Central America.[15] The GEF project was undertaken in countries and during years when gains were being achieved in the control of malaria. The important question is: to what extent, if any, were those gains due to interventions promoted by the GEF project as environmentally sound approaches to malaria control without use of DDT?

Claims from research, which is not peer-reviewed and is publicized as "calculated and tested science"[16] by officials at high levels of global governance, is a cause for concern, even more so when the claims could potentially undermine malaria control with consequences for public health. With variable estimates of hundreds of millions of cases of malaria occurring every year, it is vital that policies for malaria control are based on truthful and accurate information about what works, at what costs, and at what risks. With a goal of more truthful and accurate evaluation, we undertook a detailed review of the GEF project and the validity of claims emanating from that project.

Material and methods

We include here a description of the GEF project,[15] a listing of project objectives, a description of the environmental interventions for control of malaria, and a review of its experimental design.

Description

In 2003, the GEF approved the "Regional Program of Action and Demonstration of Sustainable Alternatives to DDT for Malaria Vector Control in Mexico and Central America" (the GEF project), which aimed at preventing the "reintroduction of DDT for malaria control by promoting new integrated vector control techniques and implementing a coordinated regional program to improve national capacities"[15] in eight countries (Belize, Costa Rica, Guatemala, Honduras, Mexico, Nicaragua, Panama, and El Salvador). The GEF project was executed by the Sustainable Development and Environmental Health Program of the Pan American Health Organization (PAHO) and implemented by UNEP. It was cofinanced by the GEF with additional support from the Commission for Environmental Cooperation of North America, PAHO, and participating country governments. At the highest levels, this malaria project was controlled not by disease control experts, but by environmental groups, and was widely viewed as a GEF project. The overarching project plan was "the implementation of demonstration projects of vector control without DDT or other persistent pesticides that can be replicable in other parts of the world and which are cost-effective, environmentally sound, and sustainable".[15]

Objectives and goals

The project goals, relating directly to issues of malaria control methods and evaluations, were defined by various GEF, UNEP, and project participants. As described by a UNEP official,[17] a long-term goal of the Global DSSA program is "To contribute to a re-formulation of the WHO Global Malaria Program in order to promote global vector borne disease control interventions while at the same time eliminating the application of DDT and reducing the use of other chemicals". As justification for this goal, the UNEP official cited the World Health Assembly (WHA) resolution 50.13, which calls on member states "to take steps to reduce reliance on insecticides for control of vector borne diseases through promotion of integrated pest management approaches in accordance with WHO guidelines ...".

Specific GEF project goals as described by the UNEP[17] were to "demonstrate feasibility of integrated and environment-friendly methods for malaria vector control without the use of DDT" and to "assess the effects of these methods on malaria occurrence".

Other objectives of the project relating to educational materials about DDT and other insecticides, inventory and destruction of DDT stockpiles, and social and cultural agendas are not covered here. Our emphasis is on the scientific evaluation of methods of malaria control and validity of claims of success of the GEF project's malaria control interventions.

GEF interventions for malaria control

GEF interventions for control of malaria were evaluated in the GEF project and were described by Achim Steiner, executive director of the UNEP, at the Helsinki Chemicals Forum in 2009.[16] The specific GEF malaria control interventions evaluated in the project (as described by Steiner) were:

- Reduction of contact between mosquitoes and people via treated bed nets; meshes on doors and windows; the planting of repellent trees like neem and oak; and the liming of households
- Control of breeding sites by clearing vegetation; draining stagnant water, ditches, and channels; and the use of biological controls, such as fish and bacteria, in some countries
- Elimination of places near houses that attract and shelter mosquitoes through, eg, the cleaning and tidying up of areas in and around homes, alongside the promotion of personal hygiene.

The final 2009 evaluation[18] of the project mentions various methods of case treatment and elimination of parasites within human populations. However, these methods were ongoing components of malaria control in each country and predated the GEF project. In other words, these malaria control measures were not specific to the GEF project and operated nationally in each country before and during the project. Available evidence suggests the NMCPs did their work regardless of the presence or absence of GEF project personnel. Thus, antimalarial treatment (the major component of the NMCPs) in demonstration areas was not part of the end-of-project epidemiological evaluation[19] of the GEF project.

Experimental design

As revealed in the PAHO environmental sector's 2008 final report[20] on this project, experimental design of the GEF project included demonstration areas of GEF interventions. Design of the project also included epidemiologically similar areas without GEF interventions (ie, the controls).[19] The goal was to compare the results from demonstration areas with results from selected areas without interventions. As stated by Cesar Chelala,[21] a medical consultant affiliated with the GEF project, demonstration areas were selected "based on the high incidence of transmission and the persistence of malaria in those places". To meet this criterion, demonstration localities were selected based on three years of data on malaria indices showing repetitive problems of malaria, and where there was knowledge about presence of malaria mosquitoes and their seasonal occurrence. However, Chelala did not mention that similar areas were selected from the region with similar indications of malaria transmission, but without experimental interventions. These were the controls, and were included as the critical test or comparison unit for effectiveness of the experimental interventions. A total of 202 demonstration areas and 51 control areas were established.[19] The former included a total population of 159,018 and the latter 50,834. The most common methods used in the demonstration areas against adult mosquitoes were whitewashing of houses, cleaning of patios, and cleaning of houses. The more common methods employed against mosquito larvae (immature, aquatic forms of mosquitoes) were to fill or drain water bodies, clean edges of water bodies, and remove aquatic vegetation.[19] Other interventions were described (eg, larvivorous fish, bacterial toxins), but few were used in demonstration areas.

Results

Claims about effectiveness of GEF project interventions

The GEF project has received a considerable amount of publicity. The 2008 final report[20] claimed "... in the 202 demonstration communities there was a 63% reduction in the number of people with the disease without using DDT or any other type of pesticide ...", and that "... effectiveness ... was sustained in targeting and integrating the interventions against malaria without using any type of pesticide ...". The May 2009 UNEP/WHO/GEF press release[13] claimed the project utilized "pesticide-free techniques and management regimes" to "cut cases of malaria by over 60 per cent". They then inferred that the project showed "... sustainable alternatives to dichloro-diphenyl-trichloroethane (DDT) are emerging as cost-effective solutions that may be applicable regionally and globally". Steiner claimed the GEF project was "calculated and tested science" in his speech at the 2009 Helsinki Chemicals Forum.[16] He stated, "The project achieved a 63 per cent reduction in malaria cases and a more than 86 per cent cut in ones linked with *Plasmodium falciparum*, the malarial parasite that causes the most severe kind of infection and the highest death rate globally".[16] Chelala proclaimed "The program [the GEF project] has had significant achievements, notably a reduction in the number of malaria cases. From 2004 to 2007, reported malaria cases dropped by 63% in 200 demonstration communities in Mexico and Central America that had been chosen because of their historically high rate of transmission".[21] Similar claims also appeared in the Environmental Health Perspectives plaudits for new GEF projects, "The new projects follow a successful pilot project in Mexico and Central America that achieved an overall 63% reduction in the incidence of malaria and a more than 86% reduction in the most severe form of malaria, that caused by *Plasmodium falciparum*. This success has rekindled hopes that an end to DDT reliance is possible".[22]

Statistical evaluations of GEF interventions

As documented above, UNEP and Stockholm Convention officials have publicly claimed that GEF interventions were used to achieve very high levels of control over malaria in Mexico and seven countries of Central America. These claims of success are not supported by peer-reviewed literature, so it is critically important to confirm their scientific validity, given the publicity they have engendered.

A scientific evaluation of malaria control activities in Mexico by Dr Mario Rodriguez[23] reported that the annual parasite index (number of cases per 1000 population) for three of five demonstration areas was lowered more in years (2000–2004) leading up to the years of the GEF project (2004–2007) than during the project. Rodriguez presented data showing the large reduction of malaria from 2000 to 2004 comprised a national trend, not limited to demonstration areas.

In a separate analysis, an end-of-project epidemiological evaluation[19] reported no statistically significant differences in reductions of malaria in demonstration areas versus those in nonintervention (control) areas. Graphs of comparative data were presented, and in each country, the malaria rates in demonstration and control localities at the end of the project were equal. The epidemiologist made comparisons of malaria rates from 2004 to 2007 and reported that malaria rates in demonstration areas were less in 2007 than in 2004. This finding of less malaria in 2007 was the basis for claiming GEF interventions were highly effective in reducing malaria in demonstration areas. However, in the conclusion of the epidemiological evaluation, the epidemiologist recommended new studies because evidence was not sufficient to prove [GEF] interventions were effective. Additionally, the author of the 2009 final evaluation[18] concluded that "a problem occurred concerning the selection of control localities in each of the participating countries", and suggested "PAHO and UNEP should fund a new study to assess the impact of the project strategy used, correcting the problems that presented [sic] [probably meant 'prevented'] the evaluation of project impact, particularly the absence of control locations".

Discussion

Importantly, the claims of successes in the GEF project are not products of the malaria scientists, NMCPs, or the official malaria control organizations within PAHO or WHO. Indeed, claims formalized in the 2008 final report were produced by the environmental sector within PAHO, not by those who have technical expertise and responsibility for malaria control within PAHO. The Sustainable Development and Environmental Health Program within PAHO produced the 2008 final report.

Designation of who is responsible for UNEP/GEF/Stockholm Convention claims is important because significant malaria control successes have been achieved by NMCPs in the eight countries included in the GEF project. The NMCPs have maintained control over the disease and, in four of the countries, reportedly brought malaria cases down to historic levels. However, their successes were not a result of the interventions we describe as components of the GEF project. Their successes were mostly a result of wide distributions of antimalarial drugs to suppress malaria (see Table 1).

Data in the Table reveal trends of increased numbers of antimalarial pills distributed per diagnosed case and decreased numbers of cases. Equally obvious is the decreased numbers of pills distributed per diagnosed case, and increased numbers of cases in two countries (Costa Rica and Panama). Such strong associations show how the eight countries have been pressured to make limited use of alternative methods of malaria control, eg, use of insecticides to reduce environmental risks of malaria transmission. To generalize these relationships, with declining use of insecticides to reduce man-vector contact and malaria transmission, the trends in numbers of malaria cases will increasingly track with numbers of excess antimalarial pills distributed per diagnosed case of malaria.

Table 1 Numbers of chloroquine pills distributed per diagnosed case of malaria in Mexico and seven countries of Central America for 1990 versus 2004 and percent change in numbers of pills per case and percent change in numbers of cases from 1990[35] to 2004[36]

Country	Pills/case in 1990	Pills/case in 2004	% change in pills/case	% change in cases
Mexico	235	2566	+1092	−1307
Belize	21	82	+390	−287
Costa Rica	653	100	−653	+112
El Salvador	34	22,802	+67,064	−8276
Guatemala	38	54	+142	−144
Honduras	30	51	+170	−338
Nicaragua	279	1319	+473	−519
Panama	202	140	−144	+1337

We applaud the professionals of PAHO's Technical Area for Health Surveillance and Disease Prevention and Control (AD/HSD) for not giving credibility to GEF's claims of successful control of malaria in Mexico and Central America. In its most recent overview of malaria in the Americas,[24] the AD/HSD report gave token recognition to the GEF project, but attributed none of the successes of Mexico and Central America to GEF interventions. Additionally, the PAHO fact sheet on malaria notes that "There are no equally effective and efficient insecticide alternatives to DDT and pyrethroids . . .".[25] Of equal importance, the AD/HSD reports that malaria control in the Americas is now more difficult because of the short residual life of the pyrethroids used as replacements for DDT. In other words, without DDT, approved insecticides do not have an adequate residual life to be fully cost-effective in indoor residual spraying programs.

Issues of scientific methodology

It is not appropriate to ignore experimental controls because comparative tests with controls do not produce a desirable result. Unfortunately, the analyses and claims of the GEF project do just that. As described above, the end-of-project epidemiological evaluation[19] compared malaria rates in demonstration areas (with GEF interventions) with malaria rates in control areas (with no GEF interventions). The control areas had been selected for comparability with the demonstration areas. The comparisons revealed no statistical differences in malaria rates in demonstration areas versus rates in control areas. The epidemiological analysis called for new experiments because existing data did not show that project interventions had a significant impact on malaria. The failure of GEF interventions to reduce malaria rates quantitatively in demonstration areas compared with control areas was consistent across all eight countries. Yet, publicized claims of project successes ignored those findings. In fact, the use of control areas, even though they constituted a significant effort within the overall project, was not even mentioned in the 2008 final report.[20]

Because comparisons with control areas failed to show any impact of GEF interventions, those who publicized successes of the project employed comparisons of malaria rates in demonstration areas for 2004 with rates in the same areas for 2007. Their claims that interventions reduced malaria by 63% in demonstration areas and falciparum malaria by 86% were based on those comparisons.[16] However, the comparisons are not valid for two reasons. First, even though countrywide reductions in malaria rates in each of the eight countries, from 2004 to 2007, were included in the final report, the countrywide statistics were interpretively ignored in order to claim GEF interventions produced large reductions in malaria rates in demonstration areas. This error is important because there were large reductions in malaria rates with or without GEF interventions, so any claim that reductions in demonstration areas were due to GEF interventions is not valid. Indeed, two of the eight countries reported greater malaria reductions countrywide than in demonstration areas. Second, even if the comparisons did not require major adjustments, which they did, the underlying process of NMCPs targeting malaria control measures in high malaria transmission areas is so dominant as to invalidate the results of the analyses.

When countries were pressured to abandon use of DDT[26–28] and, in general, were discouraged from using any insecticides at all, they trended toward broad usage of drugs for suppressing malaria. The NMCPs are often described as epidemiologically stratified programs. This means control efforts are stratified according to determinations of risk, based on histories of malaria occurrences.[29] Thus, the broad distribution of drugs is greatest in areas of highest malaria risk, and correspondingly, less in areas of lower risk. As specified in the project's experimental design, demonstration areas were selected from areas of high malaria occurrence. In other words, the demonstration areas were in malaria hot spots. Thus, localities that NMCPs prioritized for rapidly detecting and treating cases, for drug prophylaxis, or for distributing mass numbers of antimalarial drugs, were the same areas where GEF project personnel applied their interventions against adult and larval mosquitoes. Thus, demonstration areas received maximum benefits from efforts of the NMCPs. The GEF project then claimed that reductions of malaria in demonstration areas were due to GEF interventions, when, in fact, reductions were due to a targeted and more vigorous application of the same measures that were being applied in other regions, albeit at lesser levels, which brought malaria rates down for the whole country.

Conclusion

There is a need to find alternatives to DDT, but the search for alternatives should not damage prospects for using DDT and other insecticides for malaria control; to do so would endanger human lives. Those who campaign against public health insecticides should understand that public health applications of DDT comprise a highly selective and environmentally safe use. The amount of DDT sprayed on just 100 acres of cotton during a growing season would suffice to protect up to 8500 people.[30] Additionally, it does not entail broad environmental contamination because it would be sprayed inside houses, not over the landscape.

The GEF-funded projects, such as the GEF project in Mexico and Central America, and as suggested by the title of the project, are damaging the prospects for using DDT. We believe the priorities and power of global public health policy is heavily skewed in favor of those who advocate against DDT, as well as other public health insecticides. As an example of this, the funds programmed by the Secretariat to halt the production of DDT in India and China is $150 million,[9] three times greater than the funds devoted by the Bill and Melinda Gates Foundation for the establishment of the Innovative Vector Control Consortium,[31] the leading public–private partnership devoted to developing new vector control technologies.

Additionally, we emphasize that the claims that DDT is unsafe for human exposure are only assumptions embraced by those within the anti-DDT campaign. In contrast with the many claims of human health harm made against DDT, it is an irrefutable truth that decades of research have not fulfilled basic epidemiological criteria for proving a cause and effect relationship between environmental exposure to DDT and any harm to human health.[32]

There is not yet an alternative to DDT that mirrors the modes of action of DDT (spatial repellency, contact irritancy, and toxicity),[33,34] nor one that is as cost-effective. Thus, unscientific claims against DDT and other public health insecticides could damage existing NMCPs and impair prospects for use of public health insecticides far into the future. Furthermore, and as illustrated in this article, claims of successful control of malaria without insecticides are not consistent with proven and successful strategies employed by many malaria control programs that use other WHO-approved insecticides. Uncritical acceptance of claims that insecticides are not needed could undermine the future success of malaria control programs.

Because malaria is the most important insect-borne disease globally, claiming, by various estimates, approximately one million lives every year, it is imperative that policies designed to control the disease be scientifically based and rigorously evaluated. Unfortunately, rigorous evaluation is lacking in the GEF project. Throughout our investigation of this project, we found a lack of transparency and failure to communicate data and scientific findings. For this reason most citations in this paper are not to peer-reviewed literature. Indeed, we have found no peer-reviewed papers that accurately report on the successes claimed by the GEF, the Secretariat, or the UNEP.

Claims about the success of the GEF project are not valid, yet they are being publicized to justify and support a timeline for stopping DDT production by 2017 and eliminating DDT entirely by 2020. The proposed actions by the Stockholm Convention Secretariat are, as described by ministers of health in endemic countries,[11,12] contrary to the public health needs of malaria control programs, and the claims made resulting from the GEF project subordinate public health needs to an ideological agenda. The same is true of public health policy enacted in WHA resolution 50.13 that calls on endemic countries to reduce use of public health insecticides. This resolution should be rescinded before it further erodes the global malaria control effort.

In conclusion, malaria will not be defeated by claims of success when no successes have been achieved. However, it can be contained and perhaps eradicated if all available tools, to include DDT, are made available and employed in an organized and systematic way.

Disclosure

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Mr. WHITFIELD. And thank all of you for your testimony. We appreciate your coming here and appreciate your remarks this morning.

First question I would like to ask you is a raise of hands. How many of you have participated in some way and at some level with the International Panel on Climate Change? OK. So everyone except one has been involved in that. OK.

Now, we find ourselves today in a situation where EPA is moving quickly on regulating greenhouse gases. So, in some ways, as far as their decision is concerned, the science is behind us. And I would just like to ask you, Dr. Christy, in your view, would EPA's regulations to control greenhouse gas emissions in the U.S. Have any real impact on the overall presence of greenhouse gases in the world?

Mr. CHRISTY. I have done several calculations in that regard, and the impact is minuscule to whatever—really both the greenhouse gas concentration total and really what the climate system might do as a result of that delta.

Mr. WHITFIELD. So you would agree with Administrator Jackson? That is basically what she said as well.

Mr. CHRISTY. Yes.

Mr. WHITFIELD. OK. Now, Dr. Roberts, I may have missed—maybe I didn't hear you correctly, but did you say that there is no relationship between climate and public health?

Mr. ROBERTS. Not precisely, but the fact is that the relationship between climate and public health is not going to go in a single direction. I think my fear that the feeling that climate change is a negative force for public health is flatly wrong. It is just wrong.

Mr. WHITFIELD. A lot of the hearings we have had relating to these regulations, the new people at EPA say, oh, this is essential because we have got to cut back on asthma. We are exposing children and elderly people to all sorts of difficulties if we don't cut back on greenhouse gas emissions with these regulations. Do you believe that the proposed EPA regulations would appreciably impact public health in any way?

Mr. ROBERTS. No, I do not.

Mr. WHITFIELD. OK. Now, I am going to make just a comment here. Obviously, this whole issue has been politicized in a way—I mean, we have got science, we have got politics, we have got all sorts of things going on, and when you look at the events at the University of East Anglia, when you consider Dr. Lai on the 2007 IPCC who made the comment that the Himalayan glaciers would melt by the year 2035, which I think then he backed off of that and said, you know, I don't—that was a mistake, we are not—this is not accurate.

I remember Dr. Landsea, who was an expert on hurricanes, served on a panel at the IPCC, in fact read the study on hurricanes, and he testified here that someone at the IPCC announced emphatically that more hurricanes were a direct cause of global warming. He was so upset about it, because he said the science is simply not there, that he resigned from IPCC. And we have heard other incidences of that.

And I know that you can pick out isolated events in anything, but you hear this so frequently with IPCC, it is disserving in many ways. So just yes or no, on the IPCC in general, do you have confidence in what they are doing? Dr. Somerville.

Mr. SOMERVILLE. I certainly do have confidence, very isolated instances.

Mr. WHITFIELD. Dr. Christy?

Mr. CHRISTY. Yes and no.

Mr. WHITFIELD. Yes, no, oK. Dr. Field?

Mr. FIELD. Yes, I have confidence.

Mr. WHITFIELD. Dr. Pielke?

Mr. PIELKE. No.

Mr. WHITFIELD. Dr. Zwiers?

Mr. ZWIERS. Yes.

Mr. WHITFIELD. Dr. Nadelhoffer?

Mr. NADELHOFFER. As a reviewer of IPCC reports, I have confidence.

Mr. WHITFIELD. OK. Do you have a comment, Dr. Roberts?

Mr. ROBERTS. I do not have a confidence.

Mr. WHITFIELD. I would also, Dr. Pielke, I don't know if I have all of the details on this, but the NOAA temperature monitoring stations—and I think I read some article that you all did an analysis and you found that 85 percent of these stations were unduly close to heat-generating areas—is that correct or is that not?

Mr. PIELKE. Well, we have a study that is almost through the review process that shows that many of the stations are very poorly located next to air conditioners, under satellite dishes, and we are showing that is contaminating the surface temperature record. In fact, it is introducing a warm bias over the United States.

Mr. WHITFIELD. Thank you. I see my time has expired. So I recognize the gentleman from Illinois, Mr. Rush.

Mr. RUSH. Thank you, Mr. Chairman.

And Dr. Nadelhoffer, I actually appreciate you being here. Explain to the subcommittee what the effects of climate change are on the economy and the environment of the Great Lakes region. You spoke something about—someone about that in the testimony. Would you like to expound upon it, please?

Mr. NADELHOFFER. Well, thank you, Congressman Rush. I am not an economist. I can refer to several reports on the Great Lakes economy, one most recently by the Michigan sea grant program which identified large numbers of jobs depending on the waters themselves. But as I mentioned in my previous testimony, we in the Great Lakes region, in particular, are dependent upon natural resources. Many of those natural resources are provided by natural systems like forests, wetlands, and agricultural ecosystems. Our agricultural ecosystems are at great risk because of not only warming temperatures and summer droughts, spring rains, and floods, but also exceeding levels of heat tolerance of major crops like corn and soybeans, which, as you know from Illinois, are major to our agricultural economy. So...

Mr. RUSH. Well, you also reference drinking water. And the question is, if we should fail to limit greenhouse gas emissions, how will this affect the supply of drinking water to the millions of people who live in the Great Lakes region in Illinois, Michigan, Wisconsin, and Indiana?

Mr. NADELHOFFER. Thank you for that question. It is a very complex and interesting question, but there are simple things and simple answers. One is, again, springtime floods which deliver large loads of waters to the large lakes with a lot of energy, carry sediments, pesticides, fertilizers, and nutrients into the water. These cause increases in production in the lakes, more algae growth, and are well associated with toxic algae blooms; that is, blooms of algae that actually produce toxins that harm people.

They also contribute to dead zones, organic matter that falls to the bottom of the lakes and then is decomposed, consuming oxygen and thereby killing fish. These are happening now again on Lake Superior. They are likely the result of floods that deliver materials and nutrients to the lakes. So this increases our costs of water treatment.

Also the flooding, when it comes early in the spring, carries more water off of the landscape, and there is less water available for percolating into aquifers and groundwater sources. So our groundwater sources paradoxically are at risk in the Great Lakes region.

Mr. RUSH. What will be the effect on the Great Lakes region if we do not curb emissions of greenhouse gases?

Mr. NADELHOFFER. Part of that answer is in deference to our climate scientists who, again, I have reviewed IPCC reports. I am not an author, but I think the evidence is very clear that business as usual with respect to emissions will exacerbate the trends we have seen and therefore, I think, compromise not only our agricultural and forestry resources, but our water supplies.

To the extent that future droughts, draw down of aquifers in the Great Plains creates needs for waters outside the basin, any policies in the futures which actually remove water from the Great Lakes could have dramatic effects on water levels. Right now, 1 percent of the volume of the Great Lakes leaves the Great Lakes annually in the Saint Lawrence Seaway, and the lake levels are relatively stable. They go up and down a meter or two, but they are relatively stable. If we start exporting large quantities to drought areas outside the basin, our water levels will more than likely decrease, decreasing supplies, as well as quality.

Thank you.

Mr. RUSH. Dr. Somerville and Dr. Zwiers, with 95 percent of the world's scientists saying that climate change is man-made and can be rolled back, do you think that it is wise policy for Congress and the Federal Government to risk our family, our children, our grandchildren's future because a few holdovers are not really certain climate change does exist and can be avoided? Will you answer that?

Mr. SOMERVILLE. I am glad to speak to that, Congressman Rush, and I harken back to Congressman Waxman's metaphors to the medical profession, that you don't go seeking the lone contrary doctor when you have received a serious diagnosis. Get a second opinion, but not 99 opinions, until you find one that you like.

I think here the scientific evidence is overwhelming. I mean, if I could use another medical metaphor, sure, there is risk and costs to taking action, and there is—we also know for elective surgery, for example, as well as climate change, there are risks and costs to not taking action, too. And I think the balanced view here is that we have a strong case. We need international action. The U.S. Can lead. It cannot do the whole job, as you have heard, but I believe that the U.S. And China together contribute more than half of the global carbon dioxide emissions. If they could reach an accommodation in which they both took action, then I think that would be an enormous step forward.

Mr. WHITFIELD. Gentleman from Texas, 5 minutes.

Mr. BURGESS. Thank you, Mr. Chairman.

Dr. Somerville, let me stay with you for just a moment. Is it your opinion that the United States Congress should pass legislation that increases the government's control over how much energy the American family uses or the type of energy that is used by American families?

Mr. SOMERVILLE. Congressman, I am not an economist or a politician, and I would leave that decision to you. I think that in many other areas we see a variety of actions to promote things that are taken to be good and to discourage those things taken to be bad.

Mr. BURGESS. Let me ask you a question. I don't mean to interrupt, but my time is limited.

In this committee just exactly 2 years ago, we had—little less than 2 years ago, we had legislation popularly known as the Waxman-Markey legislation. Are you familiar with that?

Mr. SOMERVILLE. Yes.

Mr. BURGESS. And was it your opinion that that represented a balanced and reasonable approach to addressing the problem of climate change?

Mr. SOMERVILLE. I think it is far better than doing nothing.

Mr. BURGESS. And are you aware that that bill had as its major premise to control the amount and type of energy used by American families?

Mr. SOMERVILLE. I do understand that aspect of it, sir.

Mr. BURGESS. And do you understand there was no such control over families in India or China?

Mr. SOMERVILLE. Of course, the U.S. Congress can't control India and China.

Mr. BURGESS. Exactly right. It is a global problem. And do you understand why the revulsion that the country had after that legislation was passed late at night on the floor of the United States House of Representatives, just prior to the Fourth of July recess in 2009, can you understand how Members of Congress went home to their districts and were actually reviled by their constituents for having done such an activity?

Mr. SOMERVILLE. Congressman, I am going to have to stick to the science here.

Mr. BURGESS. Well, I will tell you, having been in those town halls and actually voting against the legislation, voting "no" was not enough. People wanted us to stop that thing cold dead in its tracks, and they were not shy about telling us that.

So, again, I reference my opening statement, some of the problems that we encountered here in this very committee room in 2008 when gasoline prices went to $4 a gallon.

Now I remember after Hurricane Katrina we also had hearings in this very committee room, and gasoline went to $3 a gallon. We had hearings about that. Now the American public is kind of inured to $3 a gallon. It gets to $4 a gallon and it gets their attention again.

But I remember a panel similar to this where I asked the question that you guys have to be pretty happy now with gas up at $3 a gallon—there is going to be less used. And the answer I got actually stunned me, and I don't remember the witness at the time, but he said, Actually, sir, you have to get it to $6 a gallon before you are going to affect utilization.

People hear statements like that, and it understandably scares them to death. And that is one of the reasons why it is so important for us to have a panel like this today. It is important for people to understand just exactly what it is we are talking about. We all talk in pear-shaped tones about controlling the climate and controlling carbon dioxide, but what we are really talking about is placing energy costs beyond the reach of the average middle-class American family.

Dr. Christy, let me ask you a question. The memorandum that the minority has put out for this hearing explains that the state of the science is—climate change is occurring, it is caused largely by human activities, poses significant risks for, and in many cases is already affecting, a broad range of human and natural systems. Is that an accurate description of the state of the science as we know it now and, of course, man's role in the science?

Mr. CHRISTY. I think if I remember the comment right, they stated that humans were the cause or some major cause of it. Climate always changes. I mean, that is a fact. So the fact that climate is changing is not news to anyone, others here. But the notion that humans are causing most of it, that is purely a model-driven result that you cannot discount and cannot prove that natural enforced variability is causing this. We don't have thermometers that say this much warming was human cause and then this much warming was natural. We only have one thermometer. So you are trying to figure out how much might have been caused by human, and the fact that models fail so many times in the tests we do with the data sets that we build tell us they don't have the natural enforced variability level at all yet.

Mr. BURGESS. Thank you, Mr. Chairman. I yield back the balance of my time.

Mr. WHITFIELD. The gentleman from California is recognized for 5 minutes.

Mr. WAXMAN. Dr. Christy, is there warming going on globally?

Mr. CHRISTY. Yes, the average temperature, yes.

Mr. WAXMAN. So there is a fact of warming?

Mr. CHRISTY. Yes.

Mr. WAXMAN. OK. Now, Dr. Somerville, as I understand most people looking at this problem, they look at the fact of warming and they see climate change happening as a result. The mainstream consensus appears to be that it is primarily caused by humans.

The widespread impacts are occurring now and expected to get worse. I am not a scientist, but my understanding is that there is a tremendous amount of data to support these conclusions, not just models but actual observations and measurement. Can you briefly describe the independent lines of evidence that support these scientific conclusions?

Mr. SOMERVILLE. Yes, Congressman Waxman, I am glad to do that. I would like to say that a thread has been running through this hearing that disturbs me; that I think that it is wrong to frame this issue in terms of the evidence for human-caused climate change hanging from some very slender chain of evidence that could be cut by one brilliant insightful paper. It is not a slender thread at all. It is a thick rope woven together of many, many chains of evidence, and there is a well-developed branch of science and chapters in the IPCC report devoted to exactly this question of discerning unnatural climate change and attributing it to a cause. There are hundreds of papers cited in the report. It is very unlikely that they are going to be overturned by a single Einstein.

You know, we have hard about the Einsteins and Copernicus and Galileos. They are rare. I think they deserve extreme scrutiny. A claim to upset conventional wisdom on the basis of a few papers which we have heard mention of today, I think deserves extremely strong scrutiny.

Einstein was actually very quickly accepted by the physics community, won a Nobel prize. He wasn't the lone voice in the wilderness for very long. He was, of course, an isolated genius. Those geniuses are rare. Those people who claim that they are Galileo are just plain mistaken. In fact, I wonder, since the skeptics or contrarians tend not to agree with one another, which of them, if any, is going to turn out to upset the conventional wisdom here.

I think it will require a very strong case to go against the IPCC. You know, the IPCC was established just to get around this cacophony of hearing many voices. There are outliers in any field of science. We have retrovirus experts who don't think that AIDS is caused by HIV.

But the IPCC is not merely a consensus. I resent that characterization of it. The IPCC assesses the state of science. It says where the science is solid and relatively firm, where more research needs to be done, and it does take into account a wide range of views. I think the discussion of this has to begin with that and not with outliers.

Mr. WAXMAN. What did you think of Dr. Christy's comment? I thought it was interesting. He said that if we are going to fund the IPCC—and of course, the Republicans have said, no, we shouldn't give them any money anymore—he suggested that we have a certain amount set aside for people who have contrary points of view. What do you think of that in terms of distribution of money to scientific research?

Mr. SOMERVILLE. You have to start with the fact that the IPCC doesn't really have much money. It is a little organization with a skeleton staff in Geneva. It basically organizes scientists into writing these reports, and we serve without pay. It is our universities, our employers, who pay our salaries. We don't get a penny from the IPCC, and I think the IPCC does a very fine job of taking into account contrary opinions.

You know, the stolen e-mails from the server in East Anglia have been mentioned in this hearing. People have to realize that those events have now been thoroughly investigated. The scientists have been exonerated. They are cleared. They did not commit fraud. They did not suppress publication of their opponents' views. They did not manipulate data, and in fact, the IPCC considered the very publications alleged. I think they do a fine job of considering other opinions.

Mr. WAXMAN. I appreciate your comments. I just think it is quite amazing that scientific money for research ought to be distributed based on who has minority points of views and give them a certain amount of money. It seems to me it ought to be peer-reviewed and see what is the most promising research. Otherwise, I could see going into a pretty good business, always objecting to whatever the majority view is, and then getting my share of the allocations.

Professor Field, in your testimony, you focused on the impacts of climate change in American agriculture and wildfires in the Western United States. What are the key impacts on future crop yield? What is it that you see happening in this area?

Mr. FIELD. If we look at the observation, what we see in global agriculture a system that is very sensitive to warming. Based on farmer experiences, on models, there are a wide range of different mechanisms that kick in at different parts of the world. Some of the stresses are related to limited water availability. Some of the stresses are intrinsic to the crops. Some of the stresses have to do with outbreaks of disease and pathogens, and some have to do with complicated factors like when the farmers can get into the fields for different kinds of activities. The observations of the crops' sensitivity are based on summaries over all of these different processes, and that is one of the reasons that they are so robust.

Mr. WAXMAN. Thank yoou. Thank you, Mr. Chairman.

Mr. WHITFIELD. Yes, sir. Mr. McKinley, you are recognized for 5 minutes.

Mr. MCKINLEY. Thank you, Mr. Chairman.

Dr. Roberts, let me start with you if I could, please, just to try to frame the argument a little bit here. We have been besieged now for the last 60 days on greenhouse gas questions, and we have apparently 15 million people unemployed in America. Probably an equal amount are underemployed or quit seeking work. We have 10.3 percent unemployed in West Virginia. Lisa Jackson was here just a few weeks ago and said that she feels that she has no obligation to take into consideration the economic impact of any of her decisions to the regulatory bodies.

We have had others come before this group and say that there is no cost-effective way to handle the greenhouse gas emissions, not cost effective. Others have testified that higher energy costs are a result of the greenhouse gas emissions under the Clean Air Act. And others have talked about the high energy costs will cause economic malaise and deter the manufacturing expansion.

So, since West Virginia is one of the leading producers of fossil fuel and so dependent on all this, with 150 million tons in the work that we do producing coal in West Virginia, what is the future? What is going to be the impact of all this testimony that we are hearing about the EPA overregulation of greenhouse gases on West Virginian jobs?

Mr. ROBERTS. It will be a disaster.

Mr. MCKINLEY. Thank you. Dr. Pielke, do you agree with that?

Mr. PIELKE. That is really outside my area of expertise.

Mr. MCKINLEY. So you don't have an opinion of whether or not an attack on coal or war on coal is going to have an economic impact?

Mr. PIELKE. Well, I came to talk about the science, and that really is outside my area of expertise. I don't want to get into the politics of it. I just want to stick to the science.

Mr. MCKINLEY. Thank you. Dr. Christy

Mr. CHRISTY. As a State climatologist, I deal with a lot of economic development activity, and in my State, too, it would be a real problem. It would create more poverty than there is now, and I can tell you, as someone who has lived in Africa, without energy life is brutal and short.

Mr. MCKINLEY. Thank you. Do the three of you concur that has been—your predecessors that have come before the panel before have indicated to this group that the greenhouse gases are a precursor to Earth warming, global warming. Is that generally a consensus?

Mr. PIELKE. I think we have to realize that greenhouse gas increases are one component of the climate system. It is not the entire picture, and I think that is one of the failures of the IPCC to adequately take intoaccount these factors.

Mr. MCKINLEY. Dr. Pielke, we have had some come before us and say it is a precursor to global warming; you are going to see the emission of greenhouse gases is a precursor to global warming. But yet, from my reading, your paper, Landsea's, Hal Lewis', and others have indicated that what they are finding in Antarctica, the Russian scientists down there, that the reverse is true.

Mr. PIELKE. But it is unequivocal. I think that is the wrong argument, because we can see that CO_2 is increasing because of human activities. We know that. The problem is how does that fit into these other forcings—land use change, aerosols, the natural variability? And as we learn more about the climate system, it is more complex than we thought. And the IPCC, unfortunately, takes a very narrowed, limited view of how we are altering the climate system.

So when we are talking about all these impacts about global warming, first of all, climate change is more than global warming; and secondly, even global warming and cooling is affected by more than just carbon dioxide. And we need to recognize that broader perspective and apparently the IPCC decided not to do that.

Mr. MCKINLEY. Dr. Roberts, would you like to amplify on that?

Mr. ROBERTS. I am not sure that I have the expertise or background to add much to that, actually.

Mr. SOMERVILLE. I would be glad to comment.

Mr. MCKINLEY. Sorry. Yield back my time. I am sorry, I missed something?

Mr. SOMERVILLE. I just said I would be glad to comment on the issue you raised.

Mr. MCKINLEY. Go right ahead. I am sorry. I am hard of hearing. So if someone wanted to make a joke over that, that is their problem.

Mr. SOMERVILLE. Sure. I am happy to clarify the issue of timing of carbon dioxide increases that you mentioned in the Antarctic ice coolers. We do know that the Ice Ages and transitions between Ice Ages and interglacial periods are paced by changes in the Earth's orbit around the Sun, but that after the pacing happens, then as a feedback carbon dioxide is added to the atmosphere, comes out of the ocean in a warming period, goes away out of the atmosphere, and a cooling period. So it is an amplifier. It adds probably 30 percent to the effect of the orbital forcing, but it is not a primary cause but it is an amplifying effect.

Mr. MCKINLEY. Thank you.

Mr. WHITFIELD. Thank you. Mr. Inslee, you are recognized for 5 minutes.

Mr. INSLEE. Thank you. I want to thank all of you for being here today, but I have to express some degree of embarrassment that a Nation that went to the Moon, mapped the human genome, established the best software companies in the world, does now have one of its great parties adopt a chronic anti-science syndrome; one of its great parties that has decided to have an allergy to consensus science instead of respect for science and scientists. And that is embarrassing.

In listening to this hearing, I am convinced that if we had Copernicus, Galileo, Newton, and Einstein at this table instead of you fine scientists, one of these parties would still not accept the clear science until the entire Antarctic ice sheet has melted or Hell has frozen over, whichever comes first. That is the situation that we are in today, and I think it is a pretty sad state of affairs.

There is one point I want to make particularly, and I hope some who are covering this hearing might pay attention to this. There are seven people at the table. If this hearing is reported as saying four people said one thing and three people said another, you are missing the big story here, and I want to make sure everybody understands this.

I want to put in the record a letter dated February 9 by 1,800 doctors saying specifically that the health of United States' citizens is jeopardized by greenhouse gases, and I want to put this into the record.

Mr. WHITFIELD. Without objection.

Mr. INSLEE. I want to put a statement by the CDC, the Centers for Disease Control and Prevention, which says specifically that climate change gases affect the health of human beings in America.

Mr. WHITFIELD. Without objection.

Mr. INSLEE. Thank you, Mr. Chair. I want to put in the record a letter from 250 of the most esteemed climate scientists in the world urging us to act on this clear science of climate change dated May 7th, 2010.

Mr. WHITFIELD. Without objection.

Mr. INSLEE. I want to put in the record a letter of February 2011 of 2,705 scientists basically urging us to allow the Environmental Protection Agency to do its job.

Mr. WHITFIELD. Without objection.

[The information appears at the conclusion of the hearing.]

Mr. INSLEE. Those are 4,560 scientists, and what I want to say, standing behind Dr. Field at his table are 4,560 scientists. Now, the Republican Party has found two people to raise some questions, and of course, there are lots of questions about how fast this is going to go, and what it is going to do, but there is enormous scientific consensus on the Planet Earth about this fact that we have got a problem.

Now, I want to ask a question on how fast we are going. Can we put up this slide, please, of the Arctic? I want to show an Arctic picture of the Arctic icecap. It shows 1979 the northern icecap on top. Then you see in September 2007, it shrunk by about 40 or 50 percent. The most recent science predicts it may be absolutely gone in any meaningful sense in the next 5 to 10 years. I understand a few years ago we thought that wouldn't happen for 20 or 30 years.

It appears to me like this is happening a lot faster than many of us thought was going to happen, and this is one of the things that are causing not fear, Dr. Roberts, but I think a rational concern that my 2-year-old grandson is going to grow up in a world that is really, really different than I grew up in, with no coral reefs and no Arctic icecap.

Dr. Field, could you comment on what is the most recent science in that regard?.

Mr. FIELD. The changes are occurring very rapidly. There is no question that changes in things like Arctic ice, in the positions of glaciers, in the ranges of species and in the water availability for the western U.S. Have changed dramatically.

Now, the science tends to keep up with the new observations, and so I don't think it is accurate to say that the current scientific consensus is inconsistent with these observations, but I do think it is fair to say that as of a few years ago, most scientists were projecting that the kinds of events we are seeing now might occur in the second half of the century.

Mr. INSLEE. I read yesterday that the algae bloom in the Arctic is now 50 days earlier than it was. I read that the melting of the Greenland ice sheet seems to be much more significant than perhaps we even predicted 5 or 10 years ago. Many of these indices, to a layperson such as myself, would suggest that we are in the upper, sort of the redder zone of the parameters of what we have looked at. Is that a fair assessment or not? Dr. Somerville wants to say something.

Mr. SOMERVILLE. Yes, that is very much a fair assessment, and the Greenland icecap is a good example. The IPCC has been cautious. It is not political at all, but it is intellectually conservative. It doesn't go beyond the data. It doesn't do hunches and conjectures. And it said in the last report that you could put a number on how much sea-level rise would happen from melting ice on land and thermal expansion of the ocean, but it said we don't yet know enough about what might happened to the Greenland and/or Arctic ice sheet. Now the newer science says, yes, there are positive contributions.

Mr. INSLEE. As one layperson, I had the oyster grocers of Washington State into my office last week. They are having trouble growing oysters in Puget Sound because of ocean acidification, which we haven't talked about. Carbon goes in the air, goes into the ocean, and makes it more acidic. My oyster growers are having problems today. My berry growers are having problems. This is not hypothetical. This is a problem today.

Mr. WHITFIELD. Did you want to say something, Mr. Pielke?

Mr. PIELKE. Yes, I would. I think the observations are certainly correct that the Arctic ice has been diminishing and the result are effects we talked about. I think the question is, are there other explanations that haven't been fully explored in addition to carbon dioxide? And one of them is black carbon, which I think most of the members of the IPCC would have recognized. It has been better recognized recently. There is also natural circulation effects that have caused this.

And I think that the proposal that Dr. Christy made that there needs to be an alternative view is analogous in the medical community to basically getting a second opinion. And if you had a medical drug developed by a company and that company is reporting on how well that drug does, you certainly would like to have an independent assessment of that, and I think that is what we need, and I think John's suggestion is a good one.

Mr. INSLEE. Mr. Chair, would you permit me one comment or follow-up question in light of Dr. Pielke's comment there?

Mr. WHITFIELD. Yes, I will give you one follow-up question, and then we have to move on.

Mr. INSLEE. I appreciate your courtesy, Mr. Chair.

The concern that I have, and I think many people, are that this is a profound geophysical change in the entire system of the Planet Earth to have this icecap disappear, and I am very concerned about black carbon. I actually have offered a bill to deal with black carbon. It is a problem.

But I think it is a fair statement, as far as I can tell, is that no one in any peer-reviewed research that I can find have suggested such a rapid change in a fundamentally pivotal part of the climactic system, geophysical driver which the Arctic is, other than carbon. Has anybody come up with any other peer-reviewed hypothesis to say why this is happening? I am not aware of any.

Mr. WHITFIELD. Maybe we will have a second round, but we have got a number who haven't had questions yet.

Mr. Griffith, you are recognized for 5 minutes.

Mr. GRIFFITH. Thank you, Mr. Chairman.

I want you all to know I am here today because I have lots of questions about the various things that are going on and what is happening, and so I am not sure I am going to get to answers. So, if we don't get to answers, if you all could submit those to the committee so I can review the information, that would be great.

Let me also say that I am concerned that we are shifting jobs to other parts of the world where they are not going to pay attention to this. So, even if we believe that there is a problem and we shift all the jobs to someplace that is going to create actually more greenhouse gases, are we creating a solution or are we making the problem worse by having some of the EPA regulations?

That being said, here are some of my questions. Has anybody studied what the temperatures were, or do we know what the temperatures were during the period in history known as the Great Optimum, which led to the rise of the Mesopotamian Egyptian cultures? That was a time in history of global warming. We know that. But how warm did it get? Obviously those were things that led to the rise of our earliest civilizations.

At some point, I would like to have somebody look at the Lesser Optimum, which is a little closer in time, and how much did the temperature rise then? We know that that led to the Vikings—Professor Nadelhoffer—led to the Vikings dominating Europe for several hundreds years, and also led to where the icecap in the North is melting; we are now finding evidence of Viking habitation in those areas.

Can somebody answer the question, and has the IPCC studied why are the icecaps on Mars melting? Both NASA and National Geographic have had reports on this. Is it, in fact, and has there been a study, a shift in the orbit of Mars, or is it that the Sun is putting out more radiant heat?

If we have known, as you suggest, Dr. Somerville, for 150 years the effects of greenhouse gases, then why 40 years ago, when I was in elementary and middle school, were we taught that an increase in greenhouse gas effect was going to lead to a new Ice Age?

In regard to radiant heat, the Sun spot effects, what do we know about that? I was reading one report here that indicates that by 2020 we will reach a new peak on Sun spot activity, and this report actually suggests that the Earth's temperature may be raised by .5 degrees Centigrade as a result of the Sun spot activity. And could that also be the cause—when we were talking about patients earlier, somebody said why do you distrust the doctor? Then somebody made the comment, May we get a second opinion? I would like to know if we have looked at maybe the other patients? And Mars, having a similar global warming effect or event going on, have we studied what that is and has the IPCC done that?

And then what is the optimum temperature for man? Have we looked at that? Dr. Somerville, you indicated that pre-1900 industrialized world temperatures was where you wanted to go, but in light of the fact that we had a little Ice Age in the 18th century, are you indicating that we want to return to the little Ice Age period? Or are you indicating something between 1820 and 1900?

I don't know the answer to that, and it was just kind of an interesting—these are questions that I, believe it or not, lay awake at night trying to figure out.

I would like to actually hear from Dr. Christy and Dr. Pielke first, and then if we have time we can move on to the others. But I did anticipate there wouldn't be a lot of time for answers, which is why I started my comments by saying if you have got info, you know, feel free to get it to me and please give it to the committee as well.

Mr. CHRISTY. I think what you are describing is the fact that natural, unforced viability creates a large excursion of temperature that humans have no responsibility for. I didn't see up on the chart here after the Arctic sea ice, I didn't see the Antarctic sea ice which reached its maximum recorded 2 weeks later after that particular picture was taken.

I will be happy to answer those questions. That was a boatload of them, if we can have them in writing.

[The information appears at the conclusion of the hearing.]

Mr. GRIFFITH. I would be happy to give you my notes. These are things I have been worrying about for some time and questions that—particularly the one about why we were taught there was a new Ice Age coming, if we have known about this 40 years ago because all of my constituents were taught that. Now, maybe our books in southwest Virginia just weren't up to par and maybe they were 150 years out of date, but I doubt it.

Mr. PIELKE. Can I follow up?

Mr. GRIFFITH. Yes.

Mr. PIELKE. What you asked about Mesopotamia and the other regions, these are affected by regional temperatures, and I think this really highlights the global average surface temperature trend is a very poor metric to use to diagnose climate change. Even global warming is not properly diagnosed by that metric. So the question is, What was it like in Mesopotamia, what was it like in the Arctic, for example? Those are the questions we really need to focus on.

Mr. GRIFFITH. Thank you. I only have 11 seconds but you are welcome to them, Dr. Somerville.

Mr. SOMERVILLE. I would like to respond. I wish I had time to respond to all of them.

The 1970s global cooling is a myth, perpetrated by the popular media. It is in Newsweek magazine. It is not in the scientific literature, papered by Peterson, et al., Bulletin of American Meteorological Society establishes that——

Mr. GRIFFITH. Mr. Chairman, if I might, look, I was there. I studied it. Now maybe it is a myth. Maybe I am remembering a myth, but I was there. It was in my textbook. That is all I can say.

Mr. WHITFIELD. I think we will just stipulate that there may be difference of opinions about that.

Mr. Gardner, you are recognized for 5 minutes.

Mr. GARDNER. Thank you, Mr. Chairman, and thank you to the witnesses who have joined us this morning.

And to my friend from Washington, I think I am going to get you a Kindle. I am a little concerned about that tower of books over there.

Mr. INSLEE. Would you like to read some? It might be helpful.

Mr. GARDNER. Only if you will read some of mine.

Mr. INSLEE. I would be happy because it is a lot shorter list.

Mr. GARDNER. Anyway, I wanted to just briefly touch base with Dr. Christy. We talked a little bit about agriculture in this committee hearing. In my view, farmers are really America's true environmentalists, people who work every day in the land, and if global warming really threatened to cause extreme weather, they would be the first in line to want to stop it because it threatened their livelihoods, or livelihoods are at stake.

If the speculation is out there that warming reduces crop yields had any real-world validation, farmers would be on the front lines fighting for global warming regulations, encouraging the EPA to pass the regulations, encouraging Congress to pass the bill.

But what the agriculture community has been saying is that global warming policies are far worse than global warming itself. The Farm Bureau opposes EPA's regulations for what they would do to energy and fertilizer costs for farmers. From an agricultural standpoint, is the cure worse than the disease?

Mr. CHRISTY. Oh, I think so. I was just on the farm 2 weeks ago, working with a farmer on something, and I am just surprised at my colleagues' comments here about how agriculture changes. We grow corn from North Dakota to Alabama. When it is warm in Alabama, we still get 240 bushels an acre for irrigated corn, a tremendous amount of corn.

The temperature is not as critical when you know how to farm and deal with the variations that occur in their particular area. But I can assure you, because I talk to a lot of farmers and deal with them, that their fuel costs, their fertilizer costs, they are complaining a lot right now and just cannot bear to see those costs go up any more, which would happen if a price were put on carbon like that.

Mr. GARDNER. Thank you.

Dr. Pielke, in your testimony, there is a 2009 paper you wrote and an excerpt in your testimony that says: Therefore, the cost-benefit analysis regarding the mitigation of CO_2 and other greenhouse gases need to be considered along with the other human climate forcings in a broader environmental context, as well as with respect to their role in a climate system.

Do you feel that there hasn't been adequate cost-benefit analysis regarding the CO_2 regulations?

Mr. PIELKE. No. Actually, what we proposed is a bottom-up resource-faced focus where you basically take something like corn and asked what are the threats to that resource, of which climate is one of many but it is one of them, and what are the worse of the policies and the funding go to try to minimize those risks?

Mr. GARDNER. So you believe there hasn't been enough cost-benefit analysis?

Mr. PIELKE. No, there has not been.

Mr. GARDNER. There has not been enough cost-benefit analysis.

And to follow up on that, Dr. Pielke, EPA is moving quickly on a number of greenhouse gas and other regulations right now, and we have seen a chart that shows what is called the "train wreck." Do you think it is a good idea to do all of what we are talking about, greenhouse gas regulations in the middle of a recession and what those effects could be?

Mr. PIELKE. Well, now you are asking me a political policy question. I will defer that because I want to focus on the science.

Mr. GARDNER. Dr. Christy?

Mr. CHRISTY. My mind might have been drifting there, but I think you were asking about——

Mr. GARDNER. Moving forward with these regulations in the middle of a recession, given what we have said, the lack of cost-benefit analysis.

Mr. CHRISTY. Well, I think moving forward, whether it is a recession or not, is going to make energy prices go up. In a State like mine, which is very poor, that is a big fraction of the people's expenditures and their own economy, so I would——

Mr. GARDNER. When those costs go up here, will it in turn then cause jobs to go overseas where there is little or no regulation?

Mr. CHRISTY. We have seen that. I have talked to particular industries that say we have already looked at Mexico and China, because if our energy costs go up, we are going to move, period.

Mr. GARDNER. You mentioned if we could build 1,000 nuclear plants, what was that statistic you used?

Mr. CHRISTY. Yes. If we could build 1,000 nuclear plants, which is not going to happen, 1.4 gigawatts each, that would be approximately 10 percent of the CO_2 emissions taken out of the mix, and that is not going to have much effect at all on climate.

Mr. GARDNER. Thank you, Mr. Chairman. Yield back my time.

Mr. WHITFIELD. Thank you. At this time, I recognize the gentleman from Louisiana, Mr. Scalise.

Mr. SCALISE. Thank you, Mr. Chairman. I appreciate all of the panelists being with us today to talk about this issue, especially as it relates to broader efforts by the EPA to regulate greenhouse gases. We have had a number of hearings on not only the science in the past but also on economic impacts, and I would like to talk about both of those with you.

Now, one thing we hear a lot by people on the other side is this concept that the science is settled—and I think when we go into past hearings that we have had on this, as well as today, I think it is clear that the science is not settled. There is, you know, these armies of thousands of scientists somewhere that hide behind these organizations that themselves have been discredited, but that try to in essence diminish countering views. And it should all come back to science. And I know, Dr. Pielke, you talked about this, too. Would you address this?

Mr. PIELKE. Yes. There is certainly not a consensus. In fact, let me give you an example.

In 2005, a National Research Council report on expanding the radio forcing concept, was coauthored by a range of different people, including Michael Mann, for example, was on this committee, and he signed off on this report, or all of us did, in which we showed that there are these multiple other types of climate forcings. The IPCC basically ignored that report which was available to them.

Mr. SCALISE. Thank you.

Dr. Somerville, in your opening statement you used terms like "the great preponderance of experts agree." Later on, you say "Nobody should be compressed by these discredited claims." Later on you used the comment, "It is silly and just accepted and it will take a strong case to go against the IPCC."

Why is there this kind of elitest arrogant view to people that have a contrarian view in the scientific community to that that you hold?

Mr. SOMERVILLE. I am certainly not trying to be elitist or arrogant, Congressman, and I regret it if you took that impression away.

What I am saying is that obviously no science is firmly settled, so you don't get absolute 100 percent certainty from science. Everybody recognizes that. But some things are much more firmly known than others. I am not going to write a research proposal to the National Science Foundation to find out whether the Earth goes around the Sun. That is pretty firmly established.

Mr. SCALISE. And none of us dispute that. However, there is dispute over this claim that man is the cause of global warming.

And let me ask Dr. Christy because, you know, kind of in contrast to some of the statements Dr. Somerville has made, I know you have been involved, I think, in some of the IPCC, some of the scandal that has been going on over there over the last year. Can you comment on this—this concept that the science is settled?

Mr. CHRISTY. Yes. I don't agree that it is at all, and I think Dr. Somerville's comments about being exonerated for these folks in the climate gate thing is just absolutely false, because that was not a legal test of anything. There was not admissible evidence. There was not cross-examination of the evidence. There was not due process and all those things, so those were not exoneration panels. Well, that is what they were is exoneration panels. They weren't science or investigative panels.

Mr. CHRISTY. Your original question was about why are there so many scientists that seem to look one way, or——

Mr. SCALISE. Yes, let me restate it a little bit. Because, you know, we have seen—and this has been a common trend over the last over a year, well over a year. You have people like Al Gore, "The debate is over." They literally try to make somebody out to be a flat-earther if they just disagree in a scientific way. And, again——

Mr. CHRISTY. OK.

Mr. SCALISE [continuing]. Just this attempt to discredit scientists who pose scientific theories that counter their—in some cases, it is not even scientific theory. Al Gore is surely not a scientist; you are.

But then you go to what happened in Climategate, where the IPCC—and they have used the hockey-stick graph to try to, again, say this is a settled science. And we saw in Climategate, they used a trick to hide the decline. This is something that really happened.

And yet, it seems like people like you and Dr. Pielke and others who truly do go to the data—I think you have built models on data—they are trying to actually change our economy in the United States in a way that would run millions of jobs out of this country. We have already seen real evidence of that, by the way. The scientific evidence clearly is not settled on this issue, but we do know from testimony we have had about people who have said they have moved jobs to other countries.

If you can maybe give me a summary of what carbon leakage means. For those companies that go and they will build a steel plant or they will build a refinery in another country that doesn't have the standards that we have today, where they will actually emit more carbon, what does that do to the global atmosphere, if they are concerned about carbon and you are actually emitting more carbon in another country because you have sent those jobs out of America instead of keeping them here?

Mr. CHRISTY. Yes, emissions will rise as a result of that kind of unintended consequence. Poverty will increase in a State like mine.

In fact, I had this very conversation with a plant owner who said it is ironic that, with this legislative action, if it were to go forward—they were looking at Mexico, in fact—that they would emit four times more emissions if they were to move their operations, plus create a pocket of poverty that we don't need in our State that would make health concerns even worse for those folks.

Mr. SCALISE. I appreciate that. Thank you.

And I yield back, Mr. Chairman.

Mr. WHITFIELD. Mr. Terry is recognized for 5 minutes.

Mr. TERRY. Thank you for that, Mr. Chairman.

Dr. Nadelhoffer—did I pronounce that correctly? I got here a little late.

Mr. NADELHOFFER. Yes, correctly enough. Thank you.

Mr. TERRY. Should nitrogen be banned? Should the EPA ban nitrogen?

Mr. NADELHOFFER. The short answer is, no, the EPA could never ban nitrogen. It is——

Mr. TERRY. Why?

Mr. NADELHOFFER [continuing]. The dominant gas in our atmosphere.

Mr. TERRY. All right. Man's use of nitrogen?

Mr. NADELHOFFER. Again, the use of nitrogen as synthetic fertilizer has essentially allowed us to feed 8 billion, 9 billion people on Earth. I don't think EPA is proposing to ban nitrogen fertilizer.

Mr. TERRY. I didn't—OK. How about you? Do you think we should?

Mr. NADELHOFFER. No.

Mr. TERRY. OK. Just wanted to establish if we were allowed to eat anymore.

Mr. NADELHOFFER. Oh, yes, we are.

Mr. TERRY. OK.

It was interesting, it piqued my curiosity, Dr. Pielke; you had mentioned earlier in the discussion—and it is a real nuance here, but it is one that I think grasps at average, nonscientific citizens when they are trying to digest all of this global warming and man's role in it.

You had said earlier, in an answer to a question, that man's role is a part of global warming, that there are many other attributes or causes, and it is difficult to, kind of, unwind man's cause. That is the ultimate issue here, because we can only control man's role within the borders of the United States of America.

So I am curious, what are some of the other factors? Has there been scientific studies that would enable us to measure more accurately so we can have a more targeted solution here than simply trying to eliminate and go to a zero-carbon baseline from 1820?

Mr. PIELKE. Well, we have to recognize there are consequences whenever humans do anything. But what we have done—and there was that 2005 National Research Council report I referenced that talks about land-use change, talks about aerosols, talks about nitrogen deposition, for example, as well as carbon dioxide, both the biogeochemical and the radiative effect. And the more we learn about this, the more uncertain it becomes.

And to try to factor out what is the CO_2 contribution to any of these impacts, whether it is floods or heat waves, is becoming an increasingly more difficult problem. And when we discuss just CO_2, we focus just on C02, we are ignoring all these other influences and not even then considering what the natural part is.

Mr. TERRY. If the United States did go to an 1820 carbon baseline for man's emissions within the United States, has the scientific community concluded what globally the impact would be on global warming?

Mr. PIELKE. Well, in terms of the CO_2 emissions, I am sure that work has been done. And Chris can probably talk more about that.

But in terms of man's impact, look at the land-use change that has occurred since 1820. And we have done quite a bit of research showing that that has a major effect on precipitation and on temperature and extreme weather. And this factor was inadequately assessed in the IPCC.

So there are these other climate forcings in addition to CO_2 that really should be explored further, and they have not been, by the IPCC.

Mr. TERRY. Mr. Somerville, do you believe that farming contributes to global warming? Farming activities?

Mr. SOMERVILLE. I think that there is certainly a contribution, a minor contribution.

But I would like to reiterate, if I may, sir, that the overwhelming scientific consensus—that there is no doubt that land-use changes especially have an influence on the local climate. But when you talk about the global climate, the science community is not persuaded by the arguments you have heard today from——

Mr. TERRY. That there is additional contributions. Your belief is it is 100 percent caused by these activities.

Mr. SOMERVILLE. No, it is not 100 percent at all, but it is the dominant contribution. IPCC said in their last report——

Mr. TERRY. All right.

Mr. SOMERVILLE [continuing]. In this language that your government approved——

Mr. TERRY. Have you in your studies or your research been able to determine, if we went to an 1820 baseline for man's contribution of CO_2 in the United States, what impact that would have on global warming?

Mr. SOMERVILLE. Congressman, by itself it would not solve the problem. We are not advocating anybody go back to the 1820s. What is scary now——

Mr. TERRY. All right. 1880? 1900?

Mr. SOMERVILLE. What is scary now is the rate of change of climate. We are not saying there was an ideal climate in some year in the past. What is frightening, what is something to be very concerned about is the rate at which the climate is changing now.

Mr. TERRY. And my time is up. And that is part of the problem here, is we can't get our mind around what we are supposed to be doing if there is really that great of a problem.

Mr. WHITFIELD. OK. We appreciate you all coming from many long distances, and this is a very important subject.

Do you all have any interest in doing one more round?

Mr. RUSH. Oh, absolutely, Mr. Chairman.

Mr. WHITFIELD. All right. Five minutes each.

All right. I will start off.

As public-policymakers, I think the thing that concerns me, particularly, just like this—we have had 24 panels of witnesses on science. And every time basically there is an agreement there is warming, there is a disagreement on why it is.

And we know that we have had warming periods in the past. We have had the Minoan warming period, the Roman warming period, the medieval warming period. And during that time, there was no industrialization, and so CO_2 carbon emissions were not as high as they are today. Why? We don't exactly know the answer. The ice in the Arctic is diminishing; the ice in the Antarctic is growing, for lack of a better word.

So when we are asked to adopt policies unilaterally for America that would place us at a competitive disadvantage with other countries like China and India when jobs are at stake, when we have high unemployment, then it is a significant issue here.

And this administration, through EPA, has made the decision that they are going to regulate greenhouse gases. So, as I have said before, on three different occasions Congress has said no. In 1990, they said no. In 1998, they said no. They rejected the cap-and-trade legislation the last time.

So we can talk about consensus on global warming, fine. But consensus on why and the questions about the models, I don't think anyone, obviously, can say definitively, "This is the answer."

So you all have been really helpful today. I really appreciate all of you coming. I know you are all scientists, you are well-educated. You are committed to trying to improve America and our world that we live in.

So I just wanted to make that comment. And, at this point, I would recognize Mr. Rush for 5 minutes.

Mr. RUSH. I want to thank you, Mr. Chairman. And I join you in thanking these panelists, all of them, who are making some significant contributions to this subcommittee.

I want to get back to Dr. Nadelhoffer.

Dr. Nadelhoffer, you spent 20-plus years in the Arctic. And there has been some testimony, I saw you squirming and biting at the bit because you wanted to jump in.

So would you answer the question, what impact does climate change have for population centers globally? And referring to your experiences from the Arctic, what did you learn from your Arctic experiences?

Mr. NADELHOFFER. Excuse me, Congressman Rush. Could you repeat the last part of the question? It was hard to hear.

Mr. RUSH. Yes, your experiences in the Arctic drew you to certain conclusions about the effect of climate change on population centers globally. Could you expound on your experience?

Mr. NADELHOFFER. Well, the Arctic is a fragile environment. It is a cold environment, and temperature excursions change the Arctic in ways that we really are only learning are playing out. But, certainly, in many parts of the Arctic, permafrost is getting warmer, and in some places permafrost, which holds the ground firmly in place, is melting and diminishing. And so, many of our north Alaskan communities are compromised. Their building structures are sinking, often, into thawing permafrost.

The climate system—interesting that we talked about Antarctica. The Antarctic ice sheet, of course, is a very complex system. But most of the glaciers that are measured in the Antarctic continent are increasing their flow rates into the Antarctic Ocean. And so, you know, it only makes sense that there may be more ice in the Antarctic Ocean because of the donation from the landscape.

The Antarctic Peninsula, over the past 50 years, has increased more than any place on Earth of a comparable size. So there are indicators from the Antarctic region, as well.

And, of course, these regions, one of the reasons that I and others work in the Arctic and my colleagues are working in the Antarctic is they are bellwethers. Those are the parts of the Earth that in the Arctic summer and the Antarctic summer face into the sun. The field station I work in in northern Alaska has sunlight continuously from May 20th to July 20th. And when there is less reflectivity from ice in the summer, there is more heat coming into the Earth's system in the summer.

So the Arctic systems, although sparsely populated, feed back and affect the global climate in ways that I think others on the panel could express better than I can. But thank you very much for your question.

Mr. RUSH. Well, I have another question. Dr. Christy indicated that crop loss may be more contributed to farmers not really knowing what they are doing than the impacts of climate change. Do you have a response to this, his assertions?

Mr. NADELHOFFER. Well, I have an indirect response. I, again, don't cover agricultural policy and farmer behavior and attitudes in my research.

However, I think one of the things that climate change does for agriculture—or, one of the ways it impacts agriculture is to increase the uncertainty surrounding extreme events. I think farmers could well benefit from talking at high levels with climate scientists and trying to understand the risks involved with a more variable climate in agricultural regions.

Mr. RUSH. Dr. Field, would you respond to that question also?

Mr. FIELD. Sure.

I would like to congratulate John on knowing some very successful farmers.

The observations are that, in warmer periods, crop yields go down. And with corn, it is very clear that there is a threshold of about 84 degrees Fahrenheit, and when the temperatures are higher than that, yields go down.

The sensitivity of corn is quite dramatic. A single day with a temperature of 104, as opposed to 84, can decrease corn yields by about 7 percent.

Mr. RUSH. Mr. Chairman, I yield back the balance of my time.

Mr. WHITFIELD. The gentleman from Texas is recognized for 5 minutes.

Mr. BURGESS. Dr. Christy, from your study of—and we have heard some talk today and some comparison to medicine and diagnosis and treatment. So what does the evidence say about how we are going about diagnosing this problem?

Mr. CHRISTY. Well, as someone who actually builds those data sets, what I find is that we have one standard of instrumentation that gives us some answers but there are really more answers to be found. We do need a better set of satellites going up. I can divert there for a second, but I won't.

I will say——

Mr. BURGESS. Unfortunately, some of the satellites seem to be coming down, and that is a problem.

Mr. CHRISTY. Right. That is a problem.

Someone mentioned about, there were 4,500 people behind Dr. Field here. And my point in my talk was that I have looked at the very evidence for this thing, a climate model. So those 4,500 people, to make it simple, think the world is warming at 0.26 degrees C per decade right now. That is what climate model theory, that is what greenhouse theory in these models indicates. The data set does not. Does that mean they are still right and I am wrong, or what is it?

So I am not here to be a popular person. I hope I am providing the numbers of science that make this situation more understandable.

Mr. BURGESS. And you have put together these observational databases essentially from—you have built them on your own, you have built them from scratch?

Mr. CHRISTY. Yes, our group has built them and published them. They are in the literature.

Mr. BURGESS. Well, does the AIPCC or the National Academy of Sciences use your work?

Mr. CHRISTY. Sparingly.

Mr. BURGESS. Well, when they talk to you, what do they say is the justification for not including your work in the consensus?

Mr. CHRISTY. I think they would say, because we have so many people, we have to include everybody's work, and so you are just—you know, it is a democracy there, so you only get one vote. It doesn't matter how good the data are, it is one vote.

Mr. BURGESS. Well, what are your observations suggesting to you about the impact of carbon dioxide on global climate change or global warming?

Mr. CHRISTY. Yes, carbon dioxide is a greenhouse gas. There is no question about that. It will increase the surface temperature somewhat. But the effect is about one-third, the best we can figure, than what the current theory indicates, on which all these legislative actions are based.

Mr. BURGESS. Dr. Somerville, let me ask you a question. In your summation of your opening statement, which I appreciate you providing for us, item number 5, you state that, “Science has its own high standards. It does not work by unqualified people making claims and expressing opinions on television or the Internet. People who are not experts, who are not trained and experienced in this field, who do not do research and publish it following standard scientific practice, are not doing science.”

Does that statement apply to Dr. Christy?

Mr. SOMERVILLE. No.

Mr. BURGESS. Well, let me ask you this. And I alluded to it earlier, the legislation that was before us in this committee late into the night on May 31st and then on the House floor late into the night on June 26. Why do you think it is—if the vast preponderance of science and scientists agree with you and your position, why haven't you closed the deal with the public?

Mr. SOMERVILLE. That is a very good question. I think that we, as a science community, suffer as communicators. I think that we have not done a good job of outreach. The IPCC reports are hard to read. I think we haven't translated them into plain English.

I think that some people who have done that translating aren't well enough recognized, and I would put the U.S. military in that category, sir. I highly recommend to this subcommittee a report called “Climate Change and National Security” by the CNA Corporation, which is composed of retired flags officers, generals, and admirals and so on, who reviewed this area, were briefed by climate scientists——

Mr. BURGESS. Yes.

Mr. SOMERVILLE [continuing]. Said, it is a threat multiplier, it is a national security concern——

Mr. BURGESS. Let me just——

Mr. SOMERVILLE [continuing]. We don’t wait for perfect information before——

Mr. BURGESS. Let me just reclaim my time. It obviously doesn’t take a rocket scientist, or a rocket surgeon for that matter, to know that Members of Congress are not held in very high regard right now, so anything we say is certainly suspect. The military is held in very high regard.

Mr. SOMERVILLE. Right.

Mr. BURGESS. So why—again, I would pose my question to you—why have you not closed the deal with the public? Why, when I go home to my district and have my town-halls, why is the public not clamoring for me to control carbon in the atmosphere and drive up energy prices?

Mr. SOMERVILLE. I think there are many reasons for that. There is an active disinformation campaign out there, as you may know——

Mr. BURGESS. Who are you accusing of the active disinformation campaign?

Mr. SOMERVILLE. I am accusing parts of the fossil fuel industry and certain think-tanks and political centers. There is a lot of misinformation out there, and we haven’t done as good a job as we need to to counteract it, sir.

Mr. BURGESS. Mr. Chairman, if I could, just a point of personal privilege. I really appreciate Mr. Inslee bringing his own brand of carbon sequestration to the committee. It is an interesting tower he has constructed there.

Thank you.

Mr. WHITFIELD. Thank you.

Mr. Waxman, you are recognized for 5 minutes.

Mr. WAXMAN. Thank you, Mr. Chairman.

This panel was invited to give us information about the scientific record. I don’t think that it would be fair to ask any of you to tell us exactly how to solve the problem. There are a lot of different alternatives, and we could explore those alternatives if we think something needs to be done.

I think there is a moral imperative to address climate change because of the damaging consequences that appear to be occurring. We don’t have an abstract concern about how many parts per million of carbon dioxide are in the atmosphere. We are worried about extreme weather events, the reduced crop yields, the wildfires, the floods, the rising sea level, and the rest of a long list of impacts.

And when analyzing the costs of acting to address climate change, it would be irresponsible to ignore the costs of inaction. But this isn’t the panel to ask about what costs we ought to spend on acting and what are the consequences of inacting, except on the level of science.

Professor Field, let me just go back to this point. Earlier you said that corn, soybean, and cotton yields are very sensitive to increased temperatures. What effect does a very high-temperature day have on corn yields? How much are corn, soybean, and cotton yields in the U.S. expected to decline as a result of climate change? For example, if you have a single day of 104 degrees temperature, instead of 84 degrees, what would be the impact on corn? And what would be a modest warming impact?

Mr. FIELD. Currently, the best science came out in a 2010 report of the National Research Council. And what it concluded is that we should expect, in the absence of other activities, to see U.S. crop yields drop by something on the order of 5 to 10 percent for each degree Fahrenheit of warming.

We may be able to do technological fixes that avoid some of those changes. But I think that the best way to understand the climate change is, it is like an anchor that we are trying to drag as we advance agricultural technology through improved breeding and improved practices.

Mr. WAXMAN. Now, if a single day of 104 degrees temperature instead of 84 reduces corn yields by 7 percent—is that accurate?

Mr. FIELD. Yes.

Mr. WAXMAN. Even modest warming over this century is expected to reduce corn, soybean, and cotton yields by 30 to 46 percent. Is that an accurate statement?

Mr. FIELD. That is as well.

Mr. WAXMAN. And so, if we had a severe warming, that could reduce 63 to 82 percent.

Mr. FIELD. Yes.

Mr. WAXMAN. Now, maybe the farmers don't know about it; they are not clamoring for any legislation on the subject. But I could easily imagine they not knowing about it because they are not doing this research that you are doing.

Mr. FIELD. The new information is really quite striking. What it demonstrates is that, for major food crops in the U.S. and for cotton, there is very little temperature sensitivity until you reach a threshold. After you reach a threshold temperature—I indicated that it is 82 for corn, 84 for soybeans, and about 90 for cotton—you will begin to drop rapidly. And that is why people aren't generally aware of the sensitivities.

Mr. WAXMAN. Now, some of our Members represent districts in the western United States. Have the frequency and duration of western wildfires been affected by these increasing temperatures?

Mr. FIELD. Since the middle of the 1980s, we have seen a dramatic increase in the area burned, in the average length of fires, and in the length of fire season across the western U.S.

Mr. WAXMAN. And these are already happening?

Mr. FIELD. Yes.

Mr. WAXMAN. What can we expect as temperatures continue to rise?

Mr. FIELD. The best estimates, based on observations, not based on any kind of a simulation, is that a warming of about 1.8, more or less the same amount of warming that the U.S. has seen over the last century, would increase the annual area consumed in wildfires in the western U.S. From about 1.3 million acres a year to about 4.5 million acres per year, a more than threefold increase as a consequence of a very modest warming, more or less the amount of warming we have already seen.

Mr. WAXMAN. And, Professor Nadelhoffer, what climate change impacts can we expect to crop yields in the Midwest?

Mr. NADELHOFFER. Well, I don't have a percentage number, but we are seeing higher frequencies of high-heat events. And to the extent that those high-heat events exceed the critical thresholds beyond which crop yields decline qualitatively, I can say that it would damage agriculture in the U.S.

Mr. WAXMAN. Is it possible that soybean yields could decline in Illinois by as much as 55 percent by the end of the century?

Mr. NADELHOFFER. I would not rule that out.

Mr. WAXMAN. And weed-induced losses for corn could increase 22 percent in the Great Lakes States and 35 percent for soybeans?

Mr. NADELHOFFER. That is within the realm of possibility.

Mr. WAXMAN. Well, I want to end, Mr. Chairman, by saying that we have heard a lot of reasons from Members of Congress why people are afraid to do anything. But for us to do nothing, for the rest of the world to do nothing, there is a cost of inaction. And we ought to recognize that fact and try to figure out what can we do to make things better.

If we don't want something major, let's do something modest. But let's don't just put our heads in the sand and say, "We heard there is no problem from some scientists and some people that seem to be reputable, and therefore we are not going to do anything. Let's let the problem get worse." I don't think that is a responsible position.

I yield back my time.

Mr. WHITFIELD. Thank you.

Mr. Griffith, you are recognized for 5 minutes.

Mr. GRIFFITH. Thank you, Mr. Chairman.

Let me reiterate something that I mentioned previously. As you know, I was on a rapid-fire because I thought I was only going to get 5 minutes and I wanted to get all my questions out there. And I do ask you all to please get me answers, and we will get the questions in writing to you and so forth.

But one of my great concerns in this whole debate is that we shift our jobs and our wealth to other countries—Asia, Mexico—other countries that are not doing what we are doing. If it turns out that those of you who believe that it is all manmade greenhouse gases and manmade effect, I worry that we have crippled ourselves to respond to it later when other countries want to do something about it because we won't have the money. We will be a second-tier nation at that point, and that is a great concern of mine.

And I think we should have, you know, reasonable rules and regulations, but I want to make sure that we are doing it in a reasonable fashion. And I am not sure that unilaterally stopping the use of carbon fuels does this country or the world any great favors.

That being said, I was interested in the comments by you, Dr. Christy, in regard to land use. And I am wondering if you can amplify that, as to how that is affecting global warming and what we might be able to do. You know, is one of the concerns deforestation?

Are we worried about the peat bogs? I heard permafrost mentioned. I am just wondering if you could amplify on that.

Mr. CHRISTY. I will just talk about the fact that, when you look at surface temperature measurements, like I saw a chart up there earlier, we have shown how that is contaminated by the fact that it uses nighttime temperatures, which are a clear signal and affected by surface development of all kinds. It is a really complicated problem that we published on.

But there is clearly a warming component that is very large in that surface-temperature record over land that is not due to greenhouse gases at all, but it is due to humans. It is due to surface development. And so, I made the comment one time that if you turn California back into a desert, you will see the temperature fall, simply because of this effect. I don't recommend it, but.

Mr. GRIFFITH. Yes, I am not in favor of that either.

But what other—you said turn California, you know, back. What other things would we have to turn back to get back to temperatures pre-industrialization in the 19th century—or, excuse me, in the 1900s?

Mr. CHRISTY. It would be to go back to what it was like in the 18th century.

Mr. GRIFFITH. All right.

And then, Dr. Fields, I have been very interested in—and you may not have it here today, but I have been very interested in—and let me see if I have this right—90 degrees for cotton, 82 for corn, 84 for soybeans? Did I get that correct? Can you give me the same number on barley, wheat, oats, millet, rice, et cetera?

Mr. FIELD. I can't give you the specific numbers because the analysis for barley, we have only been able to do it with a global scale. And with barley, the sensitivity is about 5 percent yield loss per degree Fahrenheit of temperature increase.

Mr. GRIFFITH. But do you know the number for barley?

Mr. FIELD. I don't know if there is a threshold for barley.

Mr. GRIFFITH. OK. And how about wheat, oats, millet, rice? Just picking up some of the other grains.

Mr. FIELD. Right. So, the only grains for which—the only crops for which we have been able to identify the threshold temperatures are corn, soybean, and cotton. For the others, we can detect the sensitivity to warming and we can detect the fact that historical warming has put this anchor on yields. But as far as we can tell, we are in a part of the temperature range that is already responsive, where we are already seeing the yield decreases.

Mr. GRIFFITH. OK. Now, let me ask this, because, as Congressman Waxman pointed out, we want to deal with science here today, and that is what I am trying to do. I have all kinds of questions.

Do we not know the other grains because we haven't studied them or we have not yet reached their threshold?

Mr. FIELD. Well, we have reached the threshold. What we are seeing at the global scale is that there are already yield decreases with historical warming for wheat, maize, corn, and barley. What I said is that there is no evidence from the observations that there is a threshold. We are already in the responsive part of the system for wheat, barley, and corn.

Mr. GRIFFITH. OK. Has there been a study on oats?

Mr. FIELD. No.

Mr. GRIFFITH. So we have lack of science there.

Mr. FIELD. As far as I am aware, on oats.

Mr. GRIFFITH. OK. And the same would be true for millet and rice?

Mr. FIELD. In the study of the world's six major food crops, we do not see that rice is decreasing yields in response to the warming that has already occurred.

Mr. GRIFFITH. All right. Thank you very much.

Mr. WHITFIELD. Thank you.

Mr. Inslee, you are recognized for 5 minutes.

Mr. INSLEE. Thank you.

Dr. Somerville, I would like to suggest that you have been way too self-critical on the scientific community about why there is some remaining uncertainty in the public's mind about this. And I want to suggest that the reason there is some uncertainty is there has been a concerted war on science on this subject, just like there was in the tobacco debate.

This is a movie we have seen before. When the devastating evidence with a scientific consensus came out that tobacco killed Americans, there was a very concerted effort to distort and attack that science. It lasted for decades until it was finally overwhelmed.

And it was in part because there were people with enormous financial stakes that attacked that science, and it was in part and is part today—and here is another reason for it, and I will suggest it. Maybe it is controversial, but I will suggest it. Folks in the press report this like a divorce trial: He said, she said, then she said, then he said. That is not the way science ought to be reported in this country.

And if people start reporting that this mountain of evidence—by the way, this is just a partial list of the scientific documents on this. These things could reach to the ceiling. And there isn't one, single peer-reviewed paper in the world that supports a hypothesis about why the Arctic is melting other than this phenomena. And we need people in the press to start reporting that, frankly, so that Americans can make rational decisions.

Now, I want to bring in the parameters of what our real scientific discussion here is, because there is uncertainty about this, obviously, about how fast this is going to go and what the temperature ranges will be.

But I want to ask Dr. Christy, there was a lawsuit up in Vermont, and a judge quoted an expert who testified on behalf of the plaintiff. And he quoted this—I will call him Dr. X for the moment. I will quote from the judge's opinion.

Quote, "Plaintiff's own expert, Dr. X, agrees with the IPCC's assessment that, in light of new evidence and taking into account remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in GHG concentrations. Christy"—excuse me, I gave it away—"Dr. X agrees that the increase in carbon dioxide is real and primarily due to the burning of fossil fuels, which changes the radiated balance of the atmosphere and has an impact on the planet's surface temperature toward a warming rate."

Now, I gave away who Dr. X was. I just want to make clear, Dr. Christy, you agree, do you not, that human emissions of some of these pollutant gases is playing at least some role in changes in our climate? Now, if you could just say "yes" or "no" to that, I would really appreciate it.

Mr. CHRISTY. The question was a little confused there. Was it the pollution——

Mr. INSLEE. Let me just ask you if you agree with the statement you gave up in a court in Vermont. You said you——

Mr. CHRISTY. No, the judge got the statement wrong.

Mr. INSLEE. Oh, I see. The judge did it.

Mr. CHRISTY. I did not say that. Go back to the transcript, and that is the problem.

Mr. INSLEE. Well, let me just ask you this. Do you agree with the IPC's conclusion, assessment, that, in light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 6 years is likely to have been due to the increase in GHG concentrations, testimony by you on May 4th, 2007? Do you agree with that or disagree with that?

Mr. CHRISTY. What I said on the transcript was I mostly agreed with that. I did not say I agreed with it. And if they just changed one word, I would agree with that, instead of "most" to "some."

Mr. INSLEE. Let's show the picture of the Arctic up here again, if we can. If we can put the picture of the Arctic up here.

Now, what we have observed, due to satellite data and observations on the surface, is incontrovertible. A massive part of the Earth has changed. I don't know how many thousands of square miles are on there, but this is a bunch. And we have seen a 40 to 50 percent reduction in volume of the Arctic Sea ice in September in the last couple of decades. If current trends continue, there will be virtually no Arctic ice in September probably within this decade, perhaps within 5 or 6 years.

Now, what I am told is, this is a very significant change in the planet because of the albedo effect. And perhaps, Dr. Field, could you describe to us what that is and why this is important to us?

Mr. FIELD. Thank you.

Sea ice reflects about 90 percent of the sunlight that hits it. Seawater absorbs about 90 percent of the sunlight that hits it. That is a big difference in the amount of heat that is reflected back to space versus absorbed in the Earth's system. Sea ice tends to cool the planet. Open water tends to warm the planet.

Mr. INSLEE. Now, this appears to me to be a very dramatic change in the world that we have known since humans walked the planet. This has never existed before while humans were on the planet Earth.

Has anyone produced a peer-reviewed article to suggest a hypothesis as to why this has happened in the Arctic other than the accumulation of greenhouse gases and associated effects? Has anyone published a peer-reviewed article suggesting another hypothesis?

And I am not seeing any takers, because there are none.

Mr. PIELKE. Excuse me. If you are asking a question, that 2005 NRC report talks about the black carbon. And there is also the issue of natural circulation——

Mr. INSLEE. Black carbon is something associated with burning our fossil fuels. And that——

Mr. PIELKE. I understand, but——

Mr. INSLEE [continuing]. Is another problem we have to get——

Mr. PIELKE [continuing]. It is not a greenhouse gas.

Mr. INSLEE. Well, it is good enough to melt the Arctic. And it is one of the reasons why the EPA should not be stopped from enforcing the Clean Air Act, like the Republicans want to do. And we are going to stop it.

Mr. WHITFIELD. The gentleman's time has expired.

You know, there was some nodding going on here when we talked about there is not one peer-reviewed article relating to the Arctic diminishing of ice. Are any of you aware of any peer-reviewed articles that——

Mr. CHRISTY. There are articles that talk about the circulation being a dominant component of why that is missing up there. If you go back several—a few thousand years, not several, just a few thousand years, there were times when it was probably completely free of ice. This is not a new situation.

And I agree with you that there is no question the Arctic ice has diminished in the past 20 years. Antarctic sea ice has increased. And it has a greater albedo effect, by the way, than the Arctic does. And I think Roger knows something about that.

Mr. WHITFIELD. The gentleman from Louisiana is recognized for 5 minutes.

Mr. SCALISE. Thank you again, Mr. Chairman, for the second round.

And, obviously, I think we are seeing some more very interesting, kind of, divergent views. But, in some ways, it is not really divergent. We are really starting to see more of the details that seem to be excluded too often in other reports, when some people want to issue a report just to prove what they are trying to accomplish, as opposed to following the data.

And I want to ask you about this, Dr. Pielke, because you refer to the Climate Change Science Program's report. And I think you had done an analysis of it, maybe with some other doctors, I would like to ask you to comment on.

But in a few parts of your statement, you talk about, "The process for completing the CCSP report excluded valid scientific perspectives." You talk about, "The editor of the report systemically excluded a range of views on the issue of understanding and reconciling lower atmospheric temperature trends." Later on, you mentioned that, "The executive summary of the CCSP report ignores critical scientific issues and makes unbalanced conclusions concerning our current understanding of temperature trends."

All of you are scientists, and, respectably, you can disagree with each other if you are trying to come to a conclusion. But if you are going to issue a report and deliberately exclude certain things because maybe they don't reach the same conclusion that you are trying to reach, that is not science.

And I think, Dr. Pielke, what you are talking about here—and you reviewed this—is getting to the heart of that very concern many of us have, that there are people running around out there talking about "thousands of scientists" out there and trying to discredit anybody who comes out against it, when, in fact, some of these reports exclude key data, and then the thousands of scientists are basing their assumptions on the report that, in itself, is factually inaccurate because it excluded key data.

So if you can talk to me about maybe specifically the CCSP report and what was excluded. And in the broader picture, are there other scientists like you that have reviewed these kinds of reports and said, "Wait a minute, they are leaving out key data"?

Mr. PIELKE. Exactly, they certainly are. And in the CCPS report, I documented it for others in a series of e-mail exchanges that I had that is actually on my Web log. What you quoted was out of a public comment that I responded to. And an outgrowth of that was that we published several papers with many authors in the peer-reviewed literature that showed unresolved issues with the surface-temperature record. I am not going to go through them here, obviously, but one of them is how good is the siting of these sites; what height do they measure the temperatures at.

They deliberately excluded this, and they wanted to assume that this surface-temperature record is robust and they don't need to look at it any further. And on the CCSP report, we raise issues. They were excluded. And then I finally resigned it to the public comment. And since then we have published papers on it and have documented that there are serious issues with the use of that metric to diagnose global warming.

Mr. SCALISE. And, again, this should be based on the data. If the data backs it up, that is one thing. But then there are people running around using these reports that, in and of themselves, are corrupt because they specifically excluded key—this data.

Mr. PIELKE. As you know, the CCSP was used in preparation of the 2007 IPCC report. And I also documented peer-reviewed papers that were excluded from that report that showed an alternative perspective than what was presented in the report on that issue.

Mr. SCALISE. Thank you.

And let me ask you, Dr. Christy, because you talk about this in a similar way. You talk about, "Widely publicized consensus reports by thousands of scientists are misrepresentative and contain overstated confidence in their assertions, rarely representing the range of scientific opinion that attends a relatively murky field of climate science."

Can you expand upon that, following a similar line of questioning that I had with Dr. Pielke?

Mr. CHRISTY. Well, fundamentally, only a few people can write the report. Thousands of people don't write the report. Thousands of people don't approve of everything in the report. And so it really comes down to those few who are, as I call them, they are gatekeepers of the information rather than brokers of the information.

This is the information I presented to the InterAcademy Council last summer that they pretty much took to heart. And how do you get out of that? That was one of the things I was trying to——

Mr. SCALISE. Let me ask you this, because we have heard this in previous testimony before this committee. Some scientists—who, as you, Dr. Pielke, and others have maybe pointed out some inaccuracies or data that is left out, other things—they talk about blacklisting that goes on inside the scientific community. I don't know if you want to comment on it. But, I mean, what kind of reaction do you get from scientists when you do point out these things that are not necessarily reflective of the full picture?

Mr. CHRISTY. They are hard pressed to deal with the numbers, because all science is numbers, and that is really what we have. But——

Mr. SCALISE. And you have built your own data models, so I take it—and I looked at what you reviewed on the Sierra Nevada mountains, some other things you found in the United States and Africa in terms of temperature, and the complexities, when you get into what really causes it. It is one thing to show that you have a temperature change over thousands of years. You have seen that up and down throughout history. What causes it, I guess, is at the heart of the issue here, and the complexities of that.

So if you can make one final comment there.

Mr. CHRISTY. Well, I would just say, kind of, the thrust of your question, if someone would read the Climategate e-mails, and as someone who was denigrated in those e-mails, I have a completely different view about them than Dr. Somerville might.

Mr. SCALISE. Thank you.

And, Mr. Chairman, if I may, just one last thing. Today is Mardi Gras day. I just flew in from New Orleans this morning to be at this panel, so I couldn't be at the parade. But, as we are talking about icing and agriculture, I have got a king cake back in the back. So if members of the committee on either side would like to come back, we have some good king cake from New Orleans with icing on top——

Mr. WHITFIELD. How big is it?

Mr. SCALISE [continuing]. And I would invite you all to have some of that.

Mr. WHITFIELD. Is it big?

Mr. SCALISE. It is—and, by the way, your good friend Herschel Abbott is the king of Mardis Gras today.

Mr. WHITFIELD. All right.

Mr. SCALISE. So, a beautiful day back in New Orleans. Wish I could be there, but glad to be here. And I yield back.

Mr. WHITFIELD. That concludes today's hearing. I want to thank——

Mr. RUSH. Mr. Chairman?

Mr. WHITFIELD. Yes?

Mr. RUSH. Mr. Chairman, I have a unanimous consent request for some reports to be entered into the record, if I might. A very extensive——

Mr. WHITFIELD. How big is this report?

Mr. RUSH. There are a number of reports. But I would like to have them entered into the record.

Mr. WHITFIELD. Well, yes. And we will enter some in the record, too, then. All right, go ahead.

Mr. RUSH. Mr. Chairman, the first report is a 2009 report entitled, "Global Climate Change Impacts in the United States." And this study was conducted on behalf of the National Science and Technology Council and the U.S. Global Change Research Program and was transmitted to the Bush White House and the Congress in June 2009. The report summarizes the science of climate change——

Mr. WHITFIELD. How many pages is that?

Mr. RUSH. I think it is about 170, 180 pages.

Mr. WHITFIELD. OK.

Mr. RUSH. And I will quote just one part of it. It says, "Observations show that warming of the climate is unequivocal. The global warming observed over the past 50 years is due primarily to human-induced emissions."

Mr. WHITFIELD. Mr. Rush, I mean, if you would read the title, we would be happy to submit them.

Mr. RUSH. All right. Well, then this study is a 2007 study entitled, "The U.S. Economic Impacts of Climate Change and the Costs of Inaction," and it is a review and assessment by the Center for Integrative Environmental Research at the University of Maryland.

The third is a statement from the board of directors of the American Association for the Advancement of Science, the world's largest general scientific society, which serves 262 affiliated societies and academies of science and 10 million individuals.

The other is a statement by 18 scientific societies, including the American Association for the Advancement of Science, representing an assessment of the science.

The other one is a letter on behalf of 152 researchers from universities, colleges, and research institutes across the State of Michigan strongly urging members of the Michigan congressional delegation to reject any measure that will block or delay the EPA from protecting the people of Michigan from air pollution and human-caused climate change, which endangers the public agriculture and the environment and the economy.

The next is a letter on behalf of scientists and colleges and universities across the State of Wisconsin urging the Wisconsin congressional delegation to support strong Federal policies for rapid and deep reductions in emissions of carbon dioxide and other greenhouse gases at least on par with the reductions recommended by the Intergovernmental Panel on Climate Change.

And the last report, Mr. Chairman, is the report that I heard about today, along with the rest of the Members, is the report that Dr. Somerville stated—and I don't know the full name of the report. It was a military report, the CNA report. Maybe Dr. Somerville can give us the formal name of the study.

Mr. SOMERVILLE. Yes, I am glad to do that. It is "National Security and the Threat of Climate Change," 2007, the CNA Corporation.

Mr. WHITFIELD. We will be happy to do that.

And we will also include this document, "More Than 700 International Scientists Dissent Over Man-Made Global Warming Claims." Without objection, so ordered.

[The information appears at the conclusion of the hearing.]

Mr. WAXMAN. Mr. Chairman?

Mr. WHITFIELD. Yes.

Mr. WAXMAN. First of all, I want to thank you for holding this hearing. I think it was important for us to hear about the science of this whole issue.

But I was just informed that you are planning to call a meeting of our subcommittee to mark up the bill on Thursday, and I want to make a request that you not do that. I have extended an offer to you to work with you. I would hate to see Congress take a position on declaring science, a science conclusion that what the EPA determined was false, amending the Clean Air Act and denying the EPA ability to do anything.

I would hope we could come up with a more nuanced and more reasonable policy in light of what we are hearing from people today and how this issue is of a great deal of significance to many of us. So I would appeal to you to meet with us, no preconditions, and see if we can come up with something better.

Mr. WHITFIELD. Well, Mr. Waxman, thank you very much for those comments. And, you know, these are some issues that there are significant disagreements on. And I know that when we have this markup on Thursday there will be a lot of debate, a lot of amendments, and we will air it all out at that time.

And I want to thank the witnesses for being here today very much. We appreciate your testimony. This is a very—your testimony is very important.

I would like to also remind Members that they have 10 business days to submit questions for the record.

And I ask that the witnesses all agree to respond as quickly as you can to any questions that come your way. I know Mr. Griffith has a lot.

And so, with that——

Mr. RUSH. Mr. Chairman? Mr. Chairman?

Mr. WHITFIELD. Yes, sir.

Mr. RUSH. Mr. Chairman, I would ask, if I could, I would join with the ranking member of the full committee and ask that this subcommittee delay the markup that is occurring on Thursday.

You know, Mr. Chairman, it seems like we are trying to force-feed a hoax on the American people. And I just think that we should be more deliberative and that we should take our time with this.

The ranking member has offered his sincere request that we delay this and offered his participation and his eagerness to work with you and the committee and the subcommittee on trying to come up with some kind of modification of the bill that is currently going to be under markup. And I would join him in that.

I just think it is important, Mr. Chairman, that we take our time on this, because, as you can see, there is not any agreement. As a matter of fact, most of the scientific community basically take odds, enormous odds, with the opinion of the majority on this particular issue.

Mr. WHITFIELD. Well, Mr. Rush, thank you very much. I appreciate your and Mr. Waxman's comments. We certainly have a lot of respect for both of you and your views.

As I said in the beginning of this hearing, we have had 24, now 25 hearings on the science on this issue. And on this side of the aisle, we feel like that EPA is really forcing us to act quickly because Congress has addressed this issue three separate times and said "no" each time.

So we will go by regular order. It will be in the subcommittee, it will be in the full committee, and if it is able to get out of there, it will be on the floor. So we will have plenty of opportunity for debate, plenty of opportunity for amendment. And we look forward to working with all of you.

So, with that, the committee is adjourned. Thank you very much.

[Whereupon, at 12:46 p.m., the subcommittee was adjourned.]

[Material submitted for inclusion in the record follows:]

PREPARED STATEMENT OF HON. FRED UPTON

• As chair of Energy and Commerce, I see a country that needs a whole lot more of both. Accomplishing this is the core goal of this committee and is why I have introduced HR 910, the Energy Tax Prevention Act of 2011. This bill would stop the EPA's global warming regulatory agenda, an agenda that poses a serious threat to the economy and to job growth.

• The issues here are not new, as Congress grappled with cap and trade legislation in 2009. There were a lot of hearings on global warming, including the science. Some were held before this committee and more before the Select Committee. At the end of that debate, I concluded that cap and trade energy taxes would impose far more economic pain than environmental gain, and I did not support the legislation.

• For me, that decision is an even easier one when it comes to EPA's attempt to impose the regulatory equivalent of the failed climate cap-and-tax legislation.

• This subcommittee has held two hearings on the Energy Tax Prevention Act. Both focused on the economic impacts. We learned about the jobs EPA's global warming regulations are already costing manufacturers. It was the number one concern for most of the manufacturers that testified.

• At both hearings, there was a concerted effort by some to shift the emphasis away from the economics of EPA's regulatory agenda, and discuss global warming science instead. But these discussions miss the point of HR 910. The bill is not a referendum on global warming science, it is a referendum on the merits of EPA's regulations.

• We already learned about the high costs of this agenda last year, but we also gained insights into its inconsequential environmental impacts. EPA's unilateral measures would only shift emissions to other countries. In other words, we would be outsourcing both jobs and emissions, harming ourselves economically but accomplishing nothing environmentally. No matter what your beliefs in the climate science spectrum, you should have substantial doubts that EPA's regulations make any sense.

• Beyond the science, let us not lose sight of the bigger issue, and that is whether EPA has offered a reasonable response, and it most definitely has not. For that reason, we need to enact HR 910.

February 9, 2011

U.S. House of Representatives
Washington, DC 20515

Dear Representative:

As health and medical professionals, we are keenly aware of the health impacts of air pollution. Air pollution is linked to a wide range of health consequences including cancer, asthma attacks, heart attacks and strokes. The Clean Air Act guarantees all Americans, especially the most vulnerable, air that is safe and healthy to breathe. Despite tremendous air pollution reductions, more progress is needed to fulfill this promise. Please support the full implementation and enforcement of the Clean Air Act.

Throughout its four decade history protecting the public from air pollution, the Clean Air Act has enjoyed strong bi-partisan support. The original Clean Air Act and its subsequent amendments received overwhelming votes in Congress. This landmark public health law directed the Environmental Protection Agency to protect health and the environment from air pollution. The result is saved lives and improved quality of life for millions of Americans. But the job is not finished. Communities across the nation still suffer from poor air quality. Low income families face the impacts of toxic air pollution every day. From smog causing asthma attacks to toxic mercury harming children's neurological development, far too many people face a constant threat from the air they breathe and the impacts of climate change.

Please fulfill the promise of clean, healthy air for all Americans to breathe. Support full implementation of the Clean Air Act and resist any efforts to weaken, delay or block progress toward a healthier future for all Americans.

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Milwaukee
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Milwaukee

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Milwaukee
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Milwaukee
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Neenah
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Onalaska
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Onalaska
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Platteville
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Poynette
Andrew Rogahn, ADN
Poynette
Dorothy Campbell, RN
poynette
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Wausau
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West Allis
Susan Sawyer Evans, RRT, BA
West Salem
Barbara Barczak, RN, BSN
Whitehall

Wyoming

Alex Bowler, MPH
Cheyenne
Joseph Grandpre, PhD, MPH
Cheyenne

CDC Policy on Climate Change and Public Health

SCIENTIFIC FRAMEWORK

- There is widespread scientific consensus that the world's climate is changing. Some of the effects of climate change are likely to include more variable weather, heat waves, heavy precipitation events, flooding, droughts, more intense storms such as hurricanes, sea level rise, and air pollution. Each of these changes has the potential to negatively affect health. While climate change is recognized as a global issue, the effects of climate change will vary across geographic regions and populations.
- Although scientific understanding of the effects of climate change is still emerging, there is a pressing need to prepare for potential health risks. This public health preparedness approach is applied to other threats in the absence of complete data, such as terrorism and pandemic influenza. A wide variety of organizations (federal, state, local, multilateral, private and nongovernmental) is working to address the implications of global climate change. Despite this breadth of activity, the public health effects of climate change remain largely unaddressed.
- Climate change has the potential to impact health in many ways. While some of these are unpredictable, others (shown in the table) are supported by considerable evidence.

Weather Event	**Health Effects**	**Populations Most Affected**
Heat waves	Heat stress	Extremes of age, athletes, people with respiratory disease
Extreme weather events, (rain, hurricane, tornado, flooding)	Injuries, drowning	Coastal, low-lying land dwellers, low SES
Droughts, floods, increased mean temperature	Vector-, food- and water-borne diseases	Multiple populations at risk
Sea-level rise	Injuries, drowning, water and soil salinization, ecosystem and economic disruption	Coastal, low SES
Drought, ecosystem migration	Food and water shortages, malnutrition	Low SES, elderly, children
Extreme weather events, drought	Mass population movement, international conflict	General population
Increases in ground-level ozone, airborne allergens, and other pollutants	Respiratory disease exacerbations (COPD, asthma, allergic rhinitis, bronchitis)	Elderly, children, those with respiratory disease
Climate change generally; extreme events	Mental health	Young, displaced, agricultural sector, low SES

PUBLIC HEALTH APPROACH

Building on existing programs and the Essential Public Health Services, CDC has identified the following priority health actions for climate change:

1. Serve as a credible source of information on the health consequences of climate change for the U.S. population and globally.
2. Track data on environmental conditions, disease risks, and disease occurrence related to climate change.
3. Expand capacity for modeling and forecasting health effects that may be climate-related.
4. Enhance the science base to better understand the relationship between climate change and health outcomes.
5. Identify locations and population groups at greatest risk for specific health threats, such as heat waves.
6. Communicate the health-related aspects of climate change, including risks and ways to reduce them, to the public, decision makers, and healthcare providers.
7. Develop partnerships with other government agencies, the private sector, nongovernmental organizations, universities, and international organizations to more effectively address U.S. and global health aspects of climate change.
8. Provide leadership to state and local governments, community leaders, healthcare professionals, nongovernmental organizations, the faith-based communities, the private sector and the public, domestically and internationally, regarding health protection from climate change effects.
9. Develop and implement preparedness and response plans for health threats such as heat waves, severe weather events, and infectious diseases.
10. Provide technical advice and support to state and local health departments, the private sector, and others in implementing national and global preparedness measures related to the health effects of climate change.
11. Promote workforce development by helping to ensure the training of a new generation of competent, experienced public health staff to respond to the health threats posed by climate change.

CORRECTED 14 MAY 2010; SEE LAST PAGE

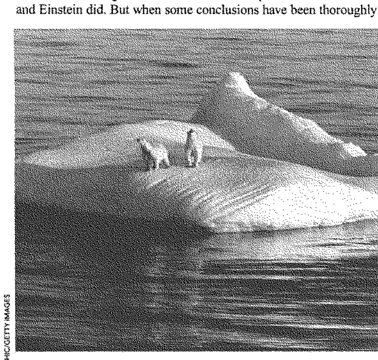
LETTERS

edited by Jennifer Sills

Climate Change and the Integrity of Science

WE ARE DEEPLY DISTURBED BY THE RECENT ESCALATION OF POLITICAL ASSAULTS ON SCIENTISTS in general and on climate scientists in particular. All citizens should understand some basic scientific facts. There is always some uncertainty associated with scientific conclusions; science never absolutely proves anything. When someone says that society should wait until scientists are absolutely certain before taking any action, it is the same as saying society should never take action. For a problem as potentially catastrophic as climate change, taking no action poses a dangerous risk for our planet.

Scientific conclusions derive from an understanding of basic laws supported by laboratory experiments, observations of nature, and mathematical and computer modeling. Like all human beings, scientists make mistakes, but the scientific process is designed to find and correct them. This process is inherently adversarial—scientists build reputations and gain recognition not only for supporting conventional wisdom, but even more so for demonstrating that the scientific consensus is wrong and that there is a better explanation. That's what Galileo, Pasteur, Darwin, and Einstein did. But when some conclusions have been thoroughly and deeply tested, questioned, and examined, they gain the status of "well-established theories" and are often spoken of as "facts."



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For instance, there is compelling scientific evidence that our planet is about 4.5 billion years old (the theory of the origin of Earth), that our universe was born from a single event about 14 billion years ago (the Big Bang theory), and that today's organisms evolved from ones living in the past (the theory of evolution). Even as these are overwhelmingly accepted by the scientific community, fame still awaits anyone who could show these theories to be wrong. Climate change now falls into this category: There is compelling, comprehensive, and consistent objective evidence that humans are changing the climate in ways that threaten our societies and the ecosystems on which we depend.

Many recent assaults on climate science and, more disturbingly, on climate scientists by climate change deniers are typically driven by special interests or dogma, not by an honest effort to provide an alternative theory that credibly satisfies the evidence. The Intergovernmental Panel on Climate Change (IPCC) and other scientific assessments of climate change, which involve thousands of scientists producing massive and comprehensive reports, have, quite expectedly and normally, made some mistakes. When errors are pointed out, they are corrected. But there is nothing remotely identified in the recent events that changes the fundamental conclusions about climate change:

(i) The planet is warming due to increased concentrations of heat-trapping gases in our atmosphere. A snowy winter in Washington does not alter this fact.

(ii) Most of the increase in the concentration of these gases over the last century is due to human activities, especially the burning of fossil fuels and deforestation.

(iii) Natural causes always play a role in changing Earth's climate, but are now being overwhelmed by human-induced changes.

(iv) Warming the planet will cause many other climatic patterns to change at speeds unprecedented in modern times, including increasing rates of sea-level rise and alterations in the hydrologic cycle. Rising concentrations of carbon dioxide are making the oceans more acidic.

(v) The combination of these complex climate changes threatens coastal communities and cities, our food and water supplies, marine and freshwater ecosystems, forests, high mountain environments, and far more.

Much more can be, and has been, said by the world's scientific societies, national academies, and individuals, but these conclusions should be enough to indicate why scientists are concerned about what future generations will face from business-as-usual practices. We urge our policy-makers and the public to move forward immediately to address the causes of climate change, including the unrestrained burning of fossil fuels.

We also call for an end to McCarthy-like threats of criminal prosecution against our colleagues based on innuendo and guilt by association, the harassment of scientists by politicians seeking distractions to avoid taking action, and the outright lies being spread about them. Society has two choices: We can ignore the science and hide our heads in the sand and hope we are lucky, or we can act in the public interest to reduce the threat of global climate change quickly and substantively. The good news is that smart and effective actions are possible. But delay must not be an option.

P. H. GLEICK,* R. M. ADAMS, R. M. AMASINO, E. ANDERS, D. J. ANDERSON, W. W. ANDERSON, L. E. ANSELIN, M. K. ARROYO, B. ASFAW, F. J. AYALA, A. BAX, A. J. BEBBINGTON, G. BELL, M. V. L. BENNETT, J. L. BENNETZEN, M. R. BERENBAUM, O. B. BERLIN, P. J. BJORKMAN, E. BLACKBURN, J. E. BLAMONT, M. R. BOTCHAN, J. S. BOYER, E. A. BOYLE, D. BRANTON, S. P. BRIGGS, W. R. BRIGGS, W. J. BRILL, R. J. BRITTEN, W. S. BROECKER, J. H. BROWN, P. O. BROWN, A. T. BRUNGER, J. CAIRNS JR., D. E. CANFIELD, S. R. CARPENTER, J. C. CARRINGTON, A. R. CASHMORE, J. C. CASTILLA, A. CAZENAVE, F. S. CHAPIN III, A. J. CIECHANOVER, D. E. CLAPHAM, W. C. CLARK, R. N. CLAYTON, M. D. COE, E. M. CONWELL, E. B. COWLING, R. M COWLING, C. S. COX, R. B. CROTEAU, D. M. CROTHERS, P. J. CRUTZEN, G. C. DAILY, G. B. DALRYMPLE, J. L. DANGL, S. A. DARST, D. R. DAVIES, M. B. DAVIS, P. V. DE CAMILLI, C. DEAN, R. S. DEFRIES, J. DEISENHOFER, D. P. DELMER, E. F. DELONG, D. J. DEROSIER, T. O. DIENER, R. DIRZO, J. E. DIXON, M. J. DONOGHUE, R. F. DOOLITTLE, T. DUNNE, P. R. EHRLICH, S. N. EISENSTADT, T. EISNER, K. A. EMANUEL, S. W. ENGLANDER, W. G. ERNST, P. G. FALKOWSKI, G. FEHER, J. A. FEREJOHN, A. FERSHT, E. H. FISCHER, R. FISCHER, K. V. FLANNERY, J. FRANK, P. A. FREY, I. FRIDOVICH, C. FRIEDEN, D. J. FUTUYMA, W. R. GARDNER, C. J. R. GARRETT, W. GILBERT, R. B. GOLDBERG, W. H. GOODENOUGH, C. S. GOODMAN, M. GOODMAN, P. GREENGARD, S. HAKE, G. HAMMEL, S. HANSON, S. C. HARRISON, S. R. HART, D. L. HARTL, R. HASELKORN, K. HAWKES, J. M. HAYES, B. HILLE, T. HÖKFELT, J. S. HOUSE, M. HOUT, D. M. HUNTEN, I. A. IZQUIERDO, A. T. JAGENDORF, D. H. JANZEN, R. JEANLOZ, C. S. JENCKS, W. A. JURY, H. R. KABACK, T. KAILATH, P. KAY, S. A. KAY, D. KENNEDY, A. KERR, R. C. KESSLER, G. S. KHUSH, S. W. KIEFFER, P. V. KIRCH, K. KIRK, M. G. KIVELSON, J. P. KLINMAN, A. KLUG, L. KNOPOFF, H. KORNBERG, J. E. KUTZBACH, J. C. LAGARIAS, K. LAMBECK, A. LANDY, C. H. LANGMUIR, B. A. LARKINS, X. T. LE PICHON, R. E. LENSKI, E. B. LEOPOLD, S. A. LEVIN, M. LEVITT, G. E. LIKENS, J. LIPPINCOTT-SCHWARTZ, L. LORAND, C. O. LOVEJOY, M. LYNCH, A. L. MABOGUNJE, T. F. MALONE, S. MANABE, J. MARCUS, D. S. MASSEY, J. C. MCWILLIAMS, E. MEDINA, H. J. MELOSH, D. J. MELTZER, C. D. MICHENER, E. L. MILES, H. A. MOONEY, P. B. MOORE, F. M. M. MOREL, E. S. MOSLEY-THOMPSON, B. MOSS, W. H. MUNK, N. MYERS, G. B. NAIR, J. NATHANS, E. W. NESTER, R. A. NICOLL, R. P. NOVICK, J. F. O'CONNELL, P. E. OLSEN, N. D. OPDYKE, G. F. OSTER, E. OSTROM, N. R. PACE, R. T. PAINE, R. D. PALMITER, J. PEDLOSKY, G. A. PETSKO, G. H. PETTENGILL, S. G. PHILANDER, D. R. PIPERNO, T. D. POLLARD, P. B. PRICE JR., P. A. REICHARD, B. F. RESKIN, R. E. RICKLEFS, R. L. RIVEST, J. D. ROBERTS, A. K. ROMNEY, M. G. ROSSMANN, D. W. RUSSELL, W. J. RUTTER, J. A. SABLOFF, R. Z. SAGDEEV, M. D. SAHLINS, A. SALMOND, J. R. SANES, R. SCHEKMAN, J. SCHELLNHUBER, D. W. SCHINDLER, J. SCHMITT, S. H. SCHNEIDER, V. L. SCHRAMM, R. R. SEDEROFF, C. J. SHATZ, F. SHERMAN, R. L. SIDMAN, K. SIEH, E. L. SIMONS, B. H. SINGER, M. F. SINGER, B. SKYRMS, N. H. SLEEP, B. D. SMITH, S. H. SNYDER, R. R. SOKAL, C. S. SPENCER, T. A. STEITZ, K. B. STRIER, T. C. SÜDHOF, S. S. TAYLOR, J. TERBORGH, D. H. THOMAS, L. G. THOMPSON, R. T. TJIAN, M. G. TURNER, S. UYEDA, J. W. VALENTINE, J. S. VALENTINE, J. L. VAN ETTEN, K. E. VAN HOLDE, M. VAUGHAN, S. VERBA, P. H. VON HIPPEL, D. B. WAKE, A. WALKER, J. E. WALKER, E. B. WATSON, P. J. WATSON, D. WEIGEL, S. R. WESSLER, M. J. WEST-EBERHARD, T. D. WHITE, W. J. WILSON, R. V. WOLFENDEN, J. A. WOOD, G. M. WOODWELL, H. E. WRIGHT JR., C. WU, C. WUNSCH, M. L. ZOBACK

*To whom correspondence should be addressed. E-mail: petergleick@pacinst.org

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2. Signatory affiliations are available as supporting material at www.sciencemag.org/cgi/content/full/328/5979/689/DC1.

Shifting the Debate on Geoengineering

AS DISCUSSED IN THE RECENT POLICY FORUM "The politics of geoengineering" (J. J. Blackstock and J. C. S. Long, 29 January, p. 527), there is growing recognition that avoiding dangerous climate change during the 21st century may require society to adopt geoengineering technologies to supplement CO_2 emission reduction efforts. Unfortunately, despite the essential role that CO_2 removal (CDR) and solar radiation management (SRM) technologies may play in reducing the risks of dangerous climate change, discussions of the necessary research and development [including the Policy Forum and others (*1*, *2*)] frequently turn into debates about the environmental costs and benefits of SRM. A more productive approach would shift the debate to comparing the relative costs and benefits of CDR and SRM.

CDR approaches are frequently discounted because, as Blackstock and Long explain, "technical challenges and large uncertainties [surround] large-scale CDR deployment." Although this may be true for human-built systems that capture CO_2 from air at ambient concentrations, there are other technologies based on biological carbon fixation that could be fast-tracked for rapid deployment during the next few decades (*3*). Most major international energy corporations are investing in algal-based biofuel technologies because of the tremendous production potential of algae relative to terrestrial energy crops (*4*). Commercial-scale production of algal biofuels will begin during the next 5 years, and rapid scaling up can be expected afterward if the economic incentives are favorable. However, becoming carbon negative will require society to develop plans for retrofitting existing coal-fired power plants and building future ones so that they can burn algal biomass and capture the emitted CO_2 for subsequent sequestration. The basic technologies described here are not novel; rather, I am proposing a conceptual rearrangement that may enable society to transition more gracefully

CORRECTIONS AND CLARIFICATIONS

Research Articles: "Doc2b is a high-affinity Ca^{2+} sensor for spontaneous neurotransmitter release" by A. J. Groffen *et al.* (26 March, p. 1614). Several author affiliations were not footnoted properly; three corrected affiliations follow. Y. Takai, Department of Biochemistry and Molecular Biology, Kobe University Graduate School of Medicine, Kobe 650-0017, Japan. J. G. Borst, Department of Neuroscience, Erasmus MC, University Medical Center, Rotterdam, 3000 CA, Netherlands. N. Brose, Max-Planck-Institut für Experimentelle Medizin, Abteilung Molekulare Neurobiologie, 37075 Göttingen, Germany.

Letters: "Oil and water do mix" by J. L. Kavanau (19 February, p. 958). Due to an editorial error, the title was incorrect. It should have been "Opposites attract."

Reports: "100-million-year dynasty of giant planktivorous bony fishes in the Mesozoic seas" by M. Friedman *et al.* (19 February, p. 990). The author Matt Friedman's affiliation should have been "Committee on Evolutionary Biology, University of Chicago, 1025 East 57th Street, Chicago, IL 60637, USA." The affiliation that was listed is his present address.

News of the Week: "*DSM-V* at a glance" by G. Miller and C. Holden (12 February, p. 770). In the sidebar, it was reported that the term "gender identity disorder" has been retained. In fact, a different term—"gender incongruence"—has been proposed.

Research Articles: "PRDM9 is a major determinant of meiotic recombination hotspots in humans and mice" by F. Baudat *et al.* (12 February, p. 836). M. Lichten was incorrectly listed as an author in references 18 and 19. The correct authors for reference 18 are C. Grey, F. Baudat, and B. de Massy; for reference 19, the correct authors are E. D. Parvanov, S. H. Ng, P. M. Petkov, and K. Paigen.

Reports: "Epigenetic transgenerational actions of endocrine disruptors and male fertility" by M. D. Anway *et al.* (3 June 2005, p. 1466). As clarification of the abstract to Anway *et al.*, the F_1 to F_4 generations were examined after vinclozolin treatment, and F_1 and F_2 generations were examined after methoxychlor treatment. To clarify data referred to in the last paragraph of the Report, serum testosterone measurements after vinclozolin treatment were shown in reference 21 (Uzumcu *et al.*) for the F_1 generation. Data for the F_1 to F_4 generations were subsequently published in Anway *et al.*, *J. Androl.* **27**, 868 (2006). Serum testosterone measurements after methoxychlor treatment were shown in reference 20 (Cupp *et al.*) for the F_1 generation, but measurements of the F_2 generation have not been published. The *Science* Anway *et al.* manuscript showed DNA methylation analysis after vinclozolin treatment, but the DNA methylation data after methoxychlor treatment have not been published.

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from fossil to modern carbon fuel sources while simultaneously reducing CO_2 levels in the atmosphere and ocean.

CHARLES H. GREENE

Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853, USA. E-mail: chg2@cornell.edu

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Response

GREENE SUGGESTS THAT CO_2 REMOVAL methods deserve expanded evaluation and research. We agree. In the long run, these methods may be the only way to reduce atmospheric concentrations of CO_2 to values closer to those of the preindustrial era. Greene suggests a scheme for using biomass to generate electricity combined with carbon capture and storage. This idea has merit. Even schemes that capture CO_2 directly from the air deserve expanded research.

However, Greene's statement that "discussions of the necessary research and development…frequently turn into debates about the environmental costs and benefits of SRM [solar radiation management]" misses a key point motivating all three of the articles he cites [our Policy Forum and (*1*, *2*)]. The two approaches differ in both strategic impact and risks. Most CO_2 removal schemes, including those suggested by Greene, would be slow acting and expensive, and would pose no transboundary risks. In contrast, SRM techniques appear inexpensive and could have rapid climatic impact, but present a host of global climatic and political risks.

The low cost and technical feasibility of some SRM technologies (particularly stratospheric aerosol injection) mean that SRM might be our only response if a "climate emergency" develops. However, these traits also mean that SRM could be globally tested unilaterally by a single country, to the possible detriment of others (*3*). Beyond the climatic risks this presents, such actions could also severely disrupt progress on international climate policy.

The discussion of urgent governance challenges in the articles Greene cites is not a distraction; it is central to figuring out how to safely and prudently conduct research into SRM technologies. No such acute research governance challenges exist for most CO_2 removal techniques.

JASON J. BLACKSTOCK[1,2]* AND JANE C. S. LONG[3]

[1]International Institute for Applied Systems Analysis, Laxenburg A2361, Austria. [2]Centre for International Governance Innovation, Waterloo, ON N2L 6C2, Canada. [3]Lawrence Livermore National Laboratory, Livermore, CA 94550, USA.

*To whom correspondence should be addressed. E-mail: jjb@iiasa.ac.at

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2. D. W. Keith, E. Parson, M. G. Morgan, *Nature* **463**, 426 (2010).
3. D. G. Victor, M. G. Morgan, J. Apt, J. Steinbruner, *Foreign Aff.* **88**, 64 (2009).

Letters to the Editor

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ERRATUM

Post date 14 May 2010

Letters: "Climate change and the integrity of science" by P. H. Gleick *et al.* (7 May, p. 689). Due to an editorial error, the original image was not a photograph but a collage. It was a mistake to have used it. The image (link available at www.sciencemag.org/cgi/content/full/328/5979/689/DC2) has been replaced in the HTML version and in the online PDF by an unaltered photograph from National Geographic (CREDIT: Paul Nicklen/National Geographic/Getty Images) of two polar bears on an ice floe.

COMMENTARY

LETTERS

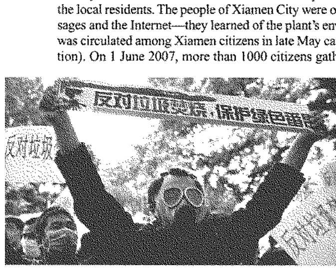
edited by Jennifer Sills

China's Environmental Civilian Activism

IN THE POLICY FORUM "CHINA'S ROAD TO SUSTAINABILITY" (2 APRIL, P. 50), J. LIU OVERLOOKS AN important cultural force. China's worsening environmental conditions have catalyzed a spirit of environmental civilian activism.

For example, in 2003, a consortium proposed erecting 13 dams on the Nujiang River. China's environmental nongovernmental organizations and scholars launched a protest campaign through the Internet and newspapers. The critics argued that as reservoirs behind the dams filled up, flooding and landslides would imperil habitats. In response, Premier Wen Jiabao suspended the dam project pending an environmental review in 2004 (*1*).

The landmark of environmental civilian activism occurred in Xiamen City in 2007. The local government supported construction of a $1.4-billion paraxylene plant near the center of the city. Information about the environmental impact of this project was not made available to the local residents. The people of Xiamen City were outraged when—through cell phone messages and the Internet—they learned of the plant's environmental risks. A phone text message was circulated among Xiamen citizens in late May calling for a "collective walk" (demonstration). On 1 June 2007, more than 1000 citizens gathered in front of the municipal building to protest. The demonstration forced the local government to cancel the largest industrial project in the history of Xiamen (*2*).



Protests. Chinese citizens protest against the planned Guangzhou trash incinerator in 2009. Their banners read, "Oppose the trash incinerator."

The burgeoning middle class has become the driver of environmental civilian activism. For example, operation of the Likeng trash incinerator in Guangzhou City started in 2005 without any protest, although local farmers worried about health risk (*3*). In contrast, the proposed Panyu trash incinerator in Guangzhou City in 2009 triggered protests that were led by the middle class (*4*), who used science-based evidence to openly challenge prevailing notions formulated by the authorities. (In earlier years, standard practice was to obey Beijing-based experts in environmental protection.) In addition, the self-organized middle class forced the local government to open discussion by Internet. By seizing the opportunity for an open discussion, the newly empowered locals took to the streets to protect their environmental rights (*4*).

Recent years have witnessed an impressive growth in environmental protests in China. The number of petitions and mass public protests related to environmental issues has increased by 30% per year in the past few years, although the number of petitions lodged with the Chinese government has dropped (*5*).

The current environmental civilian activism movements have several common characteristics: (i) They are confined to one specific geographical space. (ii) Their goal is protecting the environment, rather than political rights or commercial interests. (iii) They focus on a specific pollutant, rather than general environmental degradation. The local nature of the movement enables the organization of a large number of citizens with little effort in a very short time. Given more open social and political conditions and the increasing size of the middle class in China, environmental civilian activism will certainly be a key driver in China's transition to sustainability.

QIANG WANG

Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Science, Qingdao, 266101, China; Guangzhou Institute of Geochemistry, Chinese Academy of Science, Guangzhou, 510640, China. E-mail: tswangqiang@yahoo.com.cn

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6. The views expressed in this paper are the author's own and not necessarily those of QIBEBT-CAS, GIG-CAS.

I thank B. Jong for comments and linguistic support.

Effects of China's Economic Growth

IN A RECENT POLICY FORUM, J. LIU REVIEWED "China's road to sustainability" (2 April, p. 50). Liu focused on population growth and an increase in the number of households, but he failed to adequately address the most important socioeconomic driver behind environmental degradation in China: rapid economic growth that is not offset by efficiency improvements (*1*, *2*).

In China, exports and capital investments contribute significantly more to gross domestic product (GDP) than household and government consumption combined (*3*), and this also holds true for emissions (*1*, *2*). From 2002 to 2005, the production of exports was responsible for 50% of the growth in carbon dioxide emissions and capital formation was responsible for 35%;

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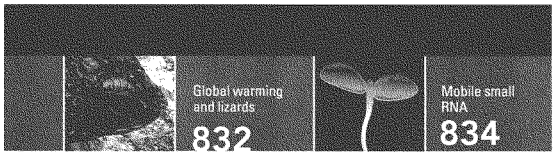

household and government consumption contributed 15% (*4*, *5*).

Liu discusses population control and household size, but a more dominant issue in terms of population dynamics is the migration from rural to urban areas (*6*). From 1990 to 2007, the urban population increased by 292 million, whereas the rural population decreased by 116 million (*3*). Urban dwellers, even if migrants from rural areas, have a higher income (*3*) and hence higher energy use and environmental impacts (*2*, *6*).

A key challenge for China is to continue strong economic growth while minimizing environmental impacts. Reductions in emissions per unit of GDP are unlikely to reduce total emissions if economic growth continues (*1*). China will need to combine aggressive domestic policies with international support to reverse the current growth in coal-dominated energy use and emissions.

GLEN P. PETERS,[1*] DABO GUAN,[2] KLAUS HUBACEK,[3,4] JAN C. MINX,[5,6] CHRISTOPHER L. WEBER[7]

[1]Center for International Climate and Environmental Research–Oslo (CICERO), Norway. [2]Cambridge Centre for Climate Change Mitigation Research, Department of Land Economy, University of Cambridge, UK. [3]Sustainability Research Institute, School of Earth and Environment, University of Leeds, UK. [4]Department of Geography, University of Maryland, College Park, MD 20742, USA. [5]Stockholm Environment Institute, University of York, York YO10 5DD, UK. [6]Department for the Economics of Climate Change, Technical University Berlin, 10623 Berlin, Germany. [7]Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA 15213, USA.

*To whom correspondence should be addressed. E-mail: glen.peters@cicero.uio.no

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TECHNICAL COMMENT ABSTRACTS

COMMENT ON "Detection of an Infectious Retrovirus, XMRV, in Blood Cells of Patients with Chronic Fatigue Syndrome"

Cathie Sudlow, Malcolm Macleod, Rustam Al-Shahi Salman, Jon Stone

Lombardi *et al.* (Reports, 23 October 2009, p. 585) reported an association between the human gammaretrovirus XMRV and chronic fatigue syndrome. However, their results may be misleading because of various potential sources of bias and confounding. If real, the association may lack generalizability because of the specific characteristics of the cases studied and could be due to reverse causality.

Full text at www.sciencemag.org/cgi/content/full/328/5980/825-a

COMMENT ON "Detection of an Infectious Retrovirus, XMRV, in Blood Cells of Patients with Chronic Fatigue Syndrome"

Andrew Lloyd, Peter White, Simon Wessely, Michael Sharpe, Dedra Buchwald

Lombardi *et al.* (Reports, 23 October 2009, p. 585) reported a significant association between the human retrovirus XMRV and chronic fatigue syndrome (CFS). However, the cases with CFS and the control subjects in their study are poorly described and unlikely to be representative. Independent replication is a critical first step before accepting the validity of this finding.

Full text at www.sciencemag.org/cgi/content/full/328/5980/825-b

COMMENT ON "Detection of an Infectious Retrovirus, XMRV, in Blood Cells of Patients with Chronic Fatigue Syndrome"

Jos W. M. van der Meer, Mihai G. Netea, Jochem M. D. Galama, Frank J. M. van Kuppeveld

Lombardi *et al.* (Reports, 23 October 2009, p. 585) reported detection of the human gammaretrovirus XMRV in the blood cells of patients with chronic fatigue syndrome (CFS). However, the patient description provided was incomplete. The inclusion of patients from a "CFS outbreak" previously linked with a viral infection, without confirmation in sporadic CFS cases, casts doubt on the role of XMRV in the pathogenesis of CFS.

Full text at www.sciencemag.org/cgi/content/full/328/5980/825-c

RESPONSE TO COMMENTS ON "Detection of an Infectious Retrovirus, XMRV, in Blood Cells of Patients with Chronic Fatigue Syndrome"

Judy A. Mikovits and Francis W. Ruscetti

We reported the detection of the human gammaretrovirus XMRV in 67% of 101 patients with chronic fatigue syndrome (CFS) and in 3.7% of 218 healthy controls, but we did not claim that XMRV causes CFS. Here, we explain why the criticisms of Sudlow *et al.*, Lloyd *et al.*, and van der Meer *et al.* regarding the selection of patients and controls in our study are unwarranted.

Full text at www.sciencemag.org/cgi/content/full/328/5980/825-d

Risks of Immune System Treatments

WE WISH TO ADD SEVERAL POINTS TO THE News Focus story "Replacing an immune system gone haywire" (J. Couzin-Frankel, 12 February, p. 772).

First, a great deal of research had already been done before the 1996 Basel meeting mentioned in the story. Stem cell transplants had been studied in animal models of autoimmune disease (*1*–*5*). Patient stem cell transplant protocols had been written, and a few human patients had already been treated specifically for autoimmune disease (*6*–*10*).

Second, we would like to stress the varying levels of risk in the treatment strategies described in the story. The immune system originates from hematopoietic stem cells (HSCs). Before receiving a transplant, patients with autoimmune diseases receive "conditioning" chemotherapy or radiation that destroys lymphocytes, inducing an immediate immune cease-fire. Subsequently, HSCs are infused to regenerate a new self-tolerant immune system. Sullivan and Nash advocate conditioning regimens with high doses of radiation. These extreme regimens cause irreversible bone marrow failure, thus requiring mandatory HSC reinfusion. The rationale for this high-dose strategy is that maximal ablation of the immune system will translate into longer and more durable disease remission. In contrast, we advocate less extreme regimens of chemotherapy, which can halt inflammation without altering the bone marrow's ability to recover. The News Focus article also comments on the risk of infertility when patients are pretreated with chemotherapy. We emphasize that the risk of infertility is higher for the more extreme regimens.

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Finally, although the News Focus story comments on problems obtaining insurance approval in the United States, medical funding is a worldwide issue, including in countries with government-funded health services. In addition to patient safety benefits, less toxic regimens also cost any health care system less money, because patients are less likely to suffer complications such as secondary cancers.

RICHARD K. BURT,[1*] MARIO ABINUN,[2] DOMINIQUE FARGE-BANCEL,[3] ATHANASIOS FASSAS,[4] FALK HIEPE,[5] EVA HAVRDOVÁ,[6] SUSUMU IKEHARA,[7] YVONNE LOH,[8] ALBERTO MARMONT DU HAUT CHAMP,[9] JÚLIO C. VOLTARELLI,[10] JOHN SNOWDEN,[11] SHIMON SLAVIN[12]

[1]Division of Immunotherapy, Department of Medicine, Northwestern University Feinberg School of Medicine, Chicago, IL 60611, USA. [2]Newcastle General Hospital, Newcastle Upon Tyne, UK. [3]Service de Médecine Interne et Pathologie Vasculaire, Inserm U976, Hôpital Saint-Louis, 75010 Paris, France. [4]Hematology Department, Bone Marrow Transplantation Unit, Cell and Gene Therapy Center, George Papanicolaou Hospital, 57010 Exokhi, Thessaloniki, Greece. [5]Charité University Medicine Berlin, Department of Rheumatology and Clinical Immunology and German Rheumatism Research Centre Berlin, A Leibniz Institute, Charitépaltz 1, D-10117 Berlin, Germany. [6]MS Center, Department of Neurology, First Medical Faculty, Charles University in Prague, Katerinská 30, 128 08, Prague, Czech Republic. [7]Department of Pathology, Regeneration Research Center for Intractable Diseases, Center for Cancer Therapy, Kansai Medical University, 10-15 Fumizono-cho, Moriguchi City, Osaka 570-8506, Japan. [8]Department of Haematology, HSCT Program, Singapore General Hospital, 169608 Singapore. [9]Division of Hematology and Stem Cell Transplantation, Azienda-Ospedaliera Universitaria San Martino, Genoa, Italy. [10]University of São Paulo (USP), Hemocentro Regional e Unidade de Transplante de Medula Óssea–HCF-MRP-USP, Rua Tenente Catão Roxo, 2501, CEP 14051-140, Ribierao, Preto, São Paulo, Brazil. [11]Sheffield Teaching Hospitals NHS Trust, University of Sheffield, UK. [12]The International Center for Cell Therapy and Cancer Immunotherapy (CTCI), Weizman Center, Tel Aviv, Israel.

*To whom correspondence should be addressed. E-mail: rburt@northwestern.edu

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News Focus: "Meeting briefs: The ins and outs of HIV" by J. Cohen (5 March, p. 1196). The earliest report of HIV predominantly entering cells through endocytosis appeared in C. D. Pauza, T. M. Price, *J. Cell Biol.* **107**, 959 (1988).

Letters to the Editor

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February 2011

Scientists' Statement on the Clean Air Act

Dear Congress,

We, the undersigned, urge you to support the Environmental Protection Agency's (EPA's) authority under the Clean Air Act to take action that will protect public health and address global warming.

On April 2, 2007, the Supreme Court ruled that global warming emissions are air pollutants covered by the Clean Air Act (CAA).[1] Subsequently, the EPA performed an exhaustive review of the relevant scientific research and determined that global warming emissions endanger public health and welfare and therefore must be regulated under the CAA. Because the EPA's finding is based on solid science, any effort to prevent or delay the agency from taking action to reduce global warming emissions is a rejection of that science.

The scientific evidence overwhelmingly suggests that climate change poses a clear threat to public health. Numerous scientific studies, including the U.S. Global Change Research Program's 2009 report *Global Climate Change Impacts in the United States* and the National Academy of Sciences' report *America's Climate Choices*, show that if heat-trapping emissions continue unabated, global warming is likely to cause more extreme heat in our cities, severe water shortages, loss of species, hazards to coasts from sea level rise, and extreme weather.[2,3,4] The economic and social costs of such impacts are potentially calamitous.

The EPA must be allowed to fulfill its responsibilities and take action to regulate global warming emissions under the Clean Air Act. This science-based law has prevented 400,000 premature deaths and hundreds of millions of cases of respiratory and cardiovascular disease during the 40 years since it was first passed[5]—all without diminishing economic growth.

As the EPA ruling now states, global warming regulation will apply only to the biggest sources of these emissions[6] (such as large coal-fired power plants, oil refineries, and cement plants[7]) while exempting small businesses and homeowners. This is a practical, fair, and effective way to target the biggest sources of pollution, which together account for 70 percent of the nation's global warming emissions from stationary sources. By targeting the oldest, dirtiest, and most inefficient power plants, these regulations can help transition our energy system to a cleaner, healthier, and more efficient one without sacrificing reliability or affordability.

Congress should work to pass a comprehensive climate and energy policy based on robust science and economics that will curb global warming, save consumers money, and create jobs. In the meantime, we urge you to oppose attacks on the Clean Air Act by respecting the scientific integrity of the EPA's endangerment finding, and the agency's authority to act based on this finding.

Sincerely,

---

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[6] EPA Final Rule: Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule. Online at *http://www.epa.gov/nsr/documents/20100413final.pdf.*

[7] The regulations will cover new facilities that emit more than 100,000 tons per year on a CO_2e basis and existing facilities that undertake modifications resulting in emissions of more than 75,000 tons per year on a CO_2e basis.

February 2011

Scientists' Statement on the Clean Air Act

ALABAMA

Richard H. Comfort, Ph.D.
Professor Emeritus
Department of Physics
University of Alabama, Huntsville
Huntsville, AL

Kyle G. Crider, M.A.
Helena, AL

Lawrence R. Holland, Ph.D.
Professor Emeritus
Huntsville, AL

Steve Perrett, Ph.D.
Birmingham, AL

David Lynn Smith, M.D.
Spanish Fort, AL

Charlotte R. Ward, Ph.D.
Associate Professor
Auburn, AL

ALASKA

W. Scott Armbruster, Ph.D.
Senior Research Scientist
Institute of Arctic Biology
University of Alaska, Fairbanks
Fairbanks, AK

Ed Feraco, Ph.D.
Dutch Harbor, AK

Derek R. Hildreth, M.A.
Fishery Biologist
Anchorage, AK

Roman J. Motyka, Ph.D.
Research Professor
Geophysical Institute
University of Alaska
Juneau, AK

Martha K. Raynolds, Ph.D.
Fairbanks, AK

John P. Skinner, M.A.
Seward, AK

Lynn Wilbur
Master's Candidate
Sitka, AK

Bruce Wright, Ph.D.
Executive Director
Conservation Science Institute
Anchorage, AK

ARIZONA

Andrea Alagammai, M.A.
Tucson, AZ

Michel Baranger, Ph.D.
Professor Emeritus
Department of Physics
Massachusetts Institute of Technology
Tucson, AZ

Jennifer L. Becker, M.A.
Tucson, AZ

Deborah Bird, M.P.H.
Professor
Tucson, AZ

Clait E. Braun, Ph.D.
Tucson, AZ

Susan L. Dalby, M.D.
Portal, AZ

Carolyn Enquist, Ph.D.
Adjunct Assistant Professor
University of Arizona
Tucson, AZ

Kathleen K. Flaccus, M.A.
Retired Science Teacher
Flagstaff, AZ

Maxwell Fogleman, Ph.D.
Associate Professor
Chino Valley, AZ

Harold C. Fritts, Ph.D.
Professor Emeritus
Laboratory of Tree-Ring Research
University of Arizona
Tucson, AZ

February 2011

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Lee Fullerton, Ph.D.
Visiting Scholar
Department of Linguistics
University of Arizona
Tucson, AZ

James A. Gessaman, Ph.D.
Professor Emeritus
Department of Biology
Utah State University
Tucson, AZ

Hoshin V. Gupta, Ph.D.
Professor
Hydrology and Water Resources
University of Arizona
Tucson, AZ

Christine C. Hass, Ph.D.
Elgin, AZ

Gary L. Herstein, Ph.D.
Professor
Department of Philosophy
Ellis University
Prescott, AZ

Fred Highton, M.A.
Computer Engineering
MIET
Tucson, AZ

Jeremy Horne, Ph.D.
Gold Canyon, AZ

Elizabeth Hunter, M.P.H.
Phoenix, AZ

Martha S. Hunter, Ph.D.
Professor
Tucson, AZ

Paul Kandell
Sun City West, AZ

Gerald J. Karches, M.A.
Tucson, AZ

Chetan M. Kumar, M.A.
Principal Product Assurance Engineer
Medtronics, Inc.
Chandler, AZ

David M. Labiner, M.D.
Professor
Tucson, AZ

Robert J. Luce
Wildlife Biologist (Retired)
Sierra Vista, AZ

Robert McDonald
Flagstaff, AZ

Brian Ross McKee, Ph.D.
Tucson, AZ

Gary E. Mechler, Ph.D.
Lead Faculty in Astronomy West Campus
Department of Physical and Earth Sciences
Pima Community College
Tucson, AZ

Pascal Mickelson, Ph.D.
Postdoctoral Research Associate
Tucson, AZ

Mark S. Ogonowski, M.A.
Flagstaff, AZ

Richard Michael Pasichnyk, Ph.D.
Mesa, AZ

Hansi R. Patience, M.D.
Green Valley, AZ

Vincent Pawlowski
Master's Candidate
Staff Engineer
University of Arizona
Prescott College
Tucson, AZ

Patricia E. Penn, Ph.D.
Tucson, AZ

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2,505 Endorsers

Gregory K. Penniston, M.D.
Clinic Director
Lifeline Chiropractic
Tucson, AZ

Wayne Perg, Ph.D.
Sierra Vista, AZ

Linda Smith Schermer, M.P.H.
Sedona, AZ

Francis Xavier Schilling
Vail, AZ

Justin O. Schmidt, Ph.D.
Tucson, AZ

Catherine Schmit
Principal Scientist
Glendale, AZ

Margaret A. Shamonsky, M.D.
Prescott, AZ

Eve R. Shapiro, M.D.
Tucson, AZ

William H. Sievers, M.A.
Engineering Manager
Tempe, AZ

Myrolee R. Stanfield
Master's Candidate
Tucson, AZ

Robert G. Strom, M.P.H.
Professor Emeritus
Department of Planetary Sciences
University of Arizona
Tucson, AZ

Glenn S. L. Stuart, Ph.D.
Tempe, AZ

Jack Steven Tuber, M.D.
Research
Sun Valley Arthritis Center, Ltd.
Paradise Valley, AZ

Frank Turkot, Ph.D.
Guest Scientist
Department of Physics
Fermilab
Tucson, AZ

Helene Unland
Doctoral Candidate
Hydrologist
Gilbert, AZ

Kenneth L. Watters, Ph.D.
Tucson, AZ

David Wright, Ph.D.
Assistant Professor
Department of Archaeology
Seoul National University
Tempe, AZ

ARKANSAS

Clark Fincher, M.D.
Fellow in the American College of Physicians
Chairman
Searcy Medical Center
Searcy, AR

J. David Gillanders, Ph.D.
State University, AR

Michael Dyan Hatch, Ph.D.
Assistant Professor
Conway, AR

Art S. Hobson, Ph.D.
Professor Emeritus
Department of Physics
University of Arkansas
Fayetteville, AR

Thomas M. Keel, M.A.
Rogers, AR

Stephen D. Manning, Ph.D.
Beebe, AR

Hosea W. McAdoo, M.D.
Sherwood, AR

February 2011

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2,505 Endorsers

Janine Perlman, Ph.D.
Alexander, AR

Chester Arthur Sautter, Ph.D.
Professor Emeritus
Bella Vista, AR

Meredith Schafer
Master's Candidate
Department of Biological Sciences
University of Arkansas
Fayetteville, AR

CALIFORNIA

Matthew Aarsvold, M.A.
CEO
Laguna Beach, CA

Jerald Abajian, M.D.
Napa, CA

Luna Abdallah, Ph.D.
University of California, San Francisco
San Francisco, CA

David Abramis, Ph.D.
Professor
Management
California State University, Long Beach
Santa Monica, CA

Frank Jay Ackerman, M.A.
Deputy Associate Division Head (Retired)
Department of Chemistry
University of California
Lawrence Livermore National Laboratory
Berkeley, CA

Renatte Adler, Ph.D.
Professor of Economics
International Business Program
San Diego State University
San Diego, CA

Steven C. Anderson, Ph.D.
Professor Emeritus
Department of Biological Sciences
University of the Pacific
Stockton, CA

Linda D. Anderson, Ph.D.
Felton, CA

Leonard M. Anderson, Ph.D.
Santa Cruz, CA

Michael Antos, M.A.
Geographer
Pasadena, CA

Kenneth J. Arrow, Ph.D.
Professor Emeritus
Stanford, CA

Vinu Arumugham
San Jose, CA

Stephen J. Asztalos, Ph.D.
Senior Research Scientist
Oakland, CA

Roger Atkinson, Ph.D.
Professor
University of California, Riverside
Riverside, CA

Lisa Atwell, M.A.
Research Assistant
Department of Natural Resources and Environmental Science
University of Nevada, Reno
Truckee, CA

Roger Michael Avery
Owner
Department of Engineering
Roger M Avery PE
San Ramon, CA

William F. Avrin, Ph.D.
Research Physicist
Insight Magnetics
San Diego, CA

Terry Lee Badger, M.A.
Paso Robles, CA

February 2011

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Cedric Bainton, M.D.
Professor Emeritus
Anesthesia
Department of Physiology
University of California San Francisco Medical Center
San Francisco, CA

Clayton C. Barbeau, M.A.
Psychotherapist
Author
Lecturer
San Jose, CA

R. Keith Bardin, Ph.D.
Retired
Saratoga, CA

James Barsimantov, Ph.D.
Santa Cruz, CA

Gary R. Bea, M.A.
Sunnyvale, CA

Charles Bellamy, Ph.D.
Senior Insect Biosystematist
Plant Pest Diagnostics Center
California Department of Food and Agriculture
Sacramento, CA

Peter Bellin, Ph.D.
Professor
Department of Environmental and Occupational Health
California State University, Northridge
Oxnard, CA

Jerry Berkman, M.A.
Berkeley, CA

Betty Bernard, M.D.
Associate Professor
Pediatrics/Neonatology
Keck School of Medicine
University of Southern California
Pasadena, CA

Anthony Bernhardt, Ph.D.
Retired
Lawrence Livermore National Laboratory
Berkeley, CA

Jill L. Bertrand, D.V.M.
Mountain View, CA

Virginia J. Bigler Engler, M.A.
Owner
Principal Scientist
San Diego, CA

Ann Blake, Ph.D.
Founder and Principal
Environmental and Public Health Consulting
Alameda, CA

Shelley B. Blam, Ph.D.
Medical Science Liaison
Medical Affairs, Oncology
Eisai Pharmaceuticals
Berkeley, CA

Ronald Blond, M.D.
Rancho Palos Verdes, CA

Catherine E. Bolten, Ph.D.
Assistant Professor
Department of Anthropology
Kroc Institute for International Peace Studies
University of Notre Dame
Pacific Palisades, CA

Martha L. Booz, Ph.D.
El Sobrante, CA

Stephen E. Branz, Ph.D.
Associate Dean
Undergraduate Studies
San Jose State University
Palo Alto, CA

John Brennan
Doctoral Candidate
Director
Conservation/Executive
Fontana Institute
Hammond Ranch, CA

February 2011

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William L. Bretz, Ph.D.
Manager of Natural Reserves
Office of Research Administration
University of California, Irvine
El Cajon, CA

William B. Bridges, Ph.D.
Professor Emeritus
Department of Electrical Engineering and Applied Physics
California Institute of Technology
Sierra Madre, CA

Holger Brix, Ph.D.
Altadena, CA

Roger Burton, Ph.D.
Venice, CA

William L. Byerly, Ph.D.
Retired
Altadena, CA

Heather Campbell
Master's Candidate
Davis, CA

June C. Cancell, Ph.D.
Counselor
Educator
Palo Alto, CA

John A. Cape, Ph.D.
San Rafael, CA

Andy Carman, Ph.D.
Santa Cruz, CA

Donna Carr, M.D.
Encinitas, CA

Scott P. Carroll, Ph.D.
Davis, CA

Alicia Cawlfield, D.V.M.
Yuba City, CA

Dan Cayan, Ph.D.
Researcher
Scripps Institution of Oceanography
La Jolla, CA

Joseph B. Chaiklin, Ph.D.
Concord, CA

Brian Charn, D.V.M.
Davis, CA

Ted Cheeseman, M.A.
CEO
Cheesemans' Ecology Safaris
Saratoga, CA

Jennifer Antoinette Chranowski, M.A.
Science Teacher
Department of Science
O'Farrell Community School
La Mesa, CA

Iris Chynoweth, M.A.
Midpines, CA

George Chynoweth, Ph.D.
dxResearch
Midpines, CA

W. Gilbert Clark, Ph.D.
Professor Emeritus
Department of Physics and Astronomy
University of California, Los Angeles
Los Angeles, CA

Howard O. Clark, M.A.
Clovis, CA

David A. Cleveland, Ph.D.
Professor
Department of Environmental Studies
University of California
Santa Barbara, CA

Melissa S. Cline, Ph.D.
Project Scientist
Department of Molecular Cell and Developmental Biology
University of California
Santa Cruz, CA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Robert N. Coats, Ph.D.
Visiting Scholar
Environmental Science and Policy
University California, Davis
Berkeley, CA

Anne C. Cohen, Ph.D.
San Rafael, CA

Howard J. Cohen, Ph.D.
Palo Alto, CA

Natalie S. Cohen, Ph.D.
Pasadena, CA

Erin E. Conlisk, Ph.D.
San Diego, CA

Scott W. Cookson, Ph.D.
Encinitas, CA

Eugene Cordero, Ph.D.
Associate Professor
Department of Meteorology and Climate Science
San Jose State University
San Jose, CA

Tara Cornelisse
Doctoral Candidate
Felton, CA

Quentin Correll, M.A.
Sunnyvale, CA

Francisco Jose Costa, Ph.D.
Environmental Scientist
Cathedral City, CA

Charles J. Coston, Ph.D.
Sunnyvale, CA

Jessica A. Couch, Ph.D.
San Francisco, CA

Michael G. Cox
Eureka, CA

Tony P. Crabb
Chartered Engineer
Puma Springs Vineyards
Healdsburg, CA

Scott Crass, Ph.D.
Professor
Department of Mathematics and Statistics
California State University, Long Beach
Long Beach, CA

Peter S. Cross, Ph.D.
Palo Alto, CA

Frederick W. Cummings, Ph.D.
Professor Emeritus
San Anselmo, CA

Steve M. Cummins, M.A.
Test Engineer
Cypress Semiconductor
Santa Cruz, CA

Alan Cunningham, Ph.D.
Professor Emeritus
Carmel Valley, CA

Jennifer Cushnie, M.A.
President of the Board
Community Environmental Council
Santa Barbara, CA

Douglas Daetz, Ph.D.
Sunnyvale, CA

Eric Danner, Ph.D.
Santa Cruz, CA

Carla D'Antonio, Ph.D.
Santa Barbara, CA

Stanley V. Dawson, Ph.D.
Davis, CA

John Jay Dayton
Doctoral Candidate
Lecturer
Department of Biology
San Jose State University
Santa Cruz, CA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Paul K. Dayton, Ph.D.
Professor
Scripps Institution of Oceanography
University California, San Diego
La Jolla, CA

William L. Denneen, M.A.
Professor Emeritus
Nipomo, CA

Danielle DeRome, M.A.
Morgan Hill, CA

David Desante, Ph.D.
Point Reyes Station, CA

Kendall Dinwiddie, M.A.
Palo Alto, CA

Anita Disney, Ph.D.
Salk Institute for Biological Studies
San Diego, CA

Timothy Quinn Donaghy, Ph.D.
Fresno, CA

John R. Donaldson, Ph.D.
Fresno, CA

John T. Donlin, M.A.
La Canada Flintridge, CA

David W. Dorn, Ph.D.
Livermore, CA

Andrew Oakley DuBois, M.A.
Alameda, CA

Leigh Wood Dudash, M.A.
Redlands, CA

Annette Ehrlich, Ph.D.
Professor Emeritus
Department of Psychology
California State University, Los Angeles
Los Angeles, CA

S. W. Ela, Ph.D.
Paso Robles, CA

Lowell J. Eliason, Ph.D.
Professor Emeritus
Department of Physics and Astronomy
California State University, Long Beach
Cypress, CA

Taffeta M. Elliott, Ph.D.
Berkeley, CA

George Wilbur Ellison, M.D.
Voluntary Clinical Professor
Department of Neuroscience
University of California, San Diego
San Diego, CA

Thomas D. English, Ph.D.
Creation Care Educator
Synod of Southern California and Hawaii
Presbyterian Church (USA)
Carlsbad, CA

Russell J. Erickson, M.D.
Physician
Pleasant Hill, CA

Lee D. Erman, Ph.D.
Mountain View, CA

Donald Mark Erway
Master's Candidate
South Pasadena, CA

Martin E. Evans, M.A.
Hercules, CA

Eirik Evenhouse, Ph.D.
Assistant Professor
Department of Economics
Mills College
Piedmont, CA

Kai K. Ewert, Ph.D.
Oak View, CA

Stephen Falgout, Ph.D.
Lake Elsinore, CA

February 2011

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2,505 Endorsers

Edmund Fantino, Ph.D.
Distinguished Professor
Department of Psychology
University of California, San Diego
Del Mar, CA

Kelleen E. Farrell, M.A.
Placerville, CA

John A. Ferguson, Ph.D.
Berkeley, CA

Stephen J. Ferry, M.A.
Systems Engineer (Retired)
Santa Barbara, CA

Sydney M. Finegold, M.D.
Attending Physician
Professor
School of Medicine
University of California, Los Angeles
Marina Del Rey, CA

Charles T. Fischer, M.D.
San Rafael, CA

Anthony C. Fisher, Ph.D.
Professor
Department of Agricultural and Resource Economics
University of California, Berkeley
Orinda, CA

Marc Fontana
Energy Efficiency Consultant
Santa Clara, CA

Scott Forrest, M.A.
Half Moon Bay, CA

Peggy S. Forster, M.A.
Studio City, CA

Dorian Fougeres, Ph.D.
San Francisco, CA

Mary Claire Frantz, Ph.D.
Burbank, CA

William E. Fraser, Ph.D.
Santa Cruz, CA

Donald R. Fredkin, Ph.D.
Professor
Department of Physics
University of California
La Jolla, CA

Jan Z. Freed, M.A.
Los Angeles, CA

Lawrence Raphael Freedman, M.D.
Los Angeles, CA

Dianne K. Fristrom, Ph.D.
Research Geneticist (Retired)
Department of Molecular and Cell Biology
University of California, Berkeley
Oakland, CA

A. Eugene Fritsche, Ph.D.
Winnetka, CA

Martin E. Frost, M.A.
Half Moon Bay, CA

Jed Fuhrman, Ph.D.
McMulloch-Crosby Chair
Department of Biological Sciences
University of Southern California
Topanga, CA

Marc Futernick, M.D.
Sherman Oaks, CA

Mary K. Gaillard, Ph.D.
Professor
Department of Physics
University of California
Berkeley, CA

Brandi Gartland
Master's Candidate
El Cerrito, CA

John O. Garvey, M.A.
Senior Systems Engineer
Redondo Beach, CA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

John Lino Gasperoni, Ph.D.
Berkeley, CA

David F. Gassman, M.A.
Oakland, CA

Lorraine Gemmell, M.A.
Mountain View, CA

Ayesha E. Gill, Ph.D.
Oakland, CA

Sarah Gilman, Ph.D.
Assistant Professor
Joint Science
The Claremont Colleges
Claremont, CA

Tullio A. Giudici, Ph.D.
Glendale, CA

Daniel Gluesenkamp, Ph.D.
Director
Habitat Protection and Restoration
Audubon Canyon Ranch
Glen Ellen, CA

David Golden, Ph.D.
Consulting Professor
Mechanical Engineering
Stanford University
Stanford, CA

Laura Gonzalez, M.A.
Associate Professor
Department of Anthropology
San Diego Miramar College
Chula Vista, CA

Nayvin Gordon, M.D.
Oakland, CA

Robert Gould, M.D.
Associate Pathologist
Physicians for Social Responsibility
San Francisco, CA

Terry Grant
Cupertino, CA

Paul Graven
CEO
Redondo Beach, CA

Stephen M. Greenberg, M.D.
Interventional Radiologist
Santa Monica, CA

John D. Greene, M.A.
Senior Advisor
Santa Cruz, CA

John W. Grula, Ph.D.
Pasadena, CA

Vonnie A. Gurgin, Ph.D.
Berkeley, CA

Judy Ann Haggard, M.A.
Wildlife Biologist
McKinleyville, CA

Harold Haight, M.A.
San Juan Capistrano, CA

Sarajane Jane Hall
Doctoral Candidate
Burbank, CA

Pamela G. Hammond, M.A.
Santa Monica, CA

Timothy Handley, M.A.
Plant Ecologist
Thousand Oaks, CA

Karen Hansen, M.A.
Sacramento, CAS

Kevin R. Hansen, M.A.
Principal
KRH Engineering
Mountain Ranch, CA

James H. Hanson, M.D.
Oakland, CA

Mary Harte, Ph.D.
Berkeley, CA

February 2011

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2,505 Endorsers

Richard C. Haskell, Ph.D.
Claremont, CA

Simon Haxton, M.A.
Long Beach, CA

Rod Hay, Ph.D.
Carson, CA

Lesle Helgason
Registered Nurse
Pacific Grove, CA

K. Kelly Hildner, Ph.D.
Goleta, CA

Rodney Hill
Auburn, CA

James W. Hilsinger
Electronic Tech III
San Luis Obispo, CA

Karen D. Holl, Ph.D.
Professor
Department of Environmental Studies
University of California, Santa Cruz
Felton, CA

Jeff G. Holmquist, Ph.D.
Bishop, CA

John W. Holtzclaw, Ph.D.
San Francisco, CA

Marcel Holyoak, Ph.D.
Professor
Department of Environmental Science and Policy
University of California, Davis
San Jose, CA

Gregg Holzer
Sonoma, CA

Fred Hrusa, Ph.D.
Senior Plant Taxonomist
Sacramento, CA

Edward Huang, Ph.D.
Principal
California Institute of Environmental Design and Management
Arcadia, CA

Robert T. Huang, M.A.
Irvine, CA

Ivan Huber, Ph.D.
Los Angeles, CA

Lynn Hudak, M.D.
El Cajon, CA

Robin D. Ikeda, M.A.
Ontario, CA

Michael D. Intriligator, Ph.D.
Professor Emeritus
Santa Monica, CA

Weldon H. Jackson
Santa Rosa, CA

Ray Jaffe, M.A.
Rosamond, CA

Leonard Bradley Job
Master's Candidate
Civil Engineer
Arcata, CA

John S. Johantgen
Bishop, CA

Benjamin Jones
Berkeley, CA

Jay H. Jones, Ph.D.
La Verne, CA

William Josephs, Ph.D.
Health Psychologist
Sherman Oaks, CA

Martin J. Joye, M.D.
Retired
American Academy of Pediatrics
Vacaville, CA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

John A. Kadyk, Ph.D.
Senior Staff Scientist (Retired)
Department of Physics
Lawrence Berkeley National Laboratory
Berkeley, CA

Brian H. Kahn, Ph.D.
Atmospheric Scientist
Altadena, CA

Peter D. Karp, Ph.D.
San Mateo, CA

George B. Kauffman, Ph.D.
Fresno, CA

Micheal G. Kelcher, M.A.
Associate Professor
San Dimas, CA

Arthur Keller, Ph.D.
Palo Alto, CA

Bruce Kendall, Ph.D.
Associate Professor
Bren School of Environmental Science and Management
University of California, Santa Barbara
Santa Barbara, CA

Allen Klinger, Ph.D.
Professor
Department of Computer Science
University of California, Los Angeles
Los Angeles, CA

David Hampton Klipstein, Ph.D.
Volunteer
Scripps Oceanographic Institute
San Diego, CA

Ron Kloberdanz
South San Francisco, CA

Peter Klosterman, Ph.D.
Piedmont, CA

Jamie Kneitel, Ph.D.
Associate Professor
Department of Biological Sciences
California State University, Sacramento
Sacramento, CA

Patricia Knobloch, Ph.D.
Research Associate
Institute of Andean Studies
La Mesa, CA

Jeannine Koshear, Ph.D.
Coarsegold, CA

Art M. Krakowsky, M.A.
Engineering Manager
Livermore, CA

Celia M. Kutcher, M.A.
Capistrano Beach, CA

Keith Laderoute, Ph.D.
Palo Alto, CA

Steve LaDochy, Ph.D.
Professor
Department of Geography
California State University, Los Angeles
Temple City, CA

Ted LaFleur
Banning, CA

Donald Lahti, M.D.
Beaumont, CA

Philip Marshall Lally, M.A.
Palo Alto, CA

Kenton Lane, M.A.
Psychotherapist
Kenton Lane Psychotherapy
Alhambra, CA

Todd W. Lane, Ph.D.
Livermore, CA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Ronald M. Lanner, Ph.D.
Visiting Emeritus Scientist
Institute of Forest Genetics
Placerville, CA

Allen E. Lavee, M.D.
Physician
San Rafael, CA

Emil A. Lawton, Ph.D.
Sherman Oaks, CA

Harold Lecar, Ph.D.
Professor Emeritus
Department of Molecular and Cell Biology
University of California, Berkeley
Berkeley, CA

Waidy Lee
Los Altos Hills, CA

Michael H. Lee, Ph.D.
Principal Scientist
San Jose, CA

Alberta M. Lesko, M.A.
Greenbrae, CA

Paula LeVeck, Ph.D.
Professor Emeritus
Stockton, CA

Sherman Lewis, Ph.D.
Professor Emeritus
Department of Political Science
California State University, East Bay Hayward
Hayward, CA

George M. Lewis, Ph.D.
Professor Emeritus
Department of Mathematics
California Polytechnic State University
Los Osos, CA

Carolyn C. Liesy, M.A.
Palos Verdes Estates, CA

Bruce Lilley, M.A.
San Leandro, CA

Irvin Lindsey, M.A.
Santa Cruz, CA

John G. Little, M.A.
Adjunct Professor
Department of Chemistry
San Joaquin Delta College
Stockton, CA

James G. Little, Ph.D.
Senior Mathematician
Palo Alto, CA

Janet Maker, Ph.D.
Los Angeles, CA

Steven L. Mandel, M.D.
Attending Physician
Marina Del Rey, CA

John R. Manning, Ph.D.
Principal Engineer
San Francisco, CA

Belinda Martineau, Ph.D.
Davis, CA

Dave L. Massen, M.A.
San Francisco, CA

Michael Matiasek
Doctoral Candidate
Davis, CA

Francis J. Matyskiela, M.A.
Systems Engineer
Palo Alto, CA

Michael D. Mauer, M.A.
Adjunct Professor
Department of Anthropology
College of the Canyons
Los Angeles, CA

Dan Mayclin, Ph.D.
Santa Cruz, CA

Sonia Mayoral
Doctoral Candidate
San Jose, CA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Mary Anne McCarthy, Ph.D.
Manhattan Beach, CA

William J. McCarthy, Ph.D.
Professor
Department of Health Services
School of Public Health
University of California, Los Angeles
Malibu, CA

Erin McCreless
Doctoral Candidate
Santa Cruz, CA

Martin R. McGartland, M.A.
Folsom, CA

Michael R. Mchenry, Ph.D.
Senior Staff Engineer
Sunnyvale, CA

James A. McRoberts, Ph.D.
Professor
University of California, Los Angeles
Newport Beach, CA

John M. Mead, M.D.
Santa Cruz, CA

Charity Meakes, M.A.
Sacramento, CA

Keith Harvey Mehl, M.A.
Professor
Department of Mathematics and Sciences
Chabot College
Livermore, CA

Marc Meyer, Ph.D.
Wawona, CA

Stephen Meyers, M.A.
Berkeley, CA

Carolyn Ruth Michaels, Ph.D.
Oakla, CA

Jean B. Millay, Ph.D.
Millay Publisher
Doyle, CA

Don Miller, Ph.D.
Associate Professor
Department of Biological Science
California State University, Chico
Chico, CA

Jason Miller, Ph.D.
San Francisco, CA

Donald C. Miller, M.A.
Professional Engineer
Newbury Park, CA

Louallen F. Miller, Ph.D.
Petaluma, CA

Wayne Warren Miller, M.A.
Newark, CA

Payam Minoofar, Ph.D.
Ventura, CA

Daniel L. Minor, Ph.D.
Associate Professor
Cardiovascular Research Institute
University of California, San Francisco
San Francisco, CA

Joseph Mitchell, Ph.D.
Owner
Ramona, CA

Jeffrey C. Mogul, Ph.D.
Menlo Park, CA

Mark B. Moldwin, Ph.D.
Professor
Department of Atmospheric Oceanic and Space Sciences
University of Michigan
Los Angeles, CA

Nick Moll, Ph.D.
Consultant
La Honda, CA

Bruce Morgan, M.A.
Riverside, CA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Steven G. Morgan, Ph.D.
Bodega Bay, CA

Ed P. Morin
Santa Barbara, CA

Ellen M. Morrison, Ph.D.
Assistant Director
California Early Childhood Mentor Program
San Carlos, CA

Susanne C. Moser, Ph.D.
Director
Principal Researcher
Susanne Moser Research and Consulting
Santa Cruz, CA

Yuko Nakajima, Ph.D.
Berkeley, CA

Virginia L. Natwick
Retired Engineer
San Diego, CA

Nermin Nergis, Ph.D.
Owner
Green Pole Research
San Diego, CA

Dale D. Nesbitt, M.A.
Berkeley, CA

Alan Nestlinger, M.A.
Lecturer
Department of Mathematics
California State University, Fullerton
Santa Ana, CA

Peter Newman, Ph.D.
Fremont, CA

Thomas Niesen, Ph.D.
Professor Emeritus
Department of Biology
San Francisco State University
San Francisco, CA

Gretchen Barrow North, Ph.D.
Professor
Department of Biology
Occidental College
Los Angeles, CA

Kevin N. O'Connor, Ph.D.
Research Specialist
Center for Neuroscience
University of California, Davis
Davis, CA

Kimberly Oldehoeft
Master's Candidate
Wildlife Biologist
Glendale, CA

Daniel C. Orey, Ph.D.
Sacramento, CA

James M. Orr, Ph.D.
Fresno, CA

Lance D. Parker, M.A.
San Diego, CA

Jerome Stanley Parsons, Ph.D.
Los Gatos, CA

Eli Patten
Doctoral Candidate
Department of Mechanical Engineering
University of California, Berkeley
Berkeley, CA

Elizabeth Patterson, M.D.
Ojai, CA

Linda E. Paul, Ph.D.
Dillon Beach, CA

Suzanne E. Paulson, Ph.D.
Professor
Department of Atmospheric and Oceanic Sciences
University of California, Los Angeles
Santa Monica, CA

David A. Pearson, Ph.D.
San Diego, CA

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Lloyd M. Peckner, M.D.
Santa Monica, CA

Claudio Pellegrini, Ph.D.
Professor
Department of Physics
University of California, Los Angeles
Los Angeles, CA

William E. Perkins, M.D.
Pacific Palisades, CA

David Perlman, M.A.
Laguna Beach, CA

Terry M. Peterson, Ph.D.
San Carlos, CA

Thomas J. Phillips, Ph.D.
Dublin, CA

Nan Phinney, Ph.D.
Los Altos Hills, CA

Marc Pilisuk, Ph.D.
Professor
Saybrook University
Berkeley, CA

Mary Francis Platter-Rieger, M.A.
Biologist (Retired)
San Diego, CA

Richard Plevin, Ph.D.
Research Engineer
Transportation Sustainability Research Center
University of California, Berkeley
Oakland, CA

Katherine S. Pollard, Ph.D.
San Francisco, CA

Theodore M. Polychronis
Glendale, CA

John Edward Popp, M.A.
Alpine, CA

Kenneth S. Post, M.A.
Newport Coast, CA

Roger Potash, Ph.D.
Menlo Park, CA

Thomas M. (Zack) Powell, Ph.D.
Professor
Department of Integrative Biology
University of California, Berkeley
Berkeley, CA

Joel R. Primack, Ph.D.
Distinguished Professor of Physics
Department of Physics
University of California, Santa Cruz
Santa Cruz, CA

William A. Prothero, Ph.D.
Professor Emeritus
Department of Earth Sciences
American Geophysical Union
Santa Barbara, CA

James Provenzano
Doctoral Candidate
President
Clean Air Now
Los Angeles, CA

Michael Puckett, M.D.
Poway, CA

Raymond S. Pugliesi, M.A.
Principal
El Cerrito, CA

Michael D. Rabbino, M.D.
San Mateo, CA

Jean Rabovsky, Ph.D.
El Cerrito, CA

Cristobal Edgardo Ramon
Pasadena, CA

Dee B. Randolph, M.A.
Yankee Hill, CA

Jon Rask, M.A.
Moffett Field, CA

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Robert R. Rector
Doctoral Candidate
Encinitas, CA

Gregory Allen Reichert, M.A.
Senior Project Manager
Alameda, CA

Sidney Reiff, M.D.
Internist (Retired)
Department of Internal Medicine
Kaiser-Permanente
Beverly Hills, CA

Sally E. Richards, Ph.D.
Ridgecrest, CA

Bruce A. Richman, Ph.D.
Senior Scientist
Sunnyvale, CA

Daniel Richter
Doctoral Candidate
Department of Oceanography
Scripps Institution of Oceanography
La Jolla, CA

Fredric J. Ridel, M.A.
San Francisco, CA

Toni Rizzo, M.A.
Fort Bragg, CA

Eleanora I. Robbins, Ph.D.
Adjunct Faculty
Department of Geological Sciences
San Diego State University
La Mesa, CA

James Rowland Roberts, M.A.
Sugarloaf, CA

Kristofer Robison
Master's Candidate
Davis, CA

Stephen E. Rock, Ph.D.
Palo Alto, CA

Nuria Rodriguez, M.A.
Teacher
Department of Physical Science
Santa Monica College
Malibu, CA

Marion J. Rojas, Ph.D.
Oakland, CA

Robert J. Rosenberg, Ph.D.
Kentfield, CA

Stephen S. Rosenblum, Ph.D.
Palo Alto, CA

Ann N. Rosenthal, M.A.
Davis, CA

Peter Rovegno
Doctoral Candidate
Santa Cruz, CA

Ana Rudolph, M.A.
Burlingame, CA

Jon Ruel, M.A.
Director of Viticulture and Winemaking
Trefethen Family Vineyards
Napa, CA

Kathy Ruppel, Ph.D.
Assistant Professor
Stanford, CA

Sean Fleming Ryan, M.A.
Sunnyvale, CA

David J. Saperia, M.D.
Santa Monica, CA

Joy Schary, Ph.D.
Sherman Oaks, CA

Stanley Scher, Ph.D.
President
Berkeley, CA

Christopher R. Schroeder, Ph.D.
San Diego, CA

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Lindon Sterling Schultz, M.A.
Professional Engineer
Los Angeles, CA

Seymour I. Schwartz, Ph.D.
Professor Emeritus
Davis, CA

Harold L. Schwartz, Ph.D.
Professor
School of Medicine
University of California, Irvine
Las Flores, CA

Martin Scolnick, M.A.
Oakland, CA

Jason Scorse, Ph.D.
Capitola, CA

Jason D. Scorse, Ph.D.
Chair and Associate Professor
Department of International Environmental Policy
Monterey Institute
Monterey, CA

James M. Scott, M.A.
Software Engineer
El Cerrito, CA

David M. Seaborg, M.A.
World Rainforest Fund
Walnut Creek, CA

Roger R. Seapy, Ph.D.
Los Alamitos, CA

John Sefton, Ph.D.
Trabuco Canyon, CA

Evalyn F. Segal, Ph.D.
Professor Emerita
Department of Psychology
San Diego State University
Walnut Creek, CA

Fredrick J. Seil, M.D.
Professor Emeritus
Berkeley, CA

Samuel Sensiper, Ph.D.
Consultant
Santa Barbara, CA

Andrew M. Sessler, Ph.D.
Oakland, CA

Rebecca F. Shipe, Ph.D.
Institute of Environment and Sustainability
Los Angeles, CA

Ann Siebert, M.A.
Engineer (Retired)
Orange, CA

Dan Silver, M.D.
Los Angeles, CA

Robert Silvern
La Mesa, CA

William J. Simon, Ph.D.
Vice President
Veterans for Peace
Santa Rosa, CA

John B. Skillman, Ph.D.
Department of Biology
California State University
Wrightwood, CA

Randolph C. Skrovan, M.A.
Watsonville, CA

Matthew Sloan, M.D.
Long Beach, CA

David T. Smernoff, Ph.D.
Portola Valley, CA

Raymond C. Smith, Ph.D.
Professor Emeritus
Department of Geography
University of California, Santa Barbara
Santa Barbara, CA

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Felix E. Smith
Fisheries and Water Management Biologist (Retired)
Save the American River Association
Carmichael, CA

Jeffrey O. Smith
Doctoral Candidate
Department of Chemistry
California Institute of Technology
Pasadena, CA

Shaun Snyder
Electrical Engineer
Santa Barbara, CA

Richard Solomon, Ph.D.
Oakland, CA

David R. Sonneborn, Ph.D.
Professor Emeritus
Orange, CA

Marko Spasojevik, Ph.D.
Berkeley, CA

Frieda A. Stahl, Ph.D.
Professor Emerita
Department of Physics and Astronomy
California State University, Los Angeles
Pasadena, CA

George Stebbins, M.A.
Senior Software Engineer
Palmdale, CA

Brandon M. Steets, M.A.
Senior Environmental Engineer
Santa Barbara, CA

Richard Stein, Ph.D.
Irvine, CA

Glenn R. Stewart, Ph.D.
Professor Emeritus
Department of Biological Sciences
California State Polytechnic University
La Verne, CA

Christopher Still, Ph.D.
Associate Professor
Department of Geography
University of California, Santa Barbara
Santa Barbara, CA

Robert Nield Stillwell, Ph.D.
Psychologist
Stockton, CA

Arthur A. Strauss, M.D.
Associate Clinical Professor
Department of Pediatrics
University of California, Irvine
Irvine, CA

Robert E. Sullivan, M.D.
Sacramento, CA

Jane Sun, M.A.
Santa Barbara, CA

Ira B. Tager, M.D.
Professor
School of Public Health
University of California, Berkeley
Sonoma, CA

Ria Tanz Kubota, M.A.
El Sobrante, CA

Eileen Taschereau, M.A.
Los Angeles, CA

Wayne E. Taylor, Ph.D.
Associate Professor
Department of Biomedical Sciences
Charles Drew University
Fullerton, CA

Amy S. Terrell, M.A.
Water Resources Control Engineer
Citrus Heights, CA

Jeanne Thatcher, M.A.
Chico, CA

Belinda Thom, Ph.D.
Mt Baldy, CA

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Carolyn R. Thomas, Ph.D.
San Diego, CA

Kathleen Anne Thompson, Ph.D.
Menlo Park, CA

Lawrence H. Thompson, Ph.D.
Livermore, CA

Jeff Tolhurst, Ph.D.
Professor
Department of Geosciences
GIS
Columbia College
Columbia, CA

Gene R. Trapp, Ph.D.
Professor Emeritus
Department of Biological Sciences
California State University, Sacramento
Davis, CA

Dee D. Trent, Ph.D.
Professor (Retired)
Department of Physical Science and Engineering
Citrus College
Claremont, CA

John S. Tucker, Ph.D.
San Pablo, CA

Karl A. Tupper, M.A.
Staff Scientist
Grassroot Science
Pesticide Action Network North America
San Francisco, CA

Randall Geddes Tyers, Ph.D.
Berkeley, CA

James Ullrey, M.A.
Principal Scientist
Research and Development
Inresco
El Sobrante, CA

Joseph Ulmer, M.A.
Sebastopol, CA

Luci Ungar, M.A.
Sonoma, CA

Cor van de Water, M.A.
Mountain View, CA

Mathias NMN van Thiel, Ph.D.
Hayward, CA

Clarence W. Vandenberg
Walnut Creek, CA

Danel Vickerman, Ph.D.
Oceanside, CA

Robert V. Wagoner, Ph.D.
Professor Emeritus
Department of Physics
Stanford University
Stanford, CA

Mark Waldrop
Senior Engineer
Research and Development
Cameron Measurement Systems
Mt Baldy, CA

Gregory Walker, Ph.D.
Professor
Department of Entomology
University of California, Riverside
Riverside, CA

Steven P. Wallace, Ph.D.
Professor
School of Public Health
University of California, Los Angenes
Culver City, CA

Yiwei Wang
Doctoral Candidate
University of California, Santa Cruz
Los Gatos, CA

Gerald J. Wasserburg, Ph.D.
Professor (Retired)
Department of Geological and Planetary Sciences
Pasadena, CA

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Stephen F. Wathen, Ph.D.
Winters, CA

Susan Way, M.A.
San Rafael, CA

Stephen C. Weber, M.D.
Sacramento, CA

Russell B. Weisz, M.A.
Santa Cruz, CA

Stephen L. Weitz, Ph.D.
Oakland, CA

Hartwell Welsh, Ph.D.
Southwest Research
U.S. Department of Agriculture Forest Service
Research Ecologist
Arcata, CA

Mel Werbach, M.D.
Camp Nelson, CA

Vanessa Weslow, M.A.
Senior Scientist
Encinitas, CA

Mindi White, M.D.
Los Angeles, CA

Adam B. Whitney
San Diego, CA

Lawrence M. Willey, M.A.
Senior Chemist
Laboratory
DPI Global
Porterville, CA

Jerry Wilson, Ph.D.
Professor (Retired)
Davis, CA

Richard G. Wilson, M.A.
Coastal Management Coordinator
Surfrider Foundation
Oceanside, CA

Andreas Wittenstein
Doctoral Candidate
Chief Scientist
Woodacre, CA

Michael T. Wollman, Ph.D.
Professor Emeritus
Department of Electrical Engineering
California Polytechnic State University, San Luis Obispo
San Luis Obispo, CA

Michael Scott Woods, M.A.
Senior Structural Engineer
San Francisco, CA

John C. Woolum, Ph.D.
Professor
Department of Physics
California State University, Los Angeles
Pasadena, CA

Terry Ann Yen, Ph.D.
Berkeley, CA

Avani Zaidi, M.A.
Fontana, CA

Heidi Zamzow, M.A.
Monterey Bay Aquarium
Pacific Grove, CA

Lyuba Zarsky, Ph.D.
Associate Professor
Graduate School of International Policy
Monterey Institute of International Studies
Berkeley, CA

Robert J. Zimmerman, Ph.D.
Martinez, CA

Muriel Madeline Zimmermann, M.A.
Emeritus Professor
Calimesa, CA

Maxine Zylberberg
Doctoral Candidate
Davis, CA

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COLORADO

Ron L. Alberty, Ph.D.
Boulder, CO

Susan Kelly Ambler, Ph.D.
Denver, CO

David M. Armstrong, Ph.D.
Professor Emeritus
Department of Ecology and Evolutionary Biology
University of Colorado, Boulder
Loveland, CO

Teresa E. Audesirk, Ph.D.
Professor Emerita
Department of Biology
University of Colorado, Denver
Steamboat Springs, CO

Paul Kevin Black, Ph.D.
Evergreen, CO

Charles H. Bucknam, M.A.
Parker, CO

Martha Bushnell, Ph.D.
Boulder, CO

Kyle Buss, M.A.
Denver, CO

Carl R. Carnein, Ph.D.
Emeritus Associate Professor
Department of Geology and Physics
Lock Haven University of Pennsylvania
Florissant, CO

Gerald J. Chambers, M.A.
Longmont, CO

Margaret A. Christon, M.D.
Arvada, CO

Rob C. Cifelli, Ph.D.
Research Scientist
Earth System Research Laboratory
National Oceanic and Atmospheric Administration
Boulder, CO

Kenneth F. Connell, Ph.D.
Denver, CO

Darrell E. Coons, Ph.D.
Broomfield, CO

Harry D. Corsover, Ph.D.
Psychologist
Corsover and Azzi
Castle Rock, CO

Wayne D. Crill, Ph.D.
Virologist
Arboviruses Diseases Branch
U.S. Centers for Disease Control and Prevention
Fort Collins, CO

J. Kevin Cross, M.A.
Energy Engineer
Fort Collins Sustainability Group
Fort Collins, CO

Kirkwood M. Cunningham, Ph.D.
Retired Research Chemist
U.S. Geological Survey Water Resources
Boulder, CO

Derek Day, M.A.
Research Associate III
Cooperative Institute for Research in the Atmosphere
Colorado State University
Laporte, CO

Peter G. Debrunner, Ph.D.
Professor Emeritus
Department of Physics and Biophysics
University of Illinois
Conifer, CO

Thomas Detman, Ph.D.
Geophysicist
Allenspark, CO

Robert B. Dorsett, M.D.
Meeker, CO

February 2011

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Murray Dryer, Ph.D.
Consultant (Retired)
Space Physics
Greenwood Village, CO

Keith Emery
Doctoral Candidate
Manager PV Performance Characterization
Arvada, CO

Frank Evans, Ph.D.
Senior Research Associate
Department of Atmospheric and Oceanic Sciences
University of Colorado
Del Norte, CO

Chris H. Floyd, Ph.D.
Associate Professor
Department of Biology
University of Wisconsin, Eau Claire
Ft Collins, CO

Dennis Froman
Mechanical Engineer Supervisor
Westminster, CO

Russell Geisthardt
Doctoral Candidate
Colorado State University
Fort Collins, CO

John F. Hall, M.A.
Grand Junction, CO

Jack Harlan, Ph.D.
Lafayette, CO

Detlev Helmig, Ph.D.
Boulder, CO

Andrew Herring, Ph.D.
Nederland, CO

Eric J. Hintsa, Ph.D.
Research Scientist
Cooperative Institute for Research in
Environmental Science
University of Colorado
Boulder, CO

Elisabeth A. Holland, Ph.D.
Senior Scientist
Boulder, CO

Kate Inman, Ph.D.
Fort Collins, CO

Jose-Luis Luis Jimenez, Ph.D.
Associate Professor
Department of Chemistry and Biochemistry
Cooperative Institute for Research in
Environmental Science
University of Colorado, Boulder
Boulder, CO

Thomas Kampe, Ph.D.
Senior Scientist
Boulder, CO

Annette Keller, M.A.
Aspen, CO

Kenneth W. Keller, M.A.
Fort Collins, CO

Mark W. Keller, Ph.D.
Boulder, CO

Lorraine Kirk, Ph.D.
Nederland, CO

Marni E. Koopman, Ph.D.
Fort Collins, CO

Kenneth J. Kutalek, M.D.
Associate Clinical Professor
Pediatric Medicine
University of Colorado School of Medicine
Evergreen, CO

Arno Rudolf Laesecke, Ph.D.
Louisville, CO

Ronal Larson, Ph.D.
Golden, CO

Deron Lawrence, M.A.
Senior Ecologist
Conifer, CO

February 2011

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Julia Lee-Taylor, Ph.D.
Project Scientist
Boulder, CO

John J. Lemmon, Ph.D.
Physicist
Institute for Telecommunication Sciences
U.S. Department of Commerce
Nederland, CO

Joel S. Leventhal, Ph.D.
Principal Scientist
Diversified Geochemistry
Lakewood, CO

Irene R. Little, Ph.D.
Retired
Estes Park, CO

Margaret A. MacMorris, Ph.D.
Senior Research Associate
Molecular, Cellular, and Developmental Biology
University of Colorado, Boulder
Golden, CO

Robert T. Magill, M.A.
Wildlife Biologist
Western Slope Wildlife LLC
Palisade, CO

Georgia Mattingly, M.A.
Longmont, CO

Victor Mayer, Ph.D.
Professor Emeritus
The Ohio State University
Windsor, CO

Alan McAllister, Ph.D.
Boulder, CO

Joel McCormack, M.A.
Senior Graphics Architect
Boulder, CO

John R. McKean, Ph.D.
Masonville, CO

Larry Miloshevich, M.A.
Lafayette, CO

George N. Oetzel, Ph.D.
Senior Technical Advisor
Boulder, CO

Sherry L. Olson, Ph.D.
Boulder, CO

A. R. Palmer, Ph.D.
Boulder, CO

James C. Pequette, Ph.D.
Managing Partner
Executive
KALA Consulting, LLC
Littleton, CO

Harry C. Poehlmann
Doctoral Candidate
Boulder, CO

Keith Porter, Ph.D.
Associate Research Professor
Department of Civil Environmental and Architectural Engineering
University of Colorado, Boulder
Denver, CO

Joseph Tant Priestley, M.A.
Physicist
Boulder, CO

Michael Prochoda, M.D.
Estes Park, CO

Charles F. Revier, Ph.D.
Associate Professor
Department of Economics
Colorado State University
Fort Collins, CO

Suzanne M. Royer, Ph.D.
Senior Research Associate
Department of Biology
Colorado State University
Loveland, CO

Thomas W. Schlatter, Ph.D.
Senior Research Associate
Boulder, CO

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

John Schuenemeyer, Ph.D.
President
Southwest Statistical Consulting, LLC
Cortez, CO

Lawrence Scrima, Ph.D.
Aurora, CO

Lisa Siconolfi, Ph.D.
Westminster, CO

Joel B. Smith, M.A.
Principal
Boulder, CO

Lesley K. Smith, Ph.D.
Research Scientist
Cooperative Institute for Research in Environmental Science
University of Colorado
Boulder, CO

Darrel Snyder, M.A.
Research Scientist
Fort Collins, CO

Will Spangler
M.D. Candidate
Boulder, CO

John Spear, Ph.D.
Golden, CO

Sheryl L. Spence, M.A.
SL Spence Consulting
Fort Collins, CO

William A. Strohl, M.D.
Professor Emeritus
Department of Molecular Genetics, Microbiology and Immunology
R.W. Johnson Medical School
Longmont, CO

David S. Thomson, Ph.D.
Boulder, CO

Kevin E. Trenberth, Ph.D.
Head Climate Analysis Section
Boulder, CO

Harold M. Tyus, Ph.D.
Research Scientist Emeritus
Cooperative Institute for Research in Environmental Science
University of Colorado, Boulder
Golden, CO

Jerry D. Unruh, Ph.D.
Senior Research Associate (Retired)
Celanese Ltd.
Manitou Springs, CO

Otto Van Geet
Idaho Springs, CO

Bolko von Roedern, Ph.D.
Golden, CO

David Waddington, M.A.
Engineer (Retired)
Subcontract to Department of Energy
National Renewable Energy Laboratory
Golden, CO

Fred L. Walls, Ph.D.
Lafayette, CO

Lee C. Wilson, M.A.
Basalt, CO

Anna Christy Wyckoff
Doctoral Candidate
Fort Collins, CO

Barbara T. Zimmerman, Ph.D.
Owner
Manager
Biomedical Communication and Consulting
Denver, CO

CONNECTICUT

Henry E. Auer, Ph.D.
Retired
New Haven, CT

Gary D. Bent, Ph.D.
Mansfield Ctr, CT

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Robert S. Capers, Ph.D.
Department of Ecology and Evolutionary Biology
University of Connecticut
Mansfield Center, CT

Robin L. Chazdon, Ph.D.
Storrs, CT

Matthew J. Enjalran, Ph.D.
Associate Professor
Department of Physics
Southern Connecticut State University
New Haven, CT

Philippe Fontaine, M.A.
Business Development Manager (Retired)
Aircraft Air Management Systems
United Technologies Corporation
East Granby, CT

Claire E. Gavin, Ph.D.
Senior Principal Scientist (Retired)
Stonington, CT

Zbigniew Jakub Grabowski, M.A.
Director
Department of Community and Ecology
Pure Interactions
Mansfield Center, CT

Jeffrey Eric Grant, M.A.
Waterbury, CT

Torrance Hanley, Ph.D.
New Haven, CT

James A. Hewett, Ph.D.
Assistant Professor
Department of Neuroscience
University of Connecticut Health Center
West Hartford, CT

Patricia A. Kusmierski
Master's Candidate
Essex, CT

David Liedlich, M.A.
Southbury, CT

Bert Moldow, M.A.
Westport, CT

Nancy M. Murray, M.A.
Senior Environmental Analyst
Willington, CT

John D. Nelson, Ph.D.
Bethlehem, CT

Sherman E. Nelson, Ph.D.
Retired
Stratford, CT

Ryan Pitera
Master's Candidate
Energy Consultant
Farmington, CT

Anthony J. Razel, Ph.D.
Retired
East Hampton, CT

Robert J. Rollefson, Ph.D.
Professor Emeritus
Department of Physics
Wesleyan University
Middletown, CT

Gary Rudnick, Ph.D.
Professor
Department of Pharmacology
Yale University
Hamden, CT

Jerry Sawyer
Doctoral Candidate
Stratford, CT

Michael Steven Sherber, M.A.
Vice President
Avon, CT

Steven C. Sherwood, Ph.D.
New Haven, CT

February 2011

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2,505 Endorsers

Arie A. Sitthichai Mobley, Ph.D.
Postdoctoral Fellow
Neurosurgery
Yale University
New Haven, CT

Clifford L. Slayman, Ph.D.
Professor
Department of Cellular and Molecular Physiology
Yale University
Hamden, CT

Merton A. Smith, Ph.D.
Southbury, CT

Joyce Stowe-Longchamp, M.A.
Professor Emerita
Department of Psychology
Central Connecticut State University
Avon, CT

John S. Strauss, M.D.
Professor Emeritus
New Haven, CT

William B. Upholt, Ph.D.
Professor
Department of Reconstructive Sciences
University of Connecticut Health Center
Hartford, CT

Mark Urban, Ph.D.
Assistant Professor
Department of Ecology and Evolutionary Biology
University of Connecticut
Storrs, CT

Melissa McShea Valentin, M.A.
Agency Field Executive
Simsbury, CT

Faith A. Weidner, M.D.
Department of Radiology
Northampton VA Medical Center
Simsbury, CT

DELAWARE

Alan Bleier, Ph.D.
Hockessin, DE

Edward Cluff, Ph.D.
Wilmington, DE

D. Robert Coulson, Ph.D.
Wilmington, DE

William B. Daniels, Ph.D.
Wilmington, DE

Marion Ehrlich, M.A.
Wilmington, DE

Andrew Favret, Ph.D.
Professor Emeritus
Department of Electrical Engineering
Catholic University
Bethany Beach, DE

Dorothy B. Flippen, M.A.
Wilmington, DE

Michael G.P. Reppy, Ph.D.
Wilmington, DE

Gilbert Sloan, Ph.D.
Wilmington, DE

Susan E. Yost, Ph.D.
Dover, DE

DISTRICT OF COLUMBIA

Walton Malcolm Byrnes, Ph.D.
Associate Professor
Department of Biochemistry and Molecular Biology
Howard University
Washington, DC

Michael Cloppert, M.A.
Security Analyst
Washington, DC

Brian A. Haugh, Ph.D.
Research Staff Member
Washington, DC

K. Marlin, M.P.H.
Washington, DC

February 2011

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2,505 Endorsers

Amanda Medori, M.A.
Washington, DC

Louise Prockter, Ph.D.
Senior Researcher
Washington, DC

Jeremy Richardson, Ph.D.
Washington, DC

FLORIDA

Juanita Baker, Ph.D.
Professor Emerita
Department of Psychology
Florida Institute of Technology
Sebastian, FL

Barbara-Anne Battelle, Ph.D.
Professor
Neuroscience and Biology
University of Florida
Palm Coast, FL

Ray E. Bellamy, M.D.
Clerkship Director of Surgery
College of Medicine
Florida State University
Tallahassee, FL

Samuel William Berkheiser, M.A.
Apalachicola, FL

David Thomas Bernardini
Master's Candidate
Program Engineer
Hobe Sound, FL

William J. Broussard, M.D.
President
Medical Director
Florida Eye Associates
Indialantic, FL

Robert J. Buschbacher, Ph.D.
Associate in Tropical Forestry
School of Forestry Resources and Conservation
University of Florida
Gainesville, FL

Ivo J. Calderin
Doctoral Candidate
Miami, FL

Kathleen E. Cavell, D.V.M.
Tallahassee, FL

Jeff Chanton, Ph.D.
Professor
Department of Earth, Ocean and Atmospheric Science
Florida State University
Tallahassee, FL

Ron Wiliam Cleminson, Ph.D.
Naples, FL

Bruce C. Cowell, Ph.D.
Retired Professor
Department of Integrative Biology
University of South Florida
Lutz, FL

William Dabby, M.A.
Professor
Department of Arts and Sciences
Edison State College
Fort Myers, FL

Kendra L. Daly, Ph.D.
Associate Professor
St. Petersburg, FL

Michael DeLoye, M.A.
Boynton Beach, FL

Roger P. Donahue, Ph.D.
Voluntary Professor
Department of Pathology
University of Miami
Miami Beach, FL

G. B. Edwards, Ph.D.
Curator
Plant Industry
Florida Department of Agriculture
Gainesville, FL

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Cathy Falvo, M.D.
International Society of Doctors for the Environment
Delray Beach, FL

Robert H. Fay
Doctoral Candidate
Center for Research Evaluation Assessment and Measurement
University of South Florida
St. Petersburg, FL

Ronaldo J. Flank, M.A.
Pinecrest, FL

Andres Garcia, Ph.D.
Coral Gables, FL

Jerome Gelover, M.A.
Lake Worth, FL

Robert C. Gillespie, Ph.D.
Saint Augustine, FL

Dick Glick, Ph.D.
President
Management
CFR Bio-Fuels Corp
Tallahassee, FL

David Groisser, Ph.D.
Gainesville, FL

James A. Hanson, Ph.D.
Winter Park, FL

Peter J. Harries, Ph.D.
Associate Professor
Tampa, FL

Arthur R. Hurwitz, Ph.D.
Highland Beach, FL

Nancy Hutton, M.A.
Professor
Department of Arts and Sciences
Florida State College, Jacksonville
St. Augustine, FL

Rita Maxine Jungman, M.A.
Psychiatric Advanced Registered Practitioner
Department of Psychiatry
Liberty Community Health Department
Havana, FL

George Kamenov, Ph.D.
Department of Geological Sciences
University of Florida
Gainesville, FL

John Klauder, Ph.D.
Gainesville, FL

Angela N. Knapp, Ph.D.
Miami, FL

Leon Philip Lounibos, Ph.D.
Professor
Vero Beach, FL

Ellen E. Martin, Ph.D.
Gainesville, FL

Laszlo Henry Martini
Jacksonville, FL

Dennis A. Mayer, M.A.
St Petersburg, FL

Kara Mcginnis
Master's of Public Health Candidate
Tampa, FL

Douglas J. Merrey, Ph.D.
Natural Resources Specialist
Tampa, FL

Peter B. Morris, Ph.D.
Fort Pierce, FL

William Moulton, Ph.D.
Tallahassee, FL

Emmett J. Murphy, Ph.D.
Bradenton, FL

David Nicholson
Sun City Center, FL

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Rose Njoroge
Doctoral Candidate
Department of Educational Psychology
Florida State University
Tallahassee, FL

Rachel Nostrom
Master's Candidate
Safety Harbor, FL

Paul A. O'Byrne, M.P.H.
Environmental Health Professional
Thonotosassa, FL

Fredrick R. OKeefe, M.P.H.
Technical Director
AIR Technical Center
Tampa, FL

Janat Fraser Parker, Ph.D.
Miami, FL

Jamie Picard
Master's Candidate
Business Development Manager
Ocean Renewable Power
Tampa, FL

Dorota L. Porazinska, Ph.D.
Oakland Park, FL

Tom L. Poulson, Ph.D.
Jupiter, FL

Johnny Shane Richardson, M.A.
Tallahassee, FL

Jack Robins, Ph.D.
West Palm Bch, FL

Bill Rosenthal, Ph.D.
Land O' Lakes, FL

Paul Ruscher, Ph.D.
Professor
Department of Earth, Ocean and Atmospheric Science
Florida State University
Tallahassee, FL

Ethel Saryee, M.P.H.
Research Assistant
Department of Anthropology
University of South Florida
Temple Terrace, FL

Thomas William Sharpless, Ph.D.
Professor Emeritus
North Bay Village, FL

Celeste Alicia Shitama
Master's Candidate
Gainesville, FL

Jan C. Siren, Ph.D.
Melbourne, FL

Elizabeth Wright Smith, D.V.M.
Veterinarian
Fort Myers, FL

Mary Margaret Snow, Ph.D.
Professor
Department of Applied Aviation Sciences
Embry-Riddle Aeronautical University
Daytona Beach, FL

Gerald C. Swanson, Ph.D.
New Smyrna Beach, FL

Barrie F. Taylor, Ph.D.
Professor Emeritus
Marine and Atmospheric Science
University of Miami
Miami, FL

Joseph Torres, Ph.D.
Saint Petersburg, FL

Alicie Warren, Ph.D.
Homestead, FL

Brenda Westhorp, M.A.
President
Westhorp and Associates, Inc.
Miami, FL

William Harold White, M.A.
Fort Walton Beach, FL

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David L. Wilson, Ph.D.
Professor
Department of Biology
University of Miami
Miami, FL

Kimberly R. Wilson, M.A.
Retired
Orlando, FL

Satya Wink, M.A.
Sarasota, FL

Philip A. Wood, Ph.D.
Professor
Orlando, FL

Andrew Zimmerman, Ph.D.
Assistant Professor
Department of Geological Sciences
University of Florida
Gainesville, FL

GEORGIA

Dayton Adams, M.A.
Jasper, GA

Donald L. Brockway, Ph.D.
Research Biologist (Retired)
Athens, GA

Kristen Cincotta
Doctoral Candidate
Department of Neurology
Emory University
Atlanta, GA

Michael J. Collier, Ph.D.
Oakwood, GA

Joseph M. Dirnberger, Ph.D.
Professor
Department of Biology and Physics
Kennesaw State University
Kennesaw, GA

Vernon Dixon, M.D.
Hiawassee, GA

Michael Elliott, Ph.D.
Atlanta, GA

Valerie Fennell, Ph.D.
Associate Professor Emerita
Atlanta, GA

James M. Gaudin, Ph.D.
Athens, GA

Gretchen T. Goldman
Doctoral Candidate
Atlanta, GA

Gail Lanterman Heaberg, Ph.D.
Executive Director
AIS for Health, Inc.
Warner Robins, GA

Mary Croft Hebblewhite, Ph.D.
Psychologist
Clinical Practice
Atlanta, GA

Jim B. Hendrickson, M.A.
Acworth, GA

Peter T. Kallay, M.A.
Manager Environmental Services
Department of Environmental Services
Atlanta Environmental Consultants
Kennesaw, GA

Andrew M. Kramer, Ph.D.
Athens, GA

Shelly Krueger, M.A.
Tybee Island, GA

Leslie E. W. LaConte, Ph.D.
Decatur, GA

Sven Lovegren, M.A.
Atlanta, GA

Krisztian Magori, Ph.D.
Postdoctoral Researcher
Athens, GA

February 2011

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Jacqueline E. Mohan, Ph.D.
Assistant Professor
Athens, GA

Dale Newfield
Doctoral Candidate
Atlanta, GA

Douglas R. Oetter, Ph.D.
Milledgeville, GA

Cynthia Anne Payne, Ph.D.
Athens, GA

Neal A. Priest, M.D.
Athens, GA

Scott Allen Reese, Ph.D.
Associate Professor
Department of Biology and Physics
Kennesaw State University
Canton, GA

Emmett Fran Stallings, Ph.D.
Donalsonville, GA

Jim C. Toler, M.A.
Alpharetta, GA

HAWAII

Michael J. Antal, Ph.D.
Distinguished Professor
Hawaii Natural Energy Institute
University of Hawaii
Honolulu, HI

David Earl Bates, Ph.D.
Research Scientist
Hawaii Institute of Geophysics and Planetology
University of Hawaii
Honolulu, HI

Marian M. Chau
Doctoral Candidate
Department of Botany
University of Hawaii Manoa
Honolulu, HI

Frederick A. Harris, Ph.D.
Professor
Department of Physics and Astronomy
University of Hawaii
Kailua, HI

Sterling C. Keeley, Ph.D.
Professor
Department of Botany
University of Hawaii, Manoa
Honolulu, HI

Pierre M. Kleiber, Ph.D.
Fishery Biologist
Honolulu, HI

Creighton M. Litton, Ph.D.
Assistant Professor
Honolulu, HI

Joseph A. McHugh, M.A.
LMFT
Honolulu, HI

John V. Mickey, M.D.
Physician
Internal Medicine
Hawaii Pacific Health
Honolulu, HI

Michele Nihipali, M.P.H.
Hauula, HI

Agnes Mitsue Niyekawa, Ph.D.
Professor Emeritus
Honolulu, HI

Mark A. Nokes, Ph.D.
Consultant
Honolulu, HI

Michael Parke, Ph.D.
Honolulu, HI

Tom A. Ranker, Ph.D.
Honolulu, HI

Daniel Saltman, M.D.
Honolulu, HI

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William Mokahi Steiner, Ph.D.
Dean
University of Hawaii, Hilo
Honolulu, HI

Allan V. T. Wang, M.D.
Assistant Clinical Professor
Department of Pediatrics
University of Hawaii School of Medicine
Holualoa, HI

IDAHO

Glen Albertson, M.D.
Twin Falls, ID

Elizabeth J. Bryant, Ph.D.
Meridian, ID

Stephan D. Flint, M.A.
Affiliate Instructor
Moscow, ID

Alan R. Hausrath, Ph.D.
Retired
Boise, ID

Michael Kiparsky, Ph.D.
University of Idaho
Moscow, ID

Barbara McClain
Idaho City, ID

Thomas Dylan Mikesell
Doctoral Candidate
Boise, ID

Stephen S. Mulkey, Ph.D.
Director
Moscow, ID

Alan Poplawsky, Ph.D.
Research Associate
Department of Plant, Soil and Entomological Sciences
University of Idaho
Moscow, ID

Mark D. Shapley, Ph.D.
Postdoctoral Research Scientist
Department of Geosciences
Idaho State University
Pocatello, ID

Chris S. Staley, M.A.
Advisory Scientist
Environmental Programs
Idaho Cleanup Project
Idaho Falls, ID

Kenneth S. Winer, M.A.
Boise, ID

Nancy Wood, M.A.
Boise, ID

ILLINOIS

Margarita V. Alario, Ph.D.
Associate Professor
Department of Sociology and Environmental Studies
University of Wisconsin, Whitewater
Whitewater, IL

Stuart K. Allison, Ph.D.
Professor
Department of Biology
Knox College
Galesburg, IL

Terence R. Anthoney, M.D.
Carbondale, IL

Joseph Armstrong, Ph.D.
Professor
Department of Biology
Illinois State University
Normal, IL

Neil G. Aronson, M.D.
Skokie, IL

James Bachman, M.A.
Saint Charles, IL

David C. Barnett, Ph.D.
Chicago, IL

February 2011

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Suhail Barot
Doctoral Candidate
Chairman
Student Sustainability Committee
University of Illinois, Urbana-Champaign
Urbana, IL

Roman John Berka
Algonquin, IL

John Howard Bodine, Ph.D.
Naperville, IL

Geoffrey T. Bodwin, Ph.D.
Woodridge, IL

Paul F. Brandt, Ph.D.
Associate Professor
Department Chair
Department of Chemistry and Physics
North Central College
Naperville, IL

Beth A. Braun, Ph.D.
Chicago, IL

William R. Bromer, Ph.D.
Professor
Joliet, IL

William Buehring, Ph.D.
Naperville, IL

Wallis F. Calaway, Ph.D.
Woodridge, IL

Angelo Capparella, Ph.D.
Associate Professor
Department of Biological Sciences
Illinois State University
Normal, IL

Patricia A. Chelmecki
Doctoral Candidate
Elburn, IL

Mary Conway, M.P.H.
Chicago, IL

Martha Elizabeth Cook, Ph.D.
Normal, IL

Robert C. Coon
Master's Candidate
Chicago, IL

Ron O. Cox, Ph.D.
Chicago, IL

Malcolm M. Dow, Ph.D.
Chicago, IL

Juliet A. D'Souza, M.A.
Ottawa, IL

Leslie A. Duram, Ph.D.
Professor and Chair
Department of Geography
Southern Illinois University, Carbondale
Carbondale, IL

Alex Clarence Esche
Doctoral Candidate
Department of Biological and Environmental Engineering
Cornell University
Crystal Lake, IL

Tessa Fischer, M.D.
Evanston, IL

Emily Kukula Forcade, M.D.
Clinical Instructor
Feinberg School of Medicine
Northwestern University
Skokie, IL

Arthur J. Freedman, Ph.D.
President
Arthur Freedman Associates, Inc.
Naperville, IL

Douglas Gerleman, M.A.
Northbrook, IL

Karen Glennemeier, Ph.D.
Wilmette, IL

February 2011

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Sandeep Gopal
Master's Candidate
Department of Engineering Design
Northwestern University
Evanston, IL

Daniel J. Graham, Ph.D.
Associate Professor
Department of Chemistry
Loyola University Chicago
Chicago, IL

Eleanor Hall, Ph.D.
Retired
Chicago, IL

David Hedin, Ph.D.
Professor
Department of Physics
Northern Illinois University
DeKalb, IL

Anne M. Hendrickson, M.A.
Teacher
Rockford, IL

Caroline L. Herzenberg, Ph.D.
Argonne, IL

Duane R. Kimme, M.A.
Champaign, IL

Jason A. Koontz, Ph.D.
Associate Professor
Department of Biology
Augustana College
Rock Island, IL

Irvin N. Lanning, M.A.
Edwardsville, IL

David W. Larsen, M.A.
DeKalb, IL

Charlotte Lehmann, M.A.
Chicago, IL

Seth Marcus, M.A.
Prospect Heights, IL

Bulmaro Martinez, M.P.H.
Chicago, IL

Kathleen J. Mattison, M.A.
Registered Dietitian
Eating Experts
Rockford, IL

Bert Ph. M. Menco, Ph.D.
Evanston, IL

Zewei Miao, Ph.D.
Research Assistant Professor
University of Illinois
Urbana, IL

Jay Mittenthal, Ph.D.
University of Illinois
Urbana, IL

Gregory A. Owens, Ph.D.
Decatur, IL

Ross D. Powell, Ph.D.
Professor
Department of Geology and Environmental Geosciences
Northern Illinois University
DeKalb, IL

Hector R. Reyes, Ph.D.
Assistant Professor
Department of Physical Science
Harold Washington College
Chicago, IL

Richard J. Robertson, Ph.D.
Glenview, IL

Rebecca A. Rossof, M.A.
Chicago, IL

Claire L. Safford, M.A.
Biologist
Health Physicist
Quincy, IL

Michael Savina, Ph.D.
Naperville, IL

February 2011

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2,505 Endorsers

Robert D. Schwartz, Ph.D.
Waukegan, IL

Anne Elizabeth Settanni, M.A.
Normal, IL

Shobha Sharma, Ph.D.
Northeastern Illinois University
Libertyville, IL

Reid Alan Sherman
Doctoral Candidate
Chicago, IL

Donna L. Siemro, Ph.D.
Arlington Heights, IL

Rael Slavensky, M.P.H.
Public Health Nurse
Geneseo, IL

Russel D. Smith, M.D.
Chicago, IL

Gregory Spahn, M.A.
Wheaton, IL

Margaret K. Thayer, Ph.D.
Associate Curator
Department of Zoology
Field Museum of Natural History
Chicago, IL

Frederick Thulin, Ph.D.
University of Illinois, Chicago
Naperville, IL

R. Scott Tindale, Ph.D.
Professor
Department of Psychology
Loyola University Chicago
Chicago, IL

Mary Urban, M.A.
Instructor
Grayslake, IL

Leroy S. Wehrle, Ph.D.
Professor
Springfield, IL

Suzanne Willis, Ph.D.
DeKalb, IL

Eric J. Wilson, M.D.
Chicago, IL

Raymond Yurkewycz, M.A.
Palatine, IL

Arlene R.K. Zide, Ph.D.
College Professor (Retired)
Chicago, IL

INDIANA

Novem Auyeung
Doctoral Candidate
Department of Forestry and Natural Resources
Purdue University
West Lafayette, IN

Andrew Bacher, Ph.D.
Professor
Bloomington, IN

Ed Bachta, M.A.
Carmel, IN

Robert Bieder, Ph.D.
Professor (Retired)
Department of History
Indiana University
Bloomington, IN

Marc Bilodeau, Ph.D.
Associate Professor
Department of Economics
Indiana University-Purdue University Indianapolis
Indianapolis, IN

Melanie Blackburn, M.A.
Fort Wayne, IN

Jenny Bodwell
Master's Candidate
Terre Haute, IN

February 2011

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Bennet Bristol Brabson, Ph.D.
Professor Emeritus
Department of Physics
Indiana University
Bloomington, IN

Kevin P. Brown, Ph.D.
Clarksville, IN

Peter Stephen Cashel-Cordo, Ph.D.
Professor
Department of Economics and Marketing
University of Southern Indiana
Evansville, IN

Patricia Davis Chang, M.A.
Registered Nurse
Indianapolis, IN

Howard R. Christofersen, M.D.
Member
United Church of Christ
Porter, IN

Douglas E. Dorman, Ph.D.
Indianapolis, IN

John Felton, Ph.D.
Newburgh, IN

Nancy A. Fischer, Ph.D.
Middletown, IN

Diana Hews, Ph.D.
Associate Professor
Department of Biology
Indiana State University
Brazil, IN

Rhonda Kohl, M.A.
Historian
Jeffersonville, IN

John T. Londergan, Ph.D.
Professor
Department of Physics
Indiana University
Bloomington, IN

Richard W. Newcomb, M.D.
Portage, IN

Joseph F. Pachut, Ph.D.
Associate Professor
Department of Earth Sciences
Indiana University-Purdue University Indianapolis
Indianapolis, IN

Nathan Pate, M.A.
Paoli, IN

Ruth Ann Sanders, M.A.
Bloomington, IN

Bruce Solomon, Ph.D.
Bloomington, IN

Maria T. Waddell, Ph.D.
Indianapolis, IN

Denise Ward, M.D.
Bristol, IN

Ray W. Wilson, M.A.
Indianapolis, IN

IOWA

Richard G. Baker, Ph.D.
Iowa City, IA

Paul E. Bartelt, Ph.D.
Professor of Biology
Research Ecologist
Department of Biology
Waldorf College
Forest City, IA

Cindy L. Borske, M.A.
Mason City, IA

Rhawn F. Denniston, Ph.D.
Associate Professor
Department of Geology
Cornell College
Iowa City, IA

February 2011

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2,505 Endorsers

David G. Fisher, Ph.D.
Associate Professor
Sustainable Living
Maharishi University of Management
Fairfield, IA

Ronald Fuchs, Ph.D.
Professor Emeritus
Department of Physics
Iowa State University, Ames
Ames, IA

Peter J. Hansen, Ph.D.
Iowa City, IA
Jo Anna Hebberger, Ph.D.
Des Moines, IA

Herbert R. Heinicke, Ph.D.
Indianola, IA

Thomas W. Hill, Ph.D.
Professor Emeritus
Department of Sociology, Anthropology, Criminology
University of Northern Iowa
Cedar Falls, IA

Laura L. Jackson, Ph.D.
Professor
Department of Biology
University of Northern Iowa
Cedar Falls, IA

Erwin E. Klaas, Ph.D.
Professor Emeritus
Natural Resources Ecology Management
Iowa State University
Ames, IA

Robert D. Klauber, Ph.D.
Fairfield, IA

Mark Madsen, Ph.D.
Professor
Department of Radiology
University of Iowa
Iowa City, IA

Maureen McCue, Ph.D.
Professor and Doctor
Global Health Studies
Physicians for Social Responsibility
Oxford, IA

R. Lee McNair, Ph.D.
Professor Emeritus
Boone, IA

John R. Menninger, Ph.D.
Iowa City, IA

Kirk A. Moloney, Ph.D.
Associate Professor
Ames, IA

Nilda E. Rodriguez, Ph.D.
Research Investigator
Department of Internal Medicine
University of Iowa
Iowa City, IA

Douglas A. Rossman, Ph.D.
Department of Biology
Luther College
Decorah, IA

Bill W. Simpkins, Ph.D.
Professor
Department of Geological and Atmospheric Sciences
Iowa State University
Ames, IA

Margot H. Tollefson-Conard, Ph.D.
Consulting Statistician
Vanward Statistical Consulting
Stratford, IA

KANSAS

Bruce S. Andersen, M.A.
Kansas City, KS

Cynthia Ann Annett, Ph.D.
Oskaloosa, KS

February 2011

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2,505 Endorsers

David Burress, Ph.D.
President
Ad Astra Institute of Kansas
Lawrence, KS

Julie B. Elfving, M.A.
Olathe, KS

Jon Hauxwell, M.D.
Hays, KS

Larry Morton
Kingman, KS

Val H. Smith, Ph.D.
Professor
Lawrence, KS

Mandy Lee Stone, M.A.
Olathe, KS

KENTUCKY

Eugene N. Bruce, Ph.D.
Professor
Center for Biomedical Engineering
University of Kentucky
Lexington, KY

James A. Drahovzal, Ph.D.
Consulting Geologist
Lexington, KY

John W. Ferner, Ph.D.
Professor
Department of Biology
Thomas More College
Independence, KY

Deborah B. Hill, Ph.D.
Lexington, KY

James F. Hopgood, Ph.D.
Professor Emeritus
Independence, KY

Jerri Dawn Martin, M.A.
Environmental Control Supervisor
Environmental Protection
Kentucky Department of Environmental Protection
Berea, KY

Jack Mckinney, M.A.
Lexington, KY

Kenneth B. Nelson, M.A.
Instructor
Department of Physics and Astronomy
La Grange, KY

Lisa Romano, M.A.
Lexington, KY

Lisa Schmoetzer, M.A.
Lawrenceburg, KY

Dick Shore, Ph.D.
Professor Emeritus
Lexington, KY

Allison S. Smith
Doctoral Candidate
Department of Biology
University of Louisville
Louisville, KY

Gary Thomas Smith
Doctoral Candidate
Lexington, KY

Anthony W. State
Sanitary Engineer
Development
Metropolitan Sewer District
Louisville, KY

Russell Warner
Doctoral Candidate
Department of Psychological and Brain Sciences
University of Louisville
Louisville, KY

Robert W. Wilcox, Ph.D.
Highland Heights, KY

February 2011

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LOUISIANA

Paul L. Klerks, Ph.D.
Lafayette, LA

William J. Platt, Ph.D.
Professor
Department of Biological Science
Louisiana State University
Baton Rouge, LA

Eric Roy
Doctoral Candidate
Baton Rouge, LA

Daniel Sage, Ph.D.
Baton Rouge, LA

Thomas W. Sherry, Ph.D.
Professor
Department of Ecology and Evolutionary Biology
Tulane University
New Orleans, LA

Jo Wiest, M.A.
Lafayette, LA

MAINE

Donald L. Anderson
Doctoral Candidate
Environmental Specialist
Maine Department of Environmental Protection
Retired
Harpswell, ME

Roberta Crowell Barbalace, M.A.
Raymond, ME

Andrew Barton, Ph.D.
Professor of Biology
Department of Biology
University of Maine, Farmington
Farmington, ME

Carleton F. Bryant, M.A.
Camden, ME

Shirley L. Davis, M.A.
Chair of Maine Chapter
Citizens for Global Solutions
Orono, ME

Heather Deese, Ph.D.
Marine Programs Director
Union, ME

Julie A. Gosse, Ph.D.
Assistant Professor
Department of Molecular and Biomedical Sciences
University of Maine
Orono, ME

Douglas Hardy, M.A.
Woolwich, ME

Donald Bion Horton, Ph.D.
Saco, ME

John Lemons, Ph.D.
Professor
Department of Environmental Studies
University of New England
Biddeford, ME

Bob J. Lodato, M.D.
Charleston, ME

Philip J. Nyhus, Ph.D.
Associate Professor
Environmental Studies Program
Colby College
Waterville, ME

Frances M. Perlman, M.A.
West Paris, ME

Mary E. Petersen, Ph.D.
Scholar in Residence
Darling Marine Center
University of Maine
Walpole, ME

Richard Peterson, Ph.D.
Portland, ME

Chris Pottle, Ph.D.
Oxford, ME

February 2011

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2,505 Endorsers

John E. Smedley, Ph.D.
Professor
Department of Physics and Astronomy
Bates College
Lewiston, ME

Bryce E. Smith, Ph.D.
Dedham, ME

Richard S. Stevens, Ph.D.
Portland, ME

Tom H. Tietenberg, Ph.D.
Mitchell Fam Professor of Economics Emeritus
Waterville, ME

Edward Z. Walworth, M.D.
Fellow American College of Surgeons
Lewiston, ME

MARYLAND

Anna Aguilera
Doctoral Candidate
Department of Biology
University of Massachusetts, Boston
Baltimore, MD

Bradford B. Behr, Ph.D.
Silver Spring, MD

James T. Bell, M.A.
Physical Science Technician
California, MD

William P. Blair, Ph.D.
Research Professor
Department of Physics and Astronomy
Johns Hopkins University
Towson, MD

David Blewett, Ph.D.
Laurel, MD

Robert M. Brown, M.A.
Parkville, MD

William Richard Bua, Ph.D.
Project Scientist
Laurel, MD

Mary C. Bunting, M.A.
Towson, MD

Marcus Chibucos, Ph.D.
Bioinformatics Analyst
Columbia, MD

Carson C. Chow, Ph.D.
Baltimore, MD

Thomas Cronin, Ph.D.
Professor
Ellicott City, MD

Laurette Cucuzza, M.P.H.
Silver Spring, MD

Elizabeth E. Dahl, Ph.D.
Assistant Professor
Department of Chemistry
Loyola University, Maryland
Baltimore, MD

Alan W. DeSilva, Ph.D.
Senior Research Scientist
Institute for Research in Electronics and Applied Physics
University of Maryland
Columbia, MD

Theodor Diener, Ph.D.
Distinguished University Professor Emeritus
College of Chemical and Life Sciences
University of Maryland
Beltsville, MD

Raymond L. Downs, Ph.D.
Cumberland, MD

Monique Dubois-dalcq, M.D.
(Retired)
Bethesda, MD

C. Mark Eakin, Ph.D.
Director
Silver Spring, MD

February 2011

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2,505 Endorsers

Mark Emerick, Ph.D.
Instructor
Department of Physiology
Emory University
Columbia, MD

Hermann Engelhardt, Ph.D.
Emeritus
Center of Environmental Sciences
University of Maryland
Frostburg, MD

Peter R. Eriksson, Ph.D.
National Institutes of Health
Rockville, MD

Michael J. Fennessy, M.A.
Research Scientist
Highland, MD

John F. Finerty, Ph.D.
Head
Damascus, MD

Eric W. Fons, M.A.
Assistant Professor
Department of Physics
Anne Arundel Community College
Arnold, MD

Chester Robert Frazier, M.A.
Baltimore, MD

Lorne K. Garrettson, M.D.
Professor Emeritus
Pediatrics and Environmental and Occupational Medicine
Schools of Medicine and Public Health
Emory University Sandy Spring, MD

W. Reid Goforth, Ph.D.
Biologist
Port Republic, MD

MaryAnn Gregory, Ph.D.
Westminster, MD

Claude Helene Guillemard, M.A.
Senior Lecturer
Towson, MD

Henry Hamburger, Ph.D.
Professor Emeritus
Department of Computer Science
George Mason University
Bethesda, MD

Ronald A. Hamlen, Ph.D.
Retired
Elkton, MD

Molly P. Hauck, Ph.D.
Kensington, MD

Allen Hirsh, Ph.D.
CEO
Cryobiophysica, Inc.
Silver Spring, MD

Larry D. Hothem
Bethesda, MD

Amy L. Huberman, M.D.
Baltimore, MD

Thomas F. Ihde, Ph.D.
Fisheries Ecosystem Modeler
Versar, Inc.
Lusby, MD

David W. Inouye, Ph.D.
Professor
Department of Biology
University of Maryland
College Park, MD

Grant Izmirlian, Ph.D.
Mathematical Statistician
Division of Cancer Prevention
National Cancer Institute
Germantown, MD

Stephen Jascourt, Ph.D.
Meteorologist
College Park, MD

Karen Jennings, M.A.
Geomorphologist
Annapolis, MD

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Arthur B. Karpas, Ph.D.
Takoma Park, MD

Daniel Bernard Kirk-Davidoff, Ph.D.
Adjunct Professor
Department of Atmospheric and Oceanic Science
University of Maryland
Columbia, MD

Ildiko M. Kovach, Ph.D.
Ordinary Professor, Biochemistry
Department of Chemistry
The Catholic University of America
Silver Spring, MD

Louis C. Kovacs, M.A.
White Plains, MD

Peter Lemkin, Ph.D.
North Potomac, MD

Edward Maibach, Ph.D.
Fairfax, MD

Michael Mayhew, Ph.D.
Principal
Synoptic LLC
Ocean City, MD

Robert E. McGaughy, Ph.D.
Senior Scientist (Retired)
Office of Research and Development
U.S. Environmental Protection Agency
Silver Spring, MD

Martha Marsh McJunkin, M.A.
Bethesda, MD

Janice Meier, Other
Gaithersburg, MD

Kenneth J. Mitchell, Ph.D.
Davidsonville, MD

Thomas Moench, M.D.
President
ReProtect, Inc.
Baltimore, MD

Raymond T. Moreland, Ph.D.
Frederick, MD

Megan O'Rourke, Ph.D.
Hyattesville, MD

Cindy L. Parker, M.D.
Assistant Professor
Department of Environmental Health Sciences
Bloomberg School of Public Health
Johns Hopkins University
Baltimore, MD

Harriette L. Phelps, Ph.D.
Professor Emeritus
University of the District of Columbia
Greenbelt, MD

Richard Reis, M.A.
Principal Engineer
Conservation Engineering
Silver Spring, MD

Robert Alan Resnik, Ph.D.
Bethesda, MD

Samantha Saalfield, Ph.D.
Sparks, MD

Leslie Sage, Ph.D.
Potomac, MD

Nicanor Zeta Saliendra, Ph.D.
Forest Biometeorologist
Center for Urban Environmental Research and Education
University of Maryland, Baltimore County
Catonsville, MD

James A. Sawitzke, Ph.D.
Senior Research Assistant
Frederick, MD

Jagadish Shukla, Ph.D.
Professor
Climate Modeling and Prediction
George Mason University
Calverton, MD

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Linda G. Silversmith, Ph.D.
Science Writer
Program Analyst
Rockville, MD

Jeffrey N. Stibick, Ph.D.
Staff Officer
Economic Development Program
U.S. Department of Agriculture
Riverdale, MD

Judith K. Temperley, Ph.D.
Retired
Joppa, MD

Kunhikrishnan Thengumthara, Ph.D.
Rockville, MD

Christopher Dennis Toscano, Ph.D.
Columbia, MD

Richard Elliott Tuck, M.A.
Bethesda, MD

Ernest Todd Waymon, M.A.
Retired
Silver Spring, MD

Theodore Weber, M.A.
Annapolis, MD

Raymond R. Weil, Ph.D.
Professor
Department of Science and Technology
University of Maryland
Hyattsville, MD

John Williams, Ph.D.
Elkton, MD

William E. Williams, Ph.D.
Professor
Department of Biology
St. Mary's College of Maryland
Dameron, MD

Allen Yun, Ph.D.
Rockville, MD

MASSACHUSETTS

Steven M. Adler-Golden, Ph.D.
Leader Passive Sensing Group
Spectral Sciences Inc.
Newtonville, MA

Revathi Ananthakrishnan, Ph.D.
Cambridge, MA

George Avrunin, Ph.D.
Professor and Department Head
Department of Mathematics and Statistics
University of Massachusetts, Amherst
Amherst, MA

Tobias I. Baskin, Ph.D.
Professor
Department of Biology
University of Massachusetts, Amherst
Amherst, MA

Richard H. Behrman, Ph.D.
Medical Physicist
Brookline, MA

Sarah-Marie Belcastro, Ph.D.
Hadley, MA

Patricia Downs Berger, M.D.
Brookline, MA

Doris E. Berger, M.D.
Brookline, MA

Bengt E. Bjarngard, Ph.D.
Winchester, MA

Van Bluemel, Ph.D.
Professor Emeritus
Department of Physics
Worcester Polytechnic Institute
Holden, MA

Ian Boardman, Ph.D.
Boston University
Arlington, MA

February 2011

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Eric Bourgeois, Ph.D.
Adjunct Professor
Cambridge, MA

Erin Boyd
Doctoral Candidate
Research Assistant
Department of Physics
Harvard University
Somerville, MA

Nancy M. Caffall, M.A.
Florence, MA

Sherri J. Carlson
Master's Candidate
Wakefield, MA

Susan D. Chapnick, M.A.
Principal Scientist
New Environmental Horizons, Inc.
Arlington, MA

Gib L. Chase, M.A.
Northboro, MA

Priscilla W. Chew, M.P.H.
Somerville, MA

William C. Clark, Ph.D.
Professor
Kennedy School of Government
Harvard University
Watertown, MA

Rachel Cleetus, Ph.D.
Climate Economist
Department of Climate and Energy
Union of Concerned Scientists
Cambridge, MA

Peter Clote, Ph.D.
Professor
Department of Biology
Boston College and Ecole Polytechnique
Chestnut Hill, MA

Lawrence Brent Cohen, M.A.
South Easton, MA

Richard G. Collins, M.A.
Maynard, MA

Heather Colman-McGill, M.A.
Cambridge, MA

Maureen H. Conte, Ph.D.
Faculty
Department of Oceanography
Bermuda Institute of Ocean Sciences
Falmouth, MA

Robert C. Cooper, Ph.D.
Wellesley, MA

Anthony D. Cortese, Ph.D.
President
Second Nature, Inc.
Cambridge, MA

Jim M. Corven, Ph.D.
Professor
Science, Mathematics, and Engineering
Bristol Community College
Sandwich, MA

R. Wayne Crandlemere, M.A.
Environmental Professional
R. W. Crandlemere, LLC
Holbrook, MA

Sam Crawford
Doctoral Candidate
Department of Materials Science and Engineering
Massachusetts Institute of Technology
Somerville, MA

Trina Cysz, M.P.H.
Belchertown, MA

Caroline Lund Dahlberg, Ph.D.
Boston, MA

William C. Dale, Ph.D.
East Longmeadow, MA

Eric A. Davidson, Ph.D.
Senior Scientist
The Woods Hole Research Center
Falmouth, MA

February 2011

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2,505 Endorsers

Oliver Deex, Ph.D.
Research Fellow (Retired)
Plastics Research
Longmeadow, MA

Rebecca Dell
Doctoral Candidate
Massachusetts Institute of Technology
Cambridge, MA

Valentina Di Santo
Doctoral Candidate
Boston, MA

S. Dingman, Ph.D.
Eastham, MA

Vincent E. Dionne, Ph.D.
Professor
Department of Biology
Boston University
Chestnut Hill, MA

Kerry Diskin, Ph.D.
Concord, MA

Bridget Dolan
Doctoral Candidate
Massachusetts Institute of Technology
Boston, MA

Alfred W. Eipper, Ph.D.
Fishery Scientist (Retired)
Easthampton, MA

James A. Fay, Ph.D.
Professor Emeritus
Mechanical Engineering
Massachusetts Institute of Technology
Weston, MA

David B. Fenner, Ph.D.
Principal Research Scientist
Photonics
Physical Sciences, Inc.
Westford, MA

Bernard J. Fine, Ph.D.
Senior Scientist
Northampton, MA

Jenny A. Fisher
Doctoral Candidate
Department of Earth and Planetary Sciences
Harvard University
Mansfield, MA

David E. Fisher, Ph.D.
East Orleans, MA

Maria Flytzani-Stephanopoulos, Ph.D.
Winchester, MA

Peter J. Fried
Doctoral Candidate
Anatomy and Neurobiology
Boston University
Brighton, MA

Christopher O. Fried
Energy Consultant
Vineyard Haven, MA

Gene R. Heinze Fry, Ph.D.
Evaluation Manager
Conservation and Load Management
Northeast Utilities
Brookfield, MA

Robert R. Gamache, Ph.D.
Dunstable, MA

Geraldine Gamburd, Ph.D.
Professor
New Bedford, MA

Russell L. Gaulin, M.A.
Winchendon, MA

Arthur T. Gionti, M.D.
Amherst, MA

Susan Goldhor, Ph.D.
President
Center for Applied Regional Studies
Cambridge, MA

February 2011

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2,505 Endorsers

Neva R. Goodwin, Ph.D.
Co-Director
Global Development and Environment Institutions
Tufts University
Cambridge, MA

Neal C. Grasso, M.A.
Danvers, MA

Kenneth Green, M.A.
Concord, MA

Brian F. Gregor, Ph.D.
Waltham, MA

Jean Grossholtz, Ph.D.
Professor Emeritus
Department of Political Science
Mount Holyoke College
South Hadley, MA

Richard J. Hassinger
Master's Candidate
Newton, MA

Bruce Hawkins, Ph.D.
Professor Emeritus
Northampton, MA

Chris Hayward
Doctoral Candidate
Cambridge, MA

Richard Oliver Heck, M.D.
Great Barrington, MA

Beverly M. Hector-Smith, M.A.
Natick, MA

Alison Hill
Doctoral Candidate
Department of Biophysics
Harvard University
Somerville, MA

Donald J. Hnatowich, Ph.D.
Professor
Brookline, MA

Robert R. Holt, Ph.D.
Vice Chair
Truro, MA

Frank W. Hopkins, M.A.
Andover, MA

William M. Irvine, Ph.D.
Professor
Department of Astronomy
University of Massachusetts
Leverett, MA

Ileana Z. Jones, M.A.
Cambridge, MA

Ben Kagan
Doctor of Veterinary Medicine Candidate
North Grafton, MA

Ben Kerman, M.D.
Arlington, MA

David I. King, Ph.D.
Amherst, MA

Paul Kirshen, Ph.D.
Concord, MA

Peter B. Klausmeyer, Ph.D.
Engineer
Research and Development
Creative Engineering
Lexington, MA

Ara Ko
M.D. Candidate
Boston, MA

Charles E. Kolb, Ph.D.
President
CEO
Aerodyne Research Inc.
Bedford, MA

Jacob Krich, Ph.D.
Postdoctoral Fellow
Department of Chemistry
Harvard University
Cambridge, MA

February 2011

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2,505 Endorsers

Thomas Langelier, M.A.
Researcher
Somerville, MA

Miriam Leeser, Ph.D.
Wellesley Hills, MA

Bob Leet, M.A.
Professional Engineer
Whetstone Engineering
Wendell, MA

Susannah Beth Lerman
Doctoral Candidate
Amherst, MA

Susan Leschine, Ph.D.
Professor
Department of Microbiology
University of Massachusetts, Amherst
Amherst, MA

C. Peter Lillya, Ph.D.
Professor Emeritus
Department of Chemistry
University of Massachusetts
Amherst, MA

Amanda Lincoln
Doctor of Veterinary Medicine Candidate
Hudson, MA

Zenos M. Linnell, M.D.
Psychiatry Emeritus
McLean Hospital
Harvard Medical School
Cambridge, MA

Tom S. Litwin, Ph.D.
Director
Whately, MA

Niall Mangan
Doctoral Candidate
Consortium on Energy and Environment
Harvard University
Cambridge, MA

G. K. Maravelas, Ph.D.
Volunteer
Coalition for Social Justice
Fairhaven, MA

David J. Marcus, Ph.D.
Somerville, MA

John Martin, Ph.D.
Principal
Foxborough, MA

Robert K. McConnell, Ph.D.
Arlington, MA

Tegan Morton
Doctoral Candidate
Somerville, MA

Lynne Mullen, Ph.D.
Somerville, MA

John Earl Naugle, Ph.D.
North Falmouth, MA

Julie A. Nelson, Ph.D.
Associate Professor
Department of Economics
University of Massachusetts, Boston
West Newton, MA

John A. Nevin, Ph.D.
Professor Emeritus
Department of Psychology
University of New Hampshire
Vineyard Haven, MA

Robert Noyes, Ph.D.
Professor Emeritus
Department of Astronomy
Harvard University
Arlington, MA

Rick A. Oches, Ph.D.
Associate Professor
Natural and Applied Sciences
Bentley University
Waltham, MA

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Jacqueline Olds, M.D.
Associate Clinical Professor
Department of Psychiatry
Harvard Medical School
Cambridge, MA

Jason Otterstrom
Master's Candidate
Somerville, MA

Mary Paradise, M.D.
Professor Emeritus
Department of Pediatrics
University of Pittsburgh School of Medicine
Belmont, MA

Augustin H. Parker, M.A.
Marblehead, MA

Charles H. Patterson, D.V.M.
Norwell, MA

Richard E. Payne, Ph.D.
Oceanographer Emeritus
Department of Physical Oceanography
Woods Hole Oceanographic Institution
West Falmouth, MA

Robert Allen Petersen, M.D.
Cambridge, MA

Paul D. Peterson, Ph.D.
Medway, MA

Walter C. Phillips, Ph.D.
Arlington, MA

Christopher M. Picone, Ph.D.
Assistant Professor
Department of Biology and Chemistry
Fitchburg State University
Ashburnham, MA

Marc A. Plante, Ph.D.
Middleton, MA

Rui M. Ponte, Ph.D.
Cambridge, MA

Monroe S. Rabin, Ph.D.
Amherst, MA

Jason R. Racela, M.A.
Adams, MA

Christine Esber Richardson, Ph.D.
Northborough, MA

Juliette N. Rooney-Varga, Ph.D.
Lowell, MA

Beth J. Rosenberg, Ph.D.
Somerville, MA

Judy Francis Rosenblith, Ph.D.
Professor Emerita
Marstons Mills, MA

Kristen S. Rounds, M.A.
Rowley, MA

Leonard M. Rubin, Ph.D.
South Hamilton, MA

Peter A. Sampou, Ph.D.
West Barnstable, MA

Jeffrey Michael Schell, Ph.D.
Faculty Oceanographer
Chief Scientist
Department of Oceanography
Sea Education Association
Woods Hole, MA

Sybil E. Schlesinger, Ph.D.
Natick, MA

Peter E. Schmidt, Ph.D.
Newtonville, MA

George O. Schneider, M.A.
Foxboro, MA

Daniel K. Scholten, M.A.
Carlisle, MA

David G. Schowalter, Ph.D.
Holden, MA

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2,505 Endorsers

Robert T. Seeley, Ph.D.
Newton Highlands, MA

Mark Sentesy
Doctoral Candidate
Brookline, MA

Douglas R. Shanklin, M.D.
Woods Hole, MA

Nathan T. Sidley, M.D.
Psychiatrist
Lexington, MA

David M. Sills, M.A.
Rehabilitation Specialist
Easthampton, MA

Arnold Simmel, Ph.D.
Adjunct Assistant Professor (Retired)
Cummington, MA

Gary Dean Simmons, M.A.
Oak Bluffs, MA

Carlos Eduardo Siqueira, M.D.
Assistant Professor
Department of Community Health and Sustainability
University of Massachusetts, Lowell
Boston, MA

Elske V.P. Smith, Ph.D.
Professor Emeritus
Department of Physics
Virginia Commonwealth University
Lenox, MA

Hilary Todd Snook, M.A.
Environmental Scientist
Merrimac, MA

D. P. Snyder, Ph.D.
Professor Emeritus
Amherst, MA

Lawrence Spatz, Ph.D.
Clinical Chemist
Lanesboro, MA

Richard S. Stein, Ph.D.
Goessmann Professor of Chemistry Emeritus
Department of Chemistry
University of Massachusetts
Amherst, MA

David W. J. Stein, Ph.D.
Newton, MA

David W. Tarbell, M.A.
Retired
Middlefield, MA

Max Tegmark, Ph.D.
Professor
Cambridge, MA

John Joseph Titus
Master's Candidate
Jefferson, MA

John Tomaszewski, Ph.D.
Andover, MA

Frona Brooks Vicksell, M.A.
Navigation Software Engineer
Concord, MA

Suzanne Hall Vogel, M.A.
Senior Clinical Social Work Supervisor
Mental Health Unit
Harvard University Health Services
Cambridge, MA

Sidney H. Wanzer, M.D.
Concord, MA

Tony Louis Watt, M.A.
Cambridge, MA

Marc Weiss, Ph.D.
Brewster, MA

Daniel B. Weissman, Ph.D.
Cambridge, MA

Richard E. Wetzler, Ph.D.
Director
International Ecological Assessment Institute
Reading, MA

February 2011

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Nicholas R. White, Ph.D.
President
Manchester, MA

Leah R. Williams, Ph.D.
Principal Scientist
Center for Aerosol and Cloud Chemistry
Aerodyne Research, Inc.
Cambridge, MA

Guy Williamson, M.A.
Process Control Engineer
Clinton, MA

Ron L. Willig, M.A.
Principal Engineer
Draper Laboratory
Maynard, MA

Francis T. Worrell, Ph.D.
Retired
Harwich, MA

Richard T. Wright, Ph.D.
Byfield, MA

Jessica Wu, M.A.
Department of Chemistry and Chemical Biology
Harvard University
Somerville, MA

Peter C. Yeager, Ph.D.
Professor
Department of Sociology
Boston University
Framingham, MA

Kayvan Zainabadi, Ph.D.
Boston, MA

Marc James Zimmerman, Ph.D.
Hudson, MA

MICHIGAN

Rolf Amsler, M.A.
Saline, MI

Norman A. Andresen, Ph.D.
Ypsilanti, MI

Brian Arbic, Ph.D.
Professor
Department of Geological Sciences
University of Michigan
Ann Arbor, MI

Jerald G. Bachman, Ph.D.
Research Professor
Gregory, MI

John R. Barker, Ph.D.
Professor
Department of Atmospheric Oceanic and Space Sciences
University of Michigan
Ann Arbor, MI

Brent W. Barker
Doctoral Candidate
Research Assistant
East Lansing, MI

Julia A. Bell, Ph.D.
Assistant Professor
Holt, MI

Steve Bertman, Ph.D.
Professor
Department of Chemistry
Western Michigan University
Kalamazoo, MI

Goran E. Blomberg, Ph.D.
Wildlife Ecologist
Lansing, MI

Sarr Blumson, M.A.
Ann Arbor, MI

Robyn Burnham, Ph.D.
Chelsea, MI

Lowell Byrd, Ph.D.
Algonac, MI

Harry Carr
Doctoral Candidate
Grand Rapids, MI

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Mary Anne Carroll, Ph.D.
Professor
Department of Atmospheric Oceanic and Space Sciences
University of Michigan
Ann Arbor, MI

Paul Carson, Ph.D.
Professor
Department of Radiology
University of Michigan
Ann Arbor, MI

Kevin M. Crupi, M.A.
Lead Forecaster
Negaunee, MI

Melvin R. Dickerson, Ph.D.
Tecumseh, MI

Stephen S. Easter, Ph.D.
Ann Arbor, MI

Ralph C. Eckerberg
Crystal Falls, MI

John Erickson, M.A.
Southgate, MI

Emily C. Farrer, Ph.D.
Postdoctoral Scientist
Ann Arbor, MI

Ted R. Feldpausch, Ph.D.
Fowler, MI

Carol Fergus
Master's Candidate
East Lansing, MI

Daniel C. Fisher, Ph.D.
Professor
Curator
University of Michigan
Ann Arbor, MI

Harley Flanders, Ph.D.
Professor
Ann Arbor, MI

Johannes Foufopoulos, Ph.D.
Associate Professor
School of Natural Resources and Environment
University of Michigan
Ann Arbor, MI

Gerald T. Gardner, Ph.D.
Professor Emeritus
Department of Behavioral Sciences
University of Michigan, Dearborn
Ann Arbor, MI

Robert Gelman, M.A.
Ann Arbor, MI

Sharon Gill, Ph.D.
Assistant Professor
Department of Biological Sciences
Western Michigan University
Kalamazoo, MI

Jonathan Gold
Doctoral Candidate
East Lansing, MI

Sharon Gourdji
Doctoral Candidate
Ann Arbor, MI

Sarah A. Green, Ph.D.
Chair and Professor
Department of Chemistry
Michigan Technological University
Calumet, MI

Eldon D. Greij, Ph.D.
Professor Emeritus
Department of Biology
Hope College
Holland, MI

Richard Han, D.D.S.
Ann Arbor, MI

Sharon Handy, M.D.
Medical Doctor
Grand Rapids, MI

February 2011

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2,505 Endorsers

Elaine C. Harmon, M.A.
Family Clinical Nurse Specialist
Traverse City, MI

Robert Lee Henderson, M.A.
Mason, MI

Joseph W. Hess, M.D.
East Lansing, MI

Alice Hudder, Ph.D.
Assistant Professor
Institute of Environmental Health Science
Wayne State University
Detroit, MI

Jennifer Johnson
Doctoral Candidate
University of Michigan
Ann Arbor, MI

Larry Junck, M.D.
Professor
Department of Neurology
University of Michigan
Ann Arbor, MI

Thonas A. Kaplan, Ph.D.
Professor Emeritus
East Lansing, MI

David N. Karowe, Ph.D.
Professor
Department of Biological Sciences
Western Michigan University
Kalamazoo, MI

Mary E. Karpen, Ph.D.
Grand Rapids, MI

Susan Elizabeth Kennedy, Ph.D.
Ann Arbor, MI

Kirk T. Korista, Ph.D.
Professor
Department of Physics
Western Michigan University
Portage, MI

Samuel Krimm, Ph.D.
Professor Emeritus
Department of Physics
University of Michigan
Ann Arbor, MI

Serge Kruk, Ph.D.
Associate Professor
Department of Mathematics
Oakland University
Shelby Township, MI

Jerry T. Lang, Ph.D.
Muskegon, MI

Scot Valdis Libants
Doctoral Candidate
Lansing, MI

Thomas Lyon, Ph.D.
Professor
Ross School of Business
University of Michigan
Ann Arbor, MI

Sheila Lyons-Sobaski, Ph.D.
Assistant Professor
Department of Biology
Albion College
Albion, MI

Philip P. Micklin, Ph.D.
Professor Emeritus
Department of Geography
Western Michigan University
Kalamazoo, MI

Anja Mueller, Ph.D.
Mt Pleasant, MI

Jodi Nachtwey, Ph.D.
Royal Oak, MI

Gayl D. Ness, Ph.D.
Professor Emeritus
Department of Sociology
University of Michigan
Ann Arbor, MI

February 2011

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2,505 Endorsers

Jack G. Norris
Director Emeritus
Water Quality Commission
Three Lakes Association
Kewadin, MI

Lewis Okun, Ph.D.
Proprietor
Consultant
Ann Arbor, MI

Stella Papasavva, Ph.D.
Senior Environmental Consultant
Stella Papasavva Consulting
Royal Oak, MI

Donald Pelz, Ph.D.
Research Scientist Emeritus
Institute for Social Research
University of Michigan
Ypsilanti, MI

Ivette Perfecto, Ph.D.
George W. Pack Professor
School of Natural Resources and Environment
University of Michigan
Ann Arbor, MI

Udo C. Pernisz, Ph.D.
Consultant
Midland, MI

David Kenneth Pitts, Ph.D.
Associate Professor
Detroit, MI

Henry N. Pollack, Ph.D.
Professor Emeritus
Department of Geological Sciences
University of Michigan
Ann Arbor, MI

Hans Posselt, Ph.D.
Dexter, MI

Chris Poulsen, Ph.D.
University of Michigan
Ann Arbor, MI

Ralph Powell, Ph.D.
Ann Arbor, MI

Mike R. Raymond, M.A.
Warren, MI

Georgia F. Richards, D.V.M.
Veterinarian
Kentwood, MI

Dana L. Richter, Ph.D.
Research Scientist
Michigan Technological University
Hancock, MI

Karel L. Rogers, Ph.D.
Professor Emeritus
Department of Biology
Grand Valley State University
West Olive, MI

Alvin M. Saperstein, Ph.D.
Wayne State University
Detroit, MI

Elke Schoffers, Ph.D.
Professor
Kalamazoo, MI

Natalie Schroeder
Jackson, MI

Amy E. Scrima, Ph.D.
St. Joseph, MI

Philip T. Shepard, Ph.D.
Professor Emeritus
Department of Philosophy
Lyman Briggs College
Michigan State University
East Lansing, MI

Barry D. Solomon, Ph.D.
Professor
Department of Social Sciences
Michigan Tech University
Houghton, MI

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Susan A. Starr, M.A.
Adjunct Instructor
Department of Life Sciences
Washtenaw Community College
University of Michigan
Pinckney, MI

R. Jan Stevenson, Ph.D.
Professor
Department of Zoology
Michigan State University
East Lansing, MI

Bryan Thibodeau, Ph.D.
Farmington Hills, MI

Greg Thompson, Ph.D.
Assistant Professor
Tecumseh, MI

Jack Vandervelde, Ph.D.
Department of Physics
University of Michigan
Ann Arbor, MI

Robert H. Wasserman, Ph.D.
East Lansing, MI

Heather Elizabeth Wendel
Doctoral Candidate
Chassell, MI

Anne E. Wiley
Department of Zoology
Michigan State University
East Lansing, MI

Genevieve Willson, M.A.
Kalamazoo, MI

Paul Winder, M.A.
Ann Arbor, MI

Warren Wilbur Wood, Ph.D.
Professor
Department of Geological Sciences
Michigan State University
East Lansing, MI

MINNESOTA

David E. Adson, M.D.
Adjunct Associate Professor
Department of Psychiatry
University of Minnesota
Saint Paul, MN

Paul M. Anderson, Ph.D.
Professor Emeritus
Duluth, MN

Cindy K. Angerhofer, Ph.D.
Executive Director of Botanical Research
Circle Pines, MN

Sara Ellen Barsel, Ph.D.
Professor
Roseville, MN

Char Anne Bezanson, M.A.
Science Teacher
Faribault High School
Northfield, MN

Dragoljub Bilanovic, Ph.D.
Professor
Center for Environmental Studies
Bemidji State University
Bemidji, MN

Cyrus Bina, Ph.D.
Distinguished Research Professor of Economics
University of Minnesota, Morris
Alexandria, MN

Elizabeth Conanat Brackett, M.D.
Physician
Family Medicine
Health Partners
Minneapolis, MN

Lois C. Braun, Ph.D.
Postdoctoral Research Associate
Department of Agronomy and Plant Genetics
University of Minnesota
Saint Paul, MN

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Jeffrey P. Broadbent, Ph.D.
Associate Professor
Department of Sociology
University of Minnesota
Minneapolis, MN

Michael Callahan, M.A.
Executive Director
Bloomington, MN

Anne Claflin
Master's Candidate
Humphrey Institute of Public Affairs
University of Minnesota
South St. Paul, MN

Jay Coggins, Ph.D.
Associate Professor
Department of Applied Economics
University of Minnesota
St Paul, MN

David L. Councilman, M.D.
Minneapolis, MN

Peter J. Czoschke, Ph.D.
Bloomington, MN

Jason M. Dahl
Doctoral Candidate
Bemidji, MN

Alexander Egan
Doctoral Candidate
Minneapolis, MN

Simon K. Emms, Ph.D.
Associate Professor
Department of Biology
University of St. Thomas
St. Paul, MN

Gary C. Fifield, M.D.
Saint Paul, MN

Michael Dean Foreman
Professional Engineer
Water/Wastewater Consultant
Hakanson Anderson Associates, Inc.
Apple Valley, MN

Lee E. Frelich, Ph.D.
Director
Center for Hardwood Ecology
Department of Forest Resources
University of Minnesota
Saint Paul, MN

Steven L. Girshick, Ph.D.
Professor
Department of Mechanical Engineering
University of Minnesota
Minneapolis, MN

Ronald C. Haglind, M.A.
Engineer (Retired)
Chanhassen, MN

J. Woods Halley, Ph.D.
University of Minnesota
Minneapolis, MN

Vicki L. Hansen, Ph.D.
Professor
Department of Geological Sciences
University of Minnesota, Duluth
Duluth, MN

Evan B. Hazard, Ph.D.
Professor Emeritus
Department of Biology
Bemidji State University
Bemidji, MN

Thomas Herdtle, Ph.D.
Inver Grove Heights, MN

Lisa Herschberger, M.P.H.
Environmental Research Scientist
Bloomington, MN

Amihan S. Huesmann, Ph.D.
Minneapolis, MN

Anne Maria Indrelie, M.A.
Mahtomedi, MN

Kristina Jensen, Ph.D.
Hopkins, MN

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Roger S. Jones, Ph.D.
Minneapolis, MN

Roman Kanivetsky, Ph.D.
University of Minnesota
St. Paul, MN

Marilyn Jean Kennedy, Ph.D.
Minneapolis, MN

Gregory King, M.A.
Product Development Specialist
Minneapolis, MN

Eric Klinger, Ph.D.
Professor Emeritus
Department of Psychology
University of Minnesota, Morris
Morris, MN

Joe P. Kuczynski, Ph.D.
Rochester, MN

Harry A. Lando, Ph.D.
Distinguished International Professor
Saint Paul, MN

Beau Lee Liddell, M.A.
Little Falls, MN

Arnold L. London, M.D.
Pediatrician
Aspen Medical Group
Mendota Heights, MN

John R. MacDonald, Ph.D.
Excelsior, MN

Dee Mcmanus, M.A.
St. Paul, MN

Nancy Jane McMullen, M.A.
Science Teacher (Retired)
Saint Paul, MN

Stacy A. Miller, M.A.
Solar Program Administrator
St. Paul, MN

Robert Francis Miller, M.D.
Professor
Department of Neuroscience
University of Minnesota
Eden Prairie, MN

Steven M. Miller, Ph.D.
Rochester, MN
Herbert Dick Mohring, Ph.D.
Professor Emeritus
Department of Economics
University of Minnesota
Minneapolis, MN

Ah-li Monahan, M.A.
Columbia Heights, MN

Julia Frost Nerbonne, Ph.D.
Minneapolis, MN

Raymond M. Newman, Ph.D.
Professor
Department of Fish Wildlife and Conservation Biology
University of Minnesota
Saint Paul, MN

Richard Olson, M.A.
Minneapolis, MN

Richard Patten, Ph.D.
Associate Professor Adjunct
Minneapolis, MN

Walter C. Pearson
Saint Paul, MN

Parker Quammen, Ph.D.
Zumbrota, MN

Earl R. Rosenwinkel, Ph.D.
Duluth, MN

Bernie Schatz, M.A.
Teacher
Minneapolis, MN

February 2011

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Louis Schwartzkopf, Ph.D.
Professor Emeritus
Department of Physics and Astronomy
Minnesota State University, Mankato
Mankato, MN

Robert W. Seidel, Ph.D.
Professor
Minneapolis, MN

Ruth G. Shaw, Ph.D.
Professor
Department of Ecology Evolution and Behavior
University of Minnesota
Roseville, MN

Bruce H. Sielaff, Ph.D.
Minneapolis, MN

David E. Siskind, Ph.D.
Retired
Minneapolis, MN

Christopher Smith
Master's Candidate
Research Assistant
Department of Fisheries Wildlife and Conservation Biology
University of Minnesota
Saint Paul, MN

Bradley K. Snyder
Master's Candidate
Mechanical Engineer
Science Teacher
Maple Grove, MN

William Kenneth Steele, Ph.D.
Professor Emeritus
Department of Geology
Eastern Washington University
Bovey, MN

Edward G. Stewart, Ph.D.
Zimmerman, MN

Pamela Thinesen, M.A.
Biology Faculty and Sustainability Coordinator
White Bear Lake, MN

Steven Usdansky, Ph.D.
Faribault, MN

Joel M. Weisberg, Ph.D.
Stark Chair of Physics and Astrology and Natural Science
Department of Physics and Astronomy
Carleton College
Northfield, MN

Sue Mary Wick, Ph.D.
Professor
St. Paul, MN

John David Yount, Ph.D.
Duluth, MN

Catherine D. Zimmer, M.A.
Principal
Zimmer Environmental Improvement, LLC
Saint Paul, MN

MISSISSIPPI

Janet L. Black, M.P.H.
Advanced Registered Nurse Practitioner
Hattiesburg, MS

Luca Bombelli, Ph.D.
Associate Professor
Department of Physics and Astronomy
University of Mississippi
Oxford, MS

Bruce Emerick
Carriere, MS

William Charles Goggin, Ph.D.
Hattiesburg, MS

Swink Hicks, M.D.
Madison, MS

James Lazell, Ph.D.
President
Headquarters
The Conservation Agency
Jackson, MS

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Glen Sandberg, M.A.
Gulfport, MS

MISSOURI

James O. Allen, Ph.D.
Hermann, MO

Wendy Anderson, Ph.D.
Professor of Biology
Department of Biology
Drury University
Springfield, MO

John E. Bauman, Ph.D.
Professor Emeritus
Columbia, MO

Carl M. Bender, Ph.D.
Konneker Distinguished Professor of Physics
Department of Physics
Washington University in St Louis
Saint Louis, MO

Claude Bernard, Ph.D.
Professor
Department of Physics
Washington University
Saint Louis, MO

Joan R. Butcher, M.D.
Saint Louis, MO

Juanita L. Carl, M.A.
Research Instructor (Retired)
University City, MO

Larry Wilbur Conant, M.D.
Psychological Examiner
Psychotherapist
Early Childhood Special Education
Ferguson-Florissant School District
Saint Louis, MO

Don Crozier, M.A.
O'Fallon, MO

Willem H. Dickhoff, Ph.D.
Professor
Department of Physics
Washington University in St. Louis
Saint Louis, MO

Taner Edis, Ph.D.
Associate Professor
Department of Physics
Truman State University
Kirksville, MO
Robert L. Elgin, Ph.D.
Saint Louis, MO

Carmen Federowich, M.D.
Monroe City, MO

Christine A. Garhart, Ph.D.
Saint Louis, MO

Alan R.P. Journet, Ph.D.
Project Manager
ClimateWise
Geos Institute
Cape Girardeau, MO

A. J.C. Lenox, M.A.
Saint Louis, MO

Judith M. Misale, Ph.D.
Kirksville, MO

Lopamudra Mohanty, M.A.
St. Peters, MO

Stephen E. Mudrick, Ph.D.
Columbia, MO

Jitka Olander, Ph.D.
Saint Louis, MO

Stephen R. Overmann, Ph.D.
Director of Environmental Science
Department of Environmental Science
Southeast Missouri State University
Cape Girardeau, MO

Miles L. Patterson, Ph.D.
Kirkwood, MO

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David Pollack, M.A.
Saint Louis, MO

Fhvjh Smith, M.D.
Kirksville, MO

Patricia P. Tursi, Ph.D.
Springfield, MO

Alexander Wait, Ph.D.
Professor
Department of Biology
Missouri State University
Springfield, MO

Charles J. Wurrey, Ph.D.
Professor
Department of Chemistry
University of Missouri
Kansas City, MO

MONTANA

Norman A. Bishop
Master's Candidate
Bozeman, MT

Robert G. Byron, M.D.
Hardin, MT

John Christopher, Ph.D.
Belgrade, MT

Janelle G. Corn, Ph.D.
Florence, MT

Eric Grimsrud, Ph.D.
Professor Emeritus
Department of Chemistry
Montana State University
Kalispell, MT

Donald W. Hyndman, Ph.D.
Professor Emeritus
Department of Geosciences
Retired
Missoula, MT

Craig Jolley, Ph.D.
Postdoctoral Research Associate
Department of Chemistry and Biochemistry
Montana State University
Bozeman, MT

Gordon G. Levin
Master's Candidate
Senior Scientist
Helena, MT

Kathleen B. Masis, M.D.
Billings, MT

Anthony J. Mccue
Master's Candidate
Ennis, MT

Twila Moon
Doctoral Candidate
Big Sky, MT

Dara Newman, Ph.D.
Missoula, MT

Geoffrey Poole, Ph.D.
Assistant Professor
Department of Land Resources and Environmental Sciences
Montana State University
Bozeman, MT

Steven Running, Ph.D.
Regents Professor
Department of Ecosystem Science
University of Montana
Missoula, MT

Scott Samuels, Ph.D.
Missoula, MT

Anthony M. Szpilka, Ph.D.
Professor
Department of Natural Science
Carroll College
Helena, MT

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NEBRASKA

Lelia M. Coyne, Ph.D.
Lincoln, NE

William Henry Hay, M.D.
Clinical Associate Professor
Family Medicine
University of Nebraska Medical Center
Omaha, NE

John A. Pollack, M.A.
Omaha, NE

Julia Torquati, Ph.D.
Lincoln, NE

NEVADA

Willliam Charles Belknap, M.A.
Boulder City, NV

Howard G. Booth, M.A.
Supervising Meteorologist (Retired)
National Weather Service
National Oceanic and Atmospheric Administration
Boulder City, NV

Peter F. Brussard, Ph.D.
Professor Emeritus
Department of Biology
University of Nevada
Reno, NV

Michael A. Crognale, Ph.D.
Professor
University of Nevada Reno
Reno, NV

Craig Downer
Doctoral Candidate
Minden, NV

Rosemary French, M.A.
Reno, NV

William Ted Hartwell, M.A.
Project Director
Community Environmental Monitoring Program
Division of Earth and Ecosystem Sciences
Desert Research Institute
Las Vegas, NV

Susan Hastings, Ph.D.
Reno, NV

Harrie F. Hess, Ph.D.
Professor Emeritus
Mesquite, NV

D. James Lawrie, M.D.
Reno, NV

David Mitchell, Ph.D.
Associate Research Professor
Department of Atmospheric Sciences
Desert Research Institute
Reno, NV

Rob Mrowka, M.A.
Ecologist
North Las Vegas, NV

Anga Rebane, M.A.
Environmental Biology Instructor
Incline Village, NV

Michael G. Robinson, Ph.D.
Professor
Department of Curriculum Teaching and Learning
University of Nevada
Reno, NV

William Schaffer, Ph.D.
Las Vegas, NV

David H. VonSeggern, Ph.D.
Emeritus
Nevada Seismological Laboratory
University of Nevada
Reno, NV

Sharon Marie Wilcox, M.A.
Reno, NV

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NEW HAMPSHIRE

Alex Barnett, Ph.D.
Assistant Professor
Department of Mathematics
Dartmouth College
Hanover, NH

John Bidwell
Grafton, NH

Ian D. Bier, Ph.D.
Durham, NH

Jeb E. Byers, Ph.D.
University of New Hampshire
Durham, NH

Paul H. Carr, Ph.D.
Fellow
Electrical and Electronic Engineers
Bedford, NH

Chris C. Chabot, Ph.D.
Professor
Department of Biological Science
Plymouth State University
Campton, NH

Anna Cloitre
Master's of Public Health Candidate
Dover, NH

Ellen Marie Douglas, Ph.D.
Assistant Professor
Environmental, Earth and Ocean Sciences
University of Massachusetts, Boston
Portsmouth, NH

Scot L. Drysdale, Ph.D.
Professor
Department of Computer Science
Dartmouth College
Hanover, NH

Kevin Flanagan, M.P.H.
Concord, NH

Fred Marvin Gardner
Doctoral Candidate
Durham, NH

Filson H. Glanz, Ph.D.
Professor Emeritus
Durham, NH

Arthur Greenberg, Ph.D.
Professor
Former Dean Engineering and Physical Science
Department of Chemistry
University of New Hampshire
Rye, NH

Kedar Gupta, Ph.D.
CEO
ARC Energy
Hollis, NH

John M. Halstead, Ph.D.
Professor and Chair
Department of Natural Resources and the Environment
University of New Hampshire
Lee, NH

Rick Harnden, Ph.D.
Program Scientist (Retired)
Deputy Director
National Aeronautics and Space Administration
Smithsonian Institution
New Ipswich, NH

Richard B. Howarth, Ph.D.
Pat and John Rosenwald Professor
Environmental Studies Program
Dartmouth College
Hanover, NH

Daniel Hubbard, Ph.D.
Program Manager
Virology and Special Testing
New Hampshire Public Health Laboratories Retired
Rochester, NH

February 2011

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Phillip R. Hunt, Ph.D.
Senior Research Associate
Center for Epidemiology and Database Analysis
United Biosource Corporation
Newfields, NH

Philip Johnson, M.A.
Systems Engineer
Durham, NH

Anne R. Kapuscinski, Ph.D.
Professor
Environmental Studies Program
Dartmouth College
Hanover, NH

Kenneth D. Kimball, Ph.D.
Director of Research
Research Department
Appalachian Mountain Club
Gorham, NH

Walter King, Ph.D.
Dover, NH
Marian Litvaitis, Ph.D.
Durham, NH

Laura Ruth Magzis, Ph.D.
Psychologist
Penacook, NH

Tyler Maikath
Master's Candidate
Department of Environmental Studies
Antioch University New England
Keene, NH

Bill W. Mautz, Ph.D.
Professor
Department of Natural Resources and the Environment
University of New Hampshire
Portsmouth, NH

Eric K. McCall, Ph.D.
Peterborough, NH

Elizabeth M. Mello, M.A.
Tech Coordinator
Teaching Assistant
Kingston, NH

Patrick Miller, M.P.H.
Research Associate Professor
New Hampshire Institute for Health Policy and Practice
University of New Hampshire
Campton, NH

Chuck Mitchell, M.A.
Consultant
Center Harbor, NH

David C. Montgomery, Ph.D.
Professor Emeritus
Department of Physics and Astronomy
Dartmouth College
Hanover, NH

Kristin Noel, M.A.
Laboratory Industrial Pretreatment Tech
Chichester, NH

Rachel M. Norris, D.V.M.
Mason, NH

Aaron S. Osofsky, Ph.D.
Clinical Psychologist
Hanover, NH

Michael J. O'Sullivan, Ph.D.
Associate Professor (Retired)
Department of Community Health and Sustainability
University of Massachusetts, Lowell
Madbury, NH

Brian Penney, Ph.D.
Associate Professor
Department of Biology
Saint Anselm College
Manchester, NH

John Pierce, M.A.
Senior Architect
Temple, NH

February 2011

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Brian J. Premore, Ph.D.
Lebanon, NH

Jerome L. Rekart, Ph.D.
Associate Professor
Department of Education
Department of Psychology
Rivier College
Hudson, NH

Barrett N. Rock, Ph.D.
Professor
Department of Natural Resources and the Environment
University of New Hampshire
Durham, NH

Lynn Rutter, M.A.
Fisheries and Oceans Program Coordinator
Ocean Process Analysis Laboratory
University of New Hampshire
Portsmouth, NH

Karen Schreiber
Master's of Public Health Candidate
Durham, NH

Hilda Weyl Sokol, Ph.D.
Professor Emeritus
Hanover, NH

Amy Stillings, M.A.
Senior Economist
Manchester, NH

Bill W. Stine, Ph.D.
Department of Psychology
University of New Hampshire
Durham, NH

Ryan T. Storey, D.V.M.
Mason, NH

Larry B. Sunderland, M.A.
Vice Chair
New Hampshire Lakes Management Advisory Committee
Hillsborough, NH

John N. Walter, M.P.H.
Keene, NH

Tom W. Wansleben, M.A.
Keene, NH

David L. Webb, Ph.D.
Professor
Hanover, NH

Richard Widhu, Ph.D.
Physical Chemistry
Nashua, NH

Mark Windt, M.D.
Physician
Pulmonary Medicine
Center for Asthma Allergy and Respiratory Disorders
North Hampton, NH

NEW JERSEY

Jonathan Allen, Ph.D.
Physicist
RF Electronics Consulting
Titusville, NJ

Daniel G. Baransky, M.A.
Milford, NJ

Thomas Barringer, Ph.D.
Stockton, NJ

Wolfgang Benz, Ph.D.
West Orange, NJ

Theodore Chase, Ph.D.
Professor Emeritus
Department of Biochemistry and Microbiology
Rutgers University
Princeton, NJ

Mark J. Chopping, Ph.D.
Department of Earth and Environmental Studies
Montclair State University
Montclair, NJ

Janine Chupa, Ph.D.
Princeton, NJ

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2,505 Endorsers

Harvey S. Cohen, Ph.D.
Middletown, NJ

Robert Cooper
Doctoral Candidate
Princeton, NJ

Stefano Carlo Crema, Ph.D.
President
Cooling America thru Local Leadership
Denville, NJ

William J. Cromartie, Ph.D.
Associate Professor
Department of Environmental Science
Richard Stockton College
Egg Harbor City, NJ

Jan W. Dash, Ph.D.
President
J. Dash Consultants LLC
Lincroft, NJ

Merelyn T. Dolins, Ph.D.
Maplewood, NJ

Loretta Dunne, M.D.
Woodbury, NJ

Abraham B. Eastwood, Ph.D.
Cliffside Park, NJ

Philip N. Eisner, Ph.D.
Environmental Columnist
TheAlternativePress.com
Summit, NJ

Robert D. Feldman, Ph.D.
Red Bank, NJ

Mira Adinda Franke, Ph.D.
Montclair, NJ

Anne Freeny, M.A.
Morristown, NJ

Frank L. Friedman, Ph.D.
Professor
Department of Computer and Information Sciences
Temple University
Riverside, NJ

Bettina M. Frost, Ph.D.
Medford, NJ

Marian Glenn, Ph.D.
Professor
Department of Biological Science
Seton Hall University
Summit, NJ

Hans-Joachim Gossmann, Ph.D.
Summit, NJ

Jaclyn Green, Ph.D.
Oakland, NJ

Alan M. Gross, Ph.D.
Somerset, NJ

Patrick B. Hall, Ph.D.
Princeton, NJ

Steven Handel, Ph.D.
Professor of Ecology
Rutgers University
New Brunswick, NJ

Cheryl F. Harding, Ph.D.
Stanton, NJ

Patricia Ann Hodgetts
Master's Candidate
Cape May, NJ

Leah Horowitz, Ph.D.
Princeton, NJ

George W. Hunt
Senior Engineer
Maple Shade, NJ

Kenneth Irvine, Ph.D.
Professor
Piscataway, NJ

February 2011

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2,505 Endorsers

Adrian Xavier Juarez
Doctoral Candidate
College of Nursing
New York University
Jersey City, NJ

Daniel Kling, Ph.D.
Ringoes, NJ

Judith Klotz, Dr.P.H.
Adjunct Associate Professor
Lawrenceville, NJ

Frederick Adam Kobylarz, M.A.
Ocean, NJ

Adam Koranyi, Ph.D.
Distinguished Professor
Department of Mathematics
H. H. Lehman College
City University of New York
Tenafly, NJ

Sarah Emily Labançe, Ph.D.
Vernon, NJ

Loretta A. Lamprecht, M.A.
Ocean Gate, NJ

Louis R. Matlack, Ph.D.
Bernardsville, NJ

David S. Mizrahi, Ph.D.
Vice-President
Cape May Court House, NJ

Roberta Morganstern, M.A.
Biologist
Asbury, NJ

Michael A. Mulligan, M.A.
Parsippany, NJ

Peter Osborn, M.A.
Westfield, NJ

Brian J. Pankuch, Ph.D.
Califon, NJ

Steven B. Rosenbaum, M.D.
Livingston, NJ

Jean C. Roy, M.A.
Software Architect
Colonia, NJ

Walter J. Royack
Collingswood, NJ

Marc Rubin, M.A.
Hamilton Square, NJ

Alison Seigel, Ph.D.
Belle Mead, NJ

Kimberly A. Serdynski, M.A.
Marlton, NJ

William Paul Shadel, M.A.
Keyport, NJ

Derek G. Shendell, Ph.D.
Chatham, NJ

Philippa H. Solomon, Ph.D.
Edison, NJ
Susan J. Stultz, M.A.
Annandale, NJ

Ronald Sverdlove, Ph.D.
Princeton, NJ

Mary Ellen Teshima, M.A.
Registered Nurse
School Health
Livingston High School
Towaco, NJ

Stanley A. Tomkiel, M.A.
Mount Laurel, NJ

George L. Trigg, Ph.D.
Pennington, NJ

Ellie Whitney, Ph.D.
Associate Professor (Retired)
Department of Biological Science
Hightstown, NJ

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Donald Arthur Wiegand, Ph.D.
Research Physicist
Energetic Materials
Armament Research Development and Engineering Center
Basking Ridge, NJ

Todd Wolf, D.V.M.
Parsippany, NJ

Michael J. Yellin, M.D.
Montclair, NJ

NEW MEXICO

Gene J. Chorostecki, M.D.
Santa Fe, NM

Patrick Culbert
Master's of Public Health Candidate
Retired
Santa Fe, NM

Donald W. Duszynski, Ph.D.
Albuquerque, NM

G. Thomas Farmer, Ph.D.
Environmental Consultant
Author
Farmer Enterprises
Las Cruces, NM

Vincent Gutschick, Ph.D.
Director
Global Change Consulting Consortium, Inc.
Las Cruces, NM

Kenneth L. Ingham, Ph.D.
Albuquerque, NM

Norton Kalishman, M.D.
Albuquerque, NM

Barry Kirschbaum, M.D.
Santa Fe, NM

John Lazaruk, Ph.D.
Las Cruces, NM

Kenneth A. Letendre
Doctoral Candidate
Albuquerque, NM

Daniel J. Levenson, D.V.M.
Albuquerque, NM

Crawford J. MacCallum, Ph.D.
Tijeras, NM

Jean Catherine MacPhail, M.D.
Santa Fe, NM

Malcolm R. MacPherson, Ph.D.
Santa Fe, NM

Gaia Mika, Ph.D.
Taos, NM

Karen K. Milstein, Ph.D.
Santa Fe, NM

Todd C. Monson, Ph.D.
Albuquerque, NM

James J. Montesinos, M.D.
Santa Fe, NM
Donald F. Neidig, Ph.D.
Las Cruces, NM

Martha Bliss Novak, Ph.D.
Albuquerque, NM

Nathan Ockman, Ph.D.
American Physical Society
Santa Fe, NM

Reese Brand Phillips
Doctoral Candidate
Albuquerque, NM

Sue Pienciak, M.A.
Silver City, NM

Andrew L. Ross, Ph.D.
Director
Center for Science, Technology and Policy
University of New Mexico
Albuquerque, NM

February 2011

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2,505 Endorsers

Jerry Saxton
Doctoral Candidate
Placitas, NM

Lawrence R. Sitney, Ph.D.
Retired
Albuquerque, NM

James B. Sitrick Jr., M.P.H.
Santa Fe, NM

Theodora Sobin, M.A.
Angel Fire, NM

Jon A. Spar, M.D.
WildEarth Guardians
Albuquerque, NM

Barbara Starfield, M.D.
Professor
Las Cruces, NM

Stanly Steinberg, Ph.D.
Albuquerque, NM

Klaus Peter Steinbrecher, M.A.
Angel Fire, NM
Alex Stelzner, M.D.
Albuquerque, NM

Paul Stokes, M.A.
Corrales, NM

Rebecca M. Summer, Ph.D.
Silver City, NM

Robert J. Tafanelli, Ph.D.
Retired
Fish, Wildlife and Conservation Ecology
New Mexico State University
Las Cruces, NM

Michael E. Thuot
Electrical Engineer
Sandia Park, NM

Paul R. Turner, Ph.D.
Las Cruces, NM

Arthur Upton, M.D.
Santa Fe, NM

Marcus Williams, M.A.
Research Associate
New Mexico Pilot Facility Research
Sapphire Energy
Las Cruces, NM

NEW YORK

Louis Gene Albano
Professional Engineer (Retired)
American Federation of State County and
Municipal Employees
Brooklyn, NY

Eric Albert, M.A.
Brooklyn, NY

Elizabeth L. Allen, Ph.D.
Professor (Retired)
Department of Speech-Language Pathology
New York University
New York, NY

Bill Altman, Ph.D.
Associate Professor
Department of Psychology and Human Services
Broome Community College
Binghamton, NY

Ralph Alvarez, M.D.
Warwick, NY

O. Roger Anderson, Ph.D.
Professor
New York, NY

Adriana E. Aquino Gerard, Ph.D.
Senior Science Content Specialist
New York, NY

Bertrand B. Aubrey, Ph.D.
New York, NY

Andi Weiss Bartczak, Ph.D.
New Paltz, NY

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Mary Ann D. Bayne, M.A.
Worcester, NY

Christian Beels, M.D.
New York, NY

Bruce A. Beesley, M.D.
Delmar, NY

Michael V. L. Bennett, Ph.D.
Professor
Department of Neuroscience
Albert Einstein College of Medicine
New Rochelle, NY

Jim Bentson, Ph.D.
Professor
Centerport, NY

Carol M. Berman, Ph.D.
Professor
Orchard Park, NY

William Bishop
Professional Engineer
Williamson, NY

Mary A. Bisson, Ph.D.
Professor
Department of Biological Science
University at Buffalo
Buffalo, NY

David N. Borton, Ph.D.
Troy, NY

William E. Boyce, Ph.D.
Professor Emeritus
Cropseyville, NY

Philip W. Brandt, Ph.D.
Professor Emeritus
Department of Pathology
Columbia University
Bronx, NY

Arthur A. Bright, Ph.D.
Croton On Hudson, NY

Peter J. Brofman, Ph.D.
Distinguished Engineer
Hopewell Junction, NY

Joan E. Budd, M.D.
Pleasantville, NY

Charles Buntschuh, Ph.D.
Lloyd Harbor, NY

Harold L. Burstyn, Ph.D.
Adjunct Professor
L. C. Smith College of Engineering and Computer Science
Syracuse University
Syracuse, NY

Daniel Cadzow
Doctoral Candidate
Buffalo, NY

Cenie Clelia Cafarelli, M.D.
Rochester, NY

Alfred G. Cammisa, M.A.
Monroe, NY

David Campbell, Ph.D.
Ithaca, NY

Mark A. Cane, Ph.D.
Professor
Department of Earth and Environmental Sciences
Columbia University
Palisades, NY

David L. Carpenter, Ph.D.
Professor Emeritus
Bemus Point, NY

Donna M. Cassidy-Hanley, Ph.D.
Freeville, NY

Barbara H. Chasin, Ph.D.
Professor Emerita
Ithaca, NY

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Mark Christensen
Doctoral Candidate
Prismark
Centerport, NY

Jonathan R. Cole, Ph.D.
University Professor
Columbia University
New York, NY

Albert E. Cordes, Ph.D.
Plattsburgh, NY

Margaret M. Craven, M.D.
Voorheesville, NY

Gerrit V. Crouse, Ph.D.
Nyack, NY

Robert P. DeSieno, Ph.D.
Saratoga Springs, NY

Steve R. Dickman, Ph.D.
Professor
Department of Geological Sciences and Environmental Studies
Binghamton University
Vestal, NY

Nathan Diegelman, Ph.D.
Orchard Park, NY

Mary Diegert, M.A.
Retired
Vestal, NY

Jozef Dodziuk, Ph.D.
Professor
Department of Mathematics
Graduate Center
City University of New York
New York, NY

John Dubendorff, Ph.D.
Sound Beach, NY

Arthur B. Eliot
Floral Park, NY

Todd Douglas Ellis, Ph.D.
Assistant Professor
State University of New York, Oneonta
Otego, NY

Joan C. Farber, Ph.D.
Clinical Psychologist
New York, NY

Donald T. Farley, Ph.D.
Professor Emeritus
Department of Electrical and Computer Engineering
Cornell University
Ithaca, NY

Rosemary Faulkner, Ph.D.
New York, NY

Sam A. Fedele, M.A.
Victor, NY

Judith Feldman, Ph.D.
Associate Clinical Professor
New York, NY

Richard S. Feldman, Ph.D.
Poughkeepsie, NY

Robert J. Festa, M.A.
Huntington, NY

Stephanie Feyne
Master's Candidate
New York, NY

Debbie Finn, M.A.
Croton On Hudson, NY

William Flank, Ph.D.
Professor
Department of Chemistry
Pace University
Chappaqua, NY

Renee A. Fleischer, M.D.
Great Neck, NY

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Michael Follman, M.A.
Huntington Station, NY

William J. Forrest, Ph.D.
Professor
Department of Physics and Astronomy
University of Rochester
Rochester, NY

Carolyn H. Friedman, Ph.D.
Nyack, NY

Ilse Funk, M.A.
Cherry Valley, NY

Sarah Graetz Gagnon, Ph.D.
Spencer, NY

Michael Garrick, Ph.D.
Professor
Getzville, NY

Michael J. Gerdes, Ph.D.
Scientist
Albany, NY

Susan K. Gibbons, M.D.
Chairman Department of Radiation Oncology
Department of Radiation Oncology
Albany Medical College
Glenmont, NY

Rebecca T. Gluskin
Doctoral Candidate
New York, NY

Peter J. Gollon, Ph.D.
Energy Chair
Sierra Club
Huntington, NY

Robert J. Gordon, Ph.D.
Slingerlands, NY

John M. Gowdy, Ph.D.
Rittenhouse Professor
Department of Economics
Rensselaer Polytechnic Institute
Poestenkill, NY

Michael E. Green, Ph.D.
Professor
Department of Chemistry
City College-City University of New York
New York, NY

Jay R. Greenberg, Ph.D.
Rochester, NY

Charles H. Greene, Ph.D.
Ithaca, NY

Michael J. Gregory, Ph.D.
Morrisonville, NY

Megan McDermott Gregory
Doctoral Candidate
Graduate Research Assistant
Department of Agroecology
Cornell University
Ithaca, NY

Carol Griffiths, Ph.D.
Professor
Department of Biology
Long Island University
Tarrytown, NY

Karlene K. Gunter, Ph.D.
Professor
Department of Biochemistry and Biophysics
University of Rochester
Rochester, NY

Michael Hadjiargyrou, Ph.D.
Coram, NY

Christina Marie Haig
Doctoral Candidate
Research Assistant
Department of Physics and Astronomy
University of North Carolina
West Henrietta, NY

Ruud A. Haring, Ph.D.
Cortlandt Manor, NY

February 2011

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Geoffrey M. Heal, Ph.D.
Professor
Columbia Business School
New York, NY

Shane Henderson, Ph.D.
Professor
Cornell University
Ithaca, NY

Ellen Henry, Ph.D.
Pittsford, NY

Leonard P. Henschel, M.D.
Kew Gardens, NY

Dee Roy Hensen, D.V.M.
Paumanok Veterinary Hospital
Miller Place, NY

Marty Hiller, Ph.D.
Ithaca, NY

Virginia Ann Hoagland, M.A.
Occupational Therapist
New York, NY

Harold Hodes, Ph.D.
Associate Professor
Department of Philosophy
Cornell University
Ithaca, NY

Joel Huberman, Ph.D.
Emeritus Professor
Department of Cancer Biology
Roswell Park Cancer Institute
Buffalo, NY

Ruth Bernstein Hyman, Ph.D.
Rockville Centre, NY

Richard Isaac, Ph.D.
Professor Emeritus
Department of Mathematics
City University of New York
Mount Vernon, NY

Christopher X. Jon Jensen, Ph.D.
Assistant Professor
Department of Mathematics and Science
Pratt Institute
Brooklyn, NY

Paul K. Johnson, M.A.
New York, NY

Raymond N. Johnson, Ph.D.
Institute of Climate Studies
Chazy, NY

Chris Jones, M.A.
New Paltz, NY

Laura E. Jones, Ph.D.
Senior Researcher
Department of Ecology and Evolutionary Biology
Cornell University
Ithaca, NY

Marilyn J. Jordan, Ph.D.
Senior Conservation Scientist
Huntington Station, NY

Jeffrey Leighton Kalman
Doctoral Candidate
Pound Ridge, NY
Theresa Kardos, M.A.
Environmental Educator and Naturalist
Cortlandt Manor, NY

Brian G. Keel, Ph.D.
Shushan, NY

Elizabeth Kinney, M.A.
Albany, NY

Laurence Kirby, Ph.D.
Woodstock, NY

Peter L. Knuepfer, Ph.D.
Director Environment Studies Program
Department of Geological Sciences and
Environmental Studies
Binghamton University
Binghamton, NY

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James T. Kofron, Ph.D.
Rochester, NY

Karen Krause, D.V.M.
Albany, NY

Edward A. Kush, Ph.D.
Water Mill, NY

William L. LaBine, M.A.
Home Energy Rater
Energy Smart Educator
Airtight Services
New York State Energy Research and Development Authority
Avon, NY

Lyssie Lakatos, M.A.
New York, NY

Leopold S. Laufer, M.D.
Yorktown Heights, NY

Peter R. Law, Ph.D.
Monroe, NY

Albion Lawrence, Ph.D.
Associate Professor
Department of Physics
Brandeis University
New York, NY

Susan Lee, Ph.D.
Hampton Bays, NY

Richard W. Leigh, Ph.D.
Director
Advocacy and Research
New York, NY

Harvey Lerner, M.D.
Smithtown, NY

Gerson T. Lesser, M.D.
Clinical Professor
Department of Internal Medicine
New York University School of Medicine
Bronx, NY

Larry B. Liddle, Ph.D.
Professor Emeritus
Department of Biology and Marine Science
Long Island University
Southampton, NY

Richard P. Lipka, Ph.D.
Distinguished Professor
Depew, NY

Ernest M. Loebl, Ph.D.
Professor Emeritus
Department of Chemistry
Polytechnic Institute of New York University
Brooklyn, NY

Frederic A. Lyman, Ph.D.
Syracuse, NY

Malgosia Madajewicz, Ph.D.
Palisades, NY

William J. Makofske, Ph.D.
Professor Emeritus
Schools of Science, Social Science
Ramapo College
Warwick, NY

Scott A. Mandia, M.A.
Professor
Department of Physical Science
Suffolk County Community College
Selden, NY

Krista L. McGuire, Ph.D.
Assistant Professor
Department of Biological Science
Barnard College, Columbia University
New York, NY

Janet McMahon, M.D.
Physician
Emergency Room
Oneida Healthcare Center
Oneida, NY

Charles O. McMahon, M.A.
Oneida, NY

February 2011

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2,505 Endorsers

Donald W. McPheeters, M.A.
Ithaca, NY

Joan Phyllis Mencher, Ph.D.
Professor
New York, NY

Judith Merritt-Wilson, Ph.D.
Ithaca, NY

Nariman B. Mistry, Ph.D.
Adjunct Professor (Retired)
Senior Scientist
Ithaca, NY

Anthony Mitchell, Ph.D.
Beacon, NY

Anna Mockler, M.A.
Brooklyn, NY

Giancarlo Moneti, Ph.D.
Professor Emeritus
Department of Physics
Syracuse University
Syracuse, NY

James H. Mulder, M.A.
Senior Technical Staff Member
Wappingers Falls, NY

Harold A. Nash, Ph.D.
Palisades, NY

Charles A. Nelson, Ph.D.
Professor
Department of Physics
State University of New York
Vestal, NY

Andrew P. Nelson, Ph.D.
Professor Emeritus
Department of Biological Sciences
State University of New York, Oswego
Oswego, NY

Marcia Kilgore Newsom4, M.D.
Private Practice
Oneida, NY

Jill Ann Nord, M.D.
Glendale, NY

Christopher Noto, Ph.D.
Visiting Professor
Department of Biomedical Sciences
Grand Valley State University
East Setauket, NY

Margaret Olness, M.P.H.
Chair Transportation Committee
Stony Brook, NY

Alan Oppenheim, Ph.D.
Adjunct Associate Professor
Department of Physics
Queensborough Community College-City
University of New York
New York, NY

Philip Orton, Ph.D.
Postdoctoral Research Scientist
Stevens Institute of Technology
New York, NY

Damian L. Osisek, M.A.
Vestal, NY

Harriet Oster, Ph.D.
Clinical Professor
Larchmont, NY

Richard S. Ostfeld, Ph.D.
Red Hook, NY

Kim Palmo, Ph.D.
Research Scientist
Harrison, NY

Romeo John Pascone, Ph.D.
Professor
New York, NY

Diane H. Peapus, Ph.D.
Professor
Albany, NY

Anthony R. Peluso, Ph.D.
Greenport, NY

February 2011

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2,505 Endorsers

Christy Pennoyer, M.A.
Hastings On Hudson, NY

Alicia Perez-Fuentetaja, Ph.D.
Associate Professor
Research Scientist
Department of Biology
Great Lakes Center
Buffalo State College
Buffalo, NY

Kirstin Peterson, M.D.
New York, NY

Anna Potempska, Ph.D.
Staten Island, NY

George Profous, M.A.
Senior Forester
New Paltz, NY

Robert M. Pruzek, Ph.D.
Professor
Division of Educational Psychology and Methodology
University at Albany, State University of New York
Gansevoort, NY

James Ralston
Environmental Engineer
Professional Consultant
Edinburg, NY

Michael K. Reed, Ph.D.
Pound Ridge, NY

Richard L. Reeves, Ph.D.
Research Associate
Honeoye Falls, NY

Melinda Reidinger, Ph.D.
Smithtown, NY

Howard Reisman, Ph.D.
Southampton, NY

Susan Riblett, Ph.D.
Rochester, NY

Mark Ritchie, Ph.D.
Professor
Department of Biology
Syracuse University
Syracuse, NY

C. S. Russell, Ph.D.
Professor Emerita
Department of Chemistry and Biochemistry
City College-City University of New York
New York, NY

Gloria Russo, M.A.
Manager Environmental Planning and Compliance
Sayville, NY

Gloria Sage, Ph.D.
Syracuse, NY

Carlton E. Salvagin, Ph.D.
Hannibal, NY

Steve Sansola, M.A.
Rhinebeck, NY

Eugene W. Sard, M.A.
Huntington, NY

Raymond H. Schneider, Ph.D.
Retired
State University of New York, Oswego
Oswego, NY

Gautam Sethi, Ph.D.
Associate Professor
Center for Environmental Policy
Bard College
Annandale, NY

Gary Shereshevsky, Ph.D.
Brooklyn, NY

Joel D. Shore, Ph.D.
Lecturer
Department of Physics
Rochester Institute of Technology
Rochester, NY

February 2011

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2,505 Endorsers

Robert N. Shorin, M.A.
Vice-President
Karen Horney Clinic, Inc.
Syosset, NY

Ted S. Shultz, M.A.
Larchmont, NY

Vincent M. B. Silenzio, M.D.
Associate Professor
Rochester, NY

Aaron Sobota, M.D.
Clinical Psychologist
Bronx, NY

Ann Sprayregen
Doctoral Candidate
New York, NY

Olaf P. Stackelberg, Ph.D.
Castleton On Hudson, NY

E. Richard Stanley, Ph.D.
Bronx, NY

Davis W. Stockman, M.A.
Barneveld, NY

Richard A. Stockton, Ph.D.
Buffalo, NY

Gaynell Stone, Ph.D.
Director
Suffolk County Archaeological Association
Wading River, NY

Sheldon Stone, Ph.D.
Manlius, NY

David B. Straus, Ph.D.
Gardiner, NY

John Stupak
Doctoral Candidate
Stony Brook, NY

Mani Subramanian, Ph.D.
Brooklyn, NY

Barnet M. Sultzer, Ph.D.
Professor Emeritus
Department of Microbiology and Immunology
State University of New York
Downstate Medical Center
New Paltz, NY

Wayne E. Sygman, M.D.
Levittown, NY

Stephen T. Tettelbach, Ph.D.
Professor of Biology
Department of Biology
Long Island University
Brookville, NY

Janice E. Thies, Ph.D.
Associate Professor
Ithaca, NY

Michael B. Todd, Ph.D.
Cornell University
Ithaca, NY

Christina Tonitto, Ph.D.
Research Scientist
Department of Ecology and Evolutionary Biology
Cornell University
Ithaca, NY

Francesco N. Tubiello, Ph.D.
Chief of Science and Technology
GET-Carbon LLC
New York, NY

Robert W. Turner, Ph.D.
Professor
Department of Economics
Department of Environmental Studies
Colgate University
Clinton, NY

David Udin, Ph.D.
Buffalo, NY

Steven G. Ungar, Ph.D.
Senior Research Scientist (Retired)
Broadband Access
Telcordia Technologies, Inc.
New York, NY

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Jenny G. Walker, M.D.
Educator
New York, NY

Ruth Helen Walker, Ph.D.
Associate Professor
Brooklyn, NY

John M. Waud, Ph.D.
Pittsford, NY

Arthur J. Weaver, Ph.D.
President
Renovus Energy Inc.
Van Etten, NY

Judith S. Weis, Ph.D.
Professor
Department of Biological Sciences
Rutgers University
New York, NY

Cynthia S. Westerman, M.A.
Vestal, NY

Ted W. Wilcox, Ph.D.
Professor Emeritus
Department of Mathematics
Rochester Institute of Technology
Rochester, NY

George A. Yabroudy, M.A.
Program Manager (Retired)
Farmingdale, NY

Leonard Zablow, M.A.
New York, NY

NORTH CAROLINA

Lee Adrian, M.A.
Durham, NC

Robin A. Alexander, Ph.D.
Durham, NC

Kris Bergstand, D.V.M.
Preclinical Toxicology Consultant
Chapel Hill, NC

Richard E. Bilsborrow, Ph.D.
Professor
Chapel Hill, NC

William Blackley, M.D.
Physician
Elkin, NC

Jacob Blum, Ph.D.
Durham, NC

Howard M. Bomze, Ph.D.
Senior Research Associate
Department of Psychology and Neuroscience
Duke University
Durham, NC

Jo Ellen Brandmeyer, Ph.D.
Research Environmental Engineer 3
Chapel Hill, NC

Peter A. Brezny, M.A.
Asheville, NC

James W. Buchanan, Ph.D.
Boone, NC

Lawrence B. Cahoon, Ph.D.
Professor
Department of Biology and Marine Biology
University of North Carolina, Wilmington
Wilmington, NC

John E. Callahan, Ph.D.
Professor Emeritus
Boone, NC

Ted R. Campbell, M.A.
Hydrogeologist
North Carolina Department of Environment and Natural Resources
Asheville, NC

Kicab Castaneda-Mendez, M.A.
Chapel Hill, NC

Barney P. Caton, Ph.D.
Hillsborough, NC

February 2011

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2,505 Endorsers

Thomas G. Clarke, Ph.D.
Greensboro, NC

Ronald M. Clayton, M.A.
Fayetteville, NC

Morgan Crawford, M.A.
Durham, NC

Roberta L. Dees, Ph.D.
Consultant
Charlotte, NC

Pamela Diliberto, Ph.D.
Pittsboro, NC

Susan Edelstein, Ph.D.
Cary, NC

Fred J. Ehrgott, M.A.
Ocean Island Beach, NC

Tracey I. Fine, M.A.
Chapel Hill, NC

Shelley M. Frazier, M.A.
Raleigh, NC

William Gettys, M.A.
Consulting Engineer
Weaverville, NC

Daniel N. Graham, Ph.D.
Adjunct Professor
Department of Political Science
North Carolina State University
Chapel Hill, NC

Richard O. Gray, Ph.D.
Boone, NC

Hermann Gucinski, Ph.D.
Associate Director of Research (Retired)
Southern Research Station
U.S. Department of Agriculture
U.S. Forest Service
Fairview, NC

Robert P. Hawkins, Ph.D.
Professor Emeritus
Department of Psychology
West Virginia University
Cary, NC

Duncan Heron, Ph.D.
Durham, NC

Karen Orton Hodges, Ph.D.
Charlotte, NC

Irving R. Hooper, Ph.D.
Beaufort, NC

William Kastern, Ph.D.
Randleman, NC

Helen Koo, Ph.D.
Durham, NC

Karen E. Krogh, Ph.D.
Apex, NC

Deborah Leiner, M.D.
Pediatrician
North Carolina Pediatric Society
Greensboro, NC

Gail R. Marsh, Ph.D.
Associate Professor
Psychiatry and Behavioral Sciences
Duke University
Durham, NC

John R. Mattox, Ph.D.
Professor
Fayetteville, NC

Claire K. Morse, Ph.D.
Greensboro, NC

Helmut Charles Mueller, Ph.D.
Professor Emeritus
Department of Biology
University of North Carolina
Chapel Hill, NC

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Thomas P. Mutton, M.D.
Surgery
Forsyth Medical Center
Winston Salem, NC

Howard S. Neufeld, Ph.D.
Professor
Department of Biology
Appalachian State University
Boone, NC

E. B. Palmore, Ph.D.
Professor Emeritus
Center on Aging
Duke University
Chapel Hill, NC

Hayne Iii Palmour III, Ph.D.
Professor Emeritus
Department of Materials Science and Engineering
North Carolina State University
Raleigh, NC

Lewis E. Patrie, M.D.
Chair
Western North Carolina Physicians for Social Responsibility
Asheville, NC

David Reusch, Ph.D.
Greensboro, NC

James H. Reynolds, Ph.D.
Associate Professor
Department of Geology
Brevard College
Brevard, NC

Peter J. Reynolds, Ph.D.
Durham, NC

Don H. Richardson, M.D.
Physicians for Social Responsibility
Brevard, NC

Wilfred J. Robin
Hickory, NC

Matthew Rubino, M.A.
Conservation Biology
Department of Biology
North Carolina State University
Raleigh, NC

Pamela J. Schwingl, Ph.D.
Research Director
Public Health Research
Social and Scientific Systems, Inc.
Durham, NC

Andrew G. Silver, M.P.H.
Epidemiologist
Cary, NC

Michael Silverberg, Ph.D.
Associate Professor Emeritus
Efland, NC

Jim Simmons, Ph.D.
Chapel Hill, NC

Thomas T. Struhsaker, Ph.D.
Duke University
Durham, NC

Brett F. Taubman, Ph.D.
Boone, NC

Walter S. Weathers, M.A.
Durham, NC

Charles E. Wilson, Ph.D.
Winston Salem, NC

Paul A. Winterhoff, Ph.D.
Hillsborough, NC

Alison Woomert, Ph.D.
Project Director
Chapel Hill, NC

Rachael H. Wooten, Ph.D.
Raleigh, NC

Susan Yarnell
Doctoral Candidate
Chapel Hill, NC

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

NORTH DAKOTA

Eric David Brevik, Ph.D.
Dickinson, ND

Krystyna Gorzelska, Ph.D.
Bismarck, ND

Paul Scott Hardersen, Ph.D.
Associate Professor
Grand Forks, ND

Spencer Meeks, Ph.D.
Professor Emeritus
Department of Chemistry
Minnesota State University, Moorhead
Fargo, ND

David Carlos Roberts, Ph.D.
Fargo, ND

OHIO

Gene Ammarell, Ph.D.
Athens, OH

James H. Andrews, Ph.D.
Professor
Department of Physics and Astronomy
Youngstown State University
Poland, OH

Anne Marie Baker, Ph.D.
CEO
Waterville, OH

Richard Lee Berry, Ph.D.
Columbus, OH

Michael Bevis, Ph.D.
Professor
School of Earth Sciences
The Ohio State University
Columbus, OH

Joan E. Brasaemle, M.A.
Environmental Geologist (Retired)
Copley, OH

Robert J. Brecha, Ph.D.
Professor
Department of Physics
University of Dayton
Yellow Springs, OH

Mary E. Brown, D.V.M.
Morrow, OH

Robert L. Brugler, M.A.
Professor
Worthington, OH

Vera Buk-Bjerre, Ph.D.
Kent, OH

Wayne M. Butler, Ph.D.
Chief Medical Physicist
Mt Pleasant, OH

Phillip Cantino, Ph.D.
Professor
Environmental and Plant Biology
Ohio University
Athens, OH

Jason Cooperrider
Doctoral Candidate
Department of Psychiatry
University of Utah
Thornville, OH

Mark Cosgriff
Master's Candidate
Lakewood, OH

Sandra L. Curry, Ph.D.
Shaker Heights, OH

Daniel M. Dawley, M.D.
Bowling Green, OH

Robert T. Deck, Ph.D.
Professor Emeritus
Department of Physics
University of Toledo
Toledo, OH

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Alice Dugar, M.A.
Laboratory Manager Chemistry
Independence, OH

Kevin Joseph Egan, Ph.D.
Associate Professor
Department of Economics
University of Toledo
Toledo, OH

Steven R. Federman, Ph.D.
Professor
Ottawa Hills, OH

Charles A. Fritsch, Ph.D.
Newark, OH

Donald Raymond Geiger, Ph.D.
Professor Emeritus
Department of Biology
University of Dayton
Dayton, OH

Elizabeth A. George, Ph.D.
Associate Professor and Chair
Springfield, OH

Enrique Gomezdelcampo, Ph.D.
Bowling Green, OH

Paula Gonzalez, Ph.D.
Cincinnati, OH

David L. Gorchov, Ph.D.
Professor
Department of Botany
Miami University
Oxford, OH

Fredrick P. Gram, M.A.
Professor
Department of Physics
Cuyahoga Community College
Cleveland, OH

Tyler Grassman, Ph.D.
Columbus, OH

Andrea Grottoli, Ph.D.
Associate Professor
Columbus, OH

David Gurarie, Ph.D.
Professor
Department of Mathematics
Center for Global Health
Case Western Reserve University
Shaker Hts, OH

Stephen Hanzley, Ph.D.
Professor Emeritus
Department of Physics and Astronomy
Youngstown State University
Youngstown, OH

LeRoy W. Haynes, Ph.D.
Wooster, OH

Robert T. Heath, Ph.D.
Professor Emeritus
Department of Biological Sciences
Kent State University
Mantua, OH

Ulrich W. Heinz, Ph.D.
Professor of Physics
Department of Physics
The Ohio State University
Hilliard, OH

Robert Paul Igo, Ph.D.
Assistant Professor
South Euclid, OH

Christopher Jekeli, Ph.D.
Professor
Department of Earth Sciences
The Ohio State University
Columbus, OH

Jeffrey R. Johansen, Ph.D.
Professor
Department of Biology
John Carroll University
Cleveland Heights, OH

David R. Jury, M.D.
Fairlawn, OH

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

William E. Katzin, M.D.
Clinical Associate Professor
Department of Pathology
Case Western Reserve University
Cleveland, OH

Brian Keane, Ph.D.
Associate Professor
Department of Zoology
Miami University
Cincinnati, OH

Quentin F. Knauer, M.D.
Cambridge, OH

Tom T. Kozel
Morrow, OH

Stephen R. Kramer, Ph.D.
Alliance, OH

Daniel Leavell, Ph.D.
Associate Professor
Department of Earth Sciences
Ohio State University
Granville, OH

Daniel J. Lesco, M.A.
Broadview Heights, OH

Robert G. Lord, Ph.D.
Cuyahoga Falls, OH

Orie L. Loucks, Ph.D.
Interfaith Climate Change Workgroup
Oxford, OH

Eric Maurer, Ph.D.
Professor
Department of Biological Sciences
University of Cincinnati
Cincinnati, OH

Gerald Edward Meike, Ph.D.
Associate Professor
Dayton, OH

John J. Metz, Ph.D.
Associate Professor
Department of History and Geography
Northern Kentucky University
Cincinnati, OH

Randy J. Mitchell, Ph.D.
Akron, OH

David Modarelli, Ph.D.
Akron, OH

Gerald H. Newsom, Ph.D.
Professor Emeritus
Department of Astronomy
The Ohio State University
Columbus, OH

Marilyn W. Ortt, M.A.
Marietta, OH

Dan D. Petersen, Ph.D.
Professor
Cincinnati, OH

Theresa P. Pretlow, Ph.D.
Professor Emerita
Pathology and Oncology
Case Western Reserve University
Cleveland, OH

Ann B. Reichsman, M.D.
Cleveland Heights, OH

Richard H. Reuning, Ph.D.
Professor Emeritus
Department of Pharmacy
The Ohio State University
Columbus, OH

Peter Richards, Ph.D.
Tiffin, OH

Lynne Rustad, Ph.D.
Health Psychologist
Chagrin Falls, OH

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Benjamin Segall, Ph.D.
Professor Emeritus
Department of Physics
Case Western Reserve University
Cleveland Heights, OH

Gerald V. Sgro, Ph.D.
Faculty
Department of Biology
John Carroll University
Cleveland Heights, OH

Hogan Sherrow, Ph.D.
Assistant Professor
Sociology and Anthropology
Ohio University
Athens, OH

Carol Skinner, Ph.D.
Associate Professor
Chesterland, OH

Nicholas Sperelakis, Ph.D.
Cincinnati, OH

Hank Stevens, Ph.D.
Oxford, OH

Martin Henry Stevens, Ph.D.
Oxford, OH

Harry J. Stone, Ph.D.
Cincinnati, OH

Charmaine Sullivan, M.A.
West Chester, OH

Glenn Talaska, Ph.D.
Professor
Environmental Health
University of Cincinnati College of Medicine
Cincinnati, OH

Pamela M. Unger, M.A.
Columbus, OH

Paul A. Voytas, Ph.D.
Springfield, OH

Fred C. Welty, M.A.
Chardon, OH

Chadwick L. Wright, M.D.
Lewis Center, OH

James Arthur Zagray, M.A.
Teacher
Science and Biology
Kent City Schools
Streetsboro, OH

Jacques Louis Zakin, Ph.D.
Worthington, OH

OKLAHOMA

Howard A. Baer, Ph.D.
Professor
Department of Physics and Astronomy
University of Oklahoma
Norman, OK

Chadwick Cox, Ph.D.
Norman, OK

George Joseph Hall, M.A.
Tulsa, OK

Gerilyn S. Soreghan, Ph.D.
Professor
Department of Geology
University of Oklahoma
Norman, OK

OREGON

John Aha, M.A.
Portland, OR

Warren W. Aney, M.A.
Senior Wildlife Ecologist
Tigard, OR

Stephen Bachhuber, M.D.
Happy Valley, OR

Susan Bartlett
Master's Candidate
Portland, OR

February 2011

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2,505 Endorsers

Chris Bates, M.A.
Corvallis, OR

Peter Bayley, Ph.D.
Courtesy Faculty
Fisheries and Wildlife
Oregon State University
Corvallis, OR

Kenneth H. Bergman, Ph.D.
Retired
National Aeronautics and Space Administration
Ashland, OR

Demelza Costa
Master's Candidate
Sweet Home, OR

Nick Paul De Morgan, M.D.
Portland, OR

Dominick Anthony DellaSala, Ph.D.
Director
World Wildlife Fund
Talent, OR

DBrian W. Doyle, Ph.D.
Consulting Engineer
Doyle Engineering Inc.
Newberg, OR

Raymond James Drapek, Ph.D.
Corvallis, OR

Frank A. Erickson, M.D.
Pendleton, OR

Edward J. Fremouw, Ph.D.
North West Research Associates (Retired)
Ashland, OR

David C. Garen, Ph.D.
Hydrologist
Portland, OR

Chris Goldfinger, Ph.D.
Albany, OR

Eldon Haines, Ph.D.
Portland, OR

Laura Hanks, M.A.
Physician Assistant
House Call Providers
Portland, OR

Mark R. Hanschka, M.D.
Obstetrics and Gynecology Physician (Retired)
Sunriver, OR

Marilyn M. Harlin, Ph.D.
Professor
Portland, OR

William Holmes, M.A.
Engineer (Retired)
Process Engineer and On-line programmer
Ashland, OR

Robert M. Hughes, Ph.D.
Courtesy Associate Professor
Department of Fisheries and Wildlife
Oregon State University
Corvallis, OR

Don Jacobson
Portland, OR

Andrew Rhys Jones, Ph.D.
Assistant Professor
Department of Sociology
California State University, Fresno
Eugene, OR

Sandra K. Joos, Ph.D.
Portland, OR

John Nicholas Kallas, Ph.D.
Portland, OR

Paul C. Katen, Ph.D.
Air Quality Consultant
KPS Associates
Otis, OR

Kimberly King, M.A.
Renewable Energy Engineer
Consultant, Kimberly's Kingdom
Portland, OR

February 2011

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Craig Knight
Redmond, OR

Edward J. Kushner, Ph.D.
Portland, OR

Anthony LaMorticella
Doctoral Candidate
Senior Engineer
Elmira, OR

Ralph T. Lampman
M.D. candidate
Florence, OR

Beverly E. Law, Ph.D.
Professor
Corvallis, OR

Peter Wayne Lawson, Ph.D.
Research Fisheries Biologist
Northwest Fisheries Science Center
National Marine Fisheries Service
Newport, OR

Jason Lewis
Portland, OR

Nancy Anne Loeb, M.D.
Portland, OR

Les E. Mace, M.A.
Bend, OR

Bruce Marron, M.A.
Richmond Neighborhood Sustainability
Portland, OR

Kay Mattson, M.P.H.
International Public Health Consultant
Albany, OR

Marianne M. McClure
Doctoral Candidate
Portland, OR

Donlon McGovern, Ph.D.
Portland, OR

Gary L. Millhollen, Ph.D.
Eugene, OR

Walt C. Mintkeski, M.A.
Portland, OR

Erin M. Moore, M.A.
Astoria, OR

John E. Morris, Ph.D.
Professor Emeritus
Department of Zoology
Oregon State University
Corvallis, OR

Chris Moser, M.A.
Senior Faculty Research Assistant
College of Oceanic and Atmospheric Science
Oregon State University
Corvallis, OR

Joelle L. Murray, Ph.D.
Associate Professor
Department of Physics
Linfield College
Portland, OR

David S. Nichols, Ph.D.
Portland, OR

Julie Norman, M.A.
Program Coordinator
Geos Institute
Ashland, OR

Kay Novak, M.A.
Corvallis, OR

Rudi Nussbaum, Ph.D.
Professor Emeritus
Department of Physics and Environmental Sciences
Portland State University
Portland, OR

Vicki Osis, M.A.
Seal Rock, OR

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Claudia Owen, Ph.D.
Instructor
Science Division
Lane Community College
Cottage Grove, OR

Laurence Padman
Doctoral Candidate
Senior Research Scientist
Earth and Space Research
Corvallis, OR

Hugh G. Peach, Ph.D.
President
H Gil Peach and Associates LLC
Beaverton, OR

William G. Pearcy, Ph.D.
Professor Emeritus
Philomath, OR

Tomm H. Pickles, M.P.H.
Portland, OR

Timothy R. Piwonka-Corle, Ph.D.
Portland, OR

Morgan D. Pope, M.A.
Hillsboro, OR
David M. Ramirez, M.A.
Klamath Falls, OR

Ruth Resch, Ph.D.
Ashland, OR

Norman C. Rose, Ph.D.
Portland, OR

Mark A. Rutherford, Ph.D.
Eugene, OR

Susan Rebecca Salafsky
Doctoral Candidate
Corvallis, OR

Todd Sargent, M.A.
Portland, OR

Steven M. Soltesz, M.A.
Salem, OR

Renee Andrea Stor, M.D.
Internist and Nephrologist (Retired)
Salem, OR

Edward W. Styskel
Certified Wildlife Biologist
Bend, OR

Catherine I. Thomasson, M.D.
Environmental Work Group Chair
Oregon Medical Association
Portland, OR

Martin E. Thompson
Corvallis, OR

Paul Torrence, Ph.D.
Professor Emeritus
Department of Chemistry and Biochemistry
Northern Arizona University
Williams, OR

Pepper W. Trail, Ph.D.
Ashland, OR

Edward J. Trione, Ph.D.
Corvallis, OR

Vicki M. Tripoli, Ph.D.
Ashland, OR

Marie Valleroy, M.D.
Portland, OR

Larry H. Weaver, Ph.D.
Senior Research Associate (Retired)
Howard Hughes Medical Institute
Creswell, OR

Heidi Weber-Wight
Master's Candidate
Tigard, OR

Sally White, M.A.
Teacher
Science
Waldo Middle School
Salem, OR

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

William M. Wiest, Ph.D.
Professor Emeritus
Department of Psychology
Reed College
Portland, OR

Jake Wiser
Milwaukie, OR

William Ryan Wishart, M.A.
Eugene, OR

William R. Wofford, M.A.
Roseburg, OR

Elliot J. Zais, Ph.D.
Senior Environmental Engineer
Portland, OR

Suzanne Zane, D.V.M.
Epidemiologist
Portland, OR

PENNSYLVANIA

Michael J. Balsai, Ph.D.
Philadelphia, PA

John H. Barnes, M.A.
Geologist
Harrisburg, PA

Fred Baurer, M.D.
Wynnewood, PA

Jeffrey D. Bedrick, M.D.
Newtown Sq., PA

Patricia T. Bradt, Ph.D.
Emerita Associate Professor
Department of Environmental Science
Muhlenberg College
Allentown, PA

Robert F. Carline, Ph.D.
Fishery Research Biologist
(Retired)
Port Matilda, PA

Garry Chick, Ph.D.
Professor and Department Head
Department of Recreation Park Tourism Management
Department of Anthropology
Pennsylvania State University
Port Matilda, PA

Rosemarie Chinni, Ph.D.
Fleetwood, PA

Terry Anderson CoBabe, Ph.D.
Point Pleasant, PA

Theodore Cohen, Ph.D.
Professor Emeritus
Department of Chemistry
University of Pittsburgh
Pittsburgh, PA

John N. Cooper, Ph.D.
Professor Emeritus
Lewisburg, PA

Kristine Danowski
Doctoral Candidate
Pittsburgh, PA

Luise K. Davis, Ph.D.
Pittsburgh, PA

John de Planque, D.V.M.
Fleetwood, PA

Candy DeBerry, Ph.D.
Associate Professor
Department of Biology
Washington and Jefferson College
Washington, PA

Bonnie DeBold, M.Arch.
York, PA

Maria K. Dillard
Doctoral Candidate
University of Pittsburgh
Pittsburgh, PA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Robert Drummey
Software Engineer
Collegeville, PA

Carl Ellenberger, M.D.
Mount Gretna, PA

Lisa Evans, M.D.
Philadelphia, PA

Georgia E. Feild
Pittsburgh, PA

Patty Ferry, M.A.
Bloomsburg, PA

Ned Fetcher, Ph.D.
Project Coordinator
Institute for Environmental Science
Wilkes University
Clarks Green, PA

Gary M. Fleeger, M.A.
Marysville, PA

Gordon N. Fleming, Ph.D.
Professor Emeritus
Department of Physics
Pennsylvania State University
State College, PA
Edward Gerjuoy, Ph.D.
Professor Emeritus
Pittsburgh, PA

Walter I. Goldburg, Ph.D.
Pittsburgh, PA

Don Goldstein, Ph.D.
Professor
Department of Economics
Allegheny College
Meadville, PA

Bernard David Goldstein, M.D.
Professor
Environmental and Occupational Health
Graduate School of Public Health
University of Pittsburgh
Pittsburgh, PA

Richard Goodman, Ph.D.
Wayne, PA

Philip R. Gordon, Ph.D.
Cheyney, PA

Robert J. Griffith, M.A.
Erie, PA

William Haaf, M.A.
CEO
Chester County Citizens for Climate Protection
Kennett Square, PA

Catherine A. Hardison, M.A.
Environmental Engineer 1
Department of Environmental Conservation
New York State
Pittsburgh, PA

Lucinda Hart-Gonzalez, Ph.D.
Paradise Gardens and Farm
Reynoldsville, PA

Dwayne Haus, M.D.
State College, PA

Alan L. Horwitz, Ph.D.
Pennsylvania State University
Wallingford, PA
Diana Lynn Hulboy, Ph.D.
Technology Manager
Philadelphia, PA

Andrew Sherwood Johnson, D.V.M.
Veterinary Internist
Practice Owner
Pittsburgh Veterinary Specialty and Emergency Center
Gibsonia, PA

Barbara C. Knickerbocker, Ph.D.
West Chester, PA

Diana Kobus, M.A.
Pittsburgh, PA

Heywood R. Kotch, M.D.
Assistant Dean for Clinical Operations
Media, PA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Roger Latham, Ph.D.
Ecologist
Conservation Biologist
Continental Conservation
Rose Valley, PA

Philip Lichtenberg, Ph.D.
Mary Hale Chase Professor Emeritus
Social Work and Social Research
Bryn Mawr College
Kennett Square, PA

Victor Lidz, Ph.D.
Associate Professor
Chesterbrook, PA

William A. Lochstet, Ph.D.
Professor Emeritus
Department of Physics
University of Pittsburgh
Lancaster, PA

Jairo H. Lora, Ph.D.
Media, PA

Kristin M. Lorent, Ph.D.
University of Pennsylvania
Philadelphia, PA

W. Lee Maloy, Ph.D.
Lansdale, PA

Walter E. Margie, M.D.
Bethlehem, PA

Louis Mariani, M.A.
Psychologist (Retired)
Whitehall, PA

James Marshall, M.A.
Associate Professor (Retired)
Department of Electrical Engineering
Acoustical Society of America
Kennett Square, PA

Russell E. Martz, M.A.
Science Teacher (Retired)
Chambersburg, PA

Gail R. Massey, Ph.D.
Research Specialist
Philadelphia, PA

Kelly Matthews, Ph.D.
Professor
Department of Physical Science
Harrisburg Area Community College
Manheim, PA

Peter Mayes, Ph.D.
Narberth, PA

Leslie Poul Melman, Ph.D.
Bala Cynwyd, PA

Jeannine Mendrola, Ph.D.
Department of Biochemistry/Biophysics
University of Pennsylvania
Broomall, PA

Douglas P. Metzler, Ph.D.
Turtle Creek, PA

Derek Molliver, Ph.D.
University of Pittsburgh
Pittsburgh, PA

Richard Morse, Ph.D.
Mechanicsburg, PA
John F. Nagle, Ph.D.
Professor
Department of Physics
Carnegie Melon University
Pittsburgh, PA

Raymond Gabriel Najjar, Ph.D.
Associate Professor
Department of Meteorology
Pennsylvania State University
State College, PA

Charles Nilsson, M.A.
Founder
Director
Integrated Resource Information Systems
Warren, PA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Dewey Odhner
Doctoral Candidate
Department of Radiology
University of Pennsylvania
Horsham, PA

Victor Paulus, Ph.D.
Global Head, Regulatory Affairs
Tannersville, PA

Louis H. Peters, Ph.D.
Kennett Square, PA

Whitney Anne Postman, Ph.D.
Philadelphia, PA

David N. Prugh
Principal Investigator
Sayre, PA

Frederick Reif, Ph.D.
Professor
Pittsburgh, PA

Marvin B. Rosenthal, M.D.
Associate Professor
Easton, PA

David R. Ross, Ph.D.
Associate Professor
Department of Economics
Bryn Mawr College
Bryn Mawr, PA

Michael Rusli, M.D.
Physician
Hummelstown, PA

Daniel Safer, Ph.D.
Research Investigator
Department of Physiology
University of Pennsylvania
Philadelphia, PA

S. C. Saltzman, M.A.
Philadelphia, PA

Carol J. Schramke, Ph.D.
Director of Behavioral Neurology
Pittsburgh, PA

Matt Schwartz, M.D.
Whitemarsh Township Environmental Advisory Board
Lafayette Hill, PA

Brian J. Sesack, M.A.
Pittsburgh, PA

Richard Nolte Sherwin, Ph.D.
Pittsburgh, PA

Elizabeth F. Shipley, Ph.D.
Research Investigator
Penn Valley, PA

John Singleton, Ph.D.
Professor Emeritus
Pittsburgh, PA

John A. Sorrentino, Ph.D.
Ambler, PA

Mitchell Struble, Ph.D.
Philadelphia, PA

Charles F. Sturm, M.D.
Murrysville, PA

Shreyas Sundaram, Ph.D.
Assistant Professor
Philadelphia, PA

Daniel B. Szyld, Ph.D.
Philadelphia, PA

Edward R. Thornton, Ph.D.
Professor
Department of Chemistry
University of Pennsylvania
Swarthmore, PA

Chris Tromley
Penn Valley, PA

Conrad N. Trumbore, Ph.D.
Professor Emeritus
Department of Chemistry and Biochemistry
University of Delaware
Kennett Square, PA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Walter H. Tsou, M.D.
Philadelphia, PA

Liz Lynne Tymkiw, M.A.
Rosemont, PA

Jessica L. Walcott, Ph.D.
Langhorne, PA

Russell Warner, M.A.
Equinunk, PA

Edward R. Wells, Ph.D.
Chair and Associate Professor
Department of Environmental Science
Wilson College
Chambersburg, PA

Thomas J. Wheeler, Ph.D.
South Abington Township, PA

Emma Williford, D.V.M.
Easton, PA

Gary L. Wire, Ph.D.
Oakdale, PA

Harry W. Woodcock, Ph.D.
Professor
School of Science and Health
Philadelphia University
Philadelphia, PA

Andrew Zentner, Ph.D.
Professor
Pittsburgh, PA

RHODE ISLAND

Andrew J. Brown, Ph.D.
Research Director
Providence, RI

Patricia J. Fontes, Ph.D.
Hopkinton, RI

Leanna Heffner
Doctoral Candidate
Department of Oceanography
University of Rhode Island
North Kingstown, RI

Kenneth M. Johnson, Ph.D.
Wyoming, RI

Matthew K. Lambert, M.A.
Newport, RI

Rainer Lohmann, Ph.D.
Narragansett, RI

Dorothy L. Read, Ph.D.
Professor Emerita
Department of Biology
University Massachusetts, Dartmouth
Kingston, RI

Barbara K. Sullivan-Watts, Ph.D.
Senior Marine Research Scientist Emerita
Department of Oceanography
University of Rhode Island
Kingston, RI

Eric J. von Wettberg, Ph.D.
Providence, RI

SOUTH CAROLINA

Ronald Benner, Ph.D.
Columbia, SC

L. M. Drucker, Ph.D.
Director
AF Consultants
Columbia, SC

Roger W. Finlay, Ph.D.
St. Helena Island, SC

Henry S. Gurr, Ph.D.
Aiken, SC

Bill Hilton Jr., M.A.
Executive Director
Hilton Pond Center for Piedmont Natural
York, SC

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

John J. Hutchens Jr., Ph.D.
Myrtle Beach, SC

Jeffrey Jalbert, Ph.D.
President
Kiawah Island, SC

Arnleiv Jensen
Master's Candidate
Project Manager
Seneca, SC

Steven Allen Kuhl, Ph.D.
Greenwood, SC

Barton Coles Marcy, M.A.
Aiken, SC

Angel D. Muehlenkamp, M.A.
Summerville, SC

Dennis E. Stevenson, Ph.D.
Associate Professor
Clemson, SC

Daniel D. Warner, Ph.D.
Professor
Central, SC

SOUTH DAKOTA

Ebun Laughing Crow Adelona, Ph.D.
Hot Springs, SD

Karel Ann Bielstein, M.A.
Professor
Department of Geology
Black Hills State University, Rapid City
Rapid City, SD

Cynthia K. Ehly
Master's Candidate
Rapid City, SD

Timothy Grady
Spearfish, SD

Anya Hartpence
Master's Candidate
Brookings, SD

Brian T. Hemmelman, Ph.D.
Associate Professor
Pierre, SD

Donald H. Kelley, M.D.
Deadwood, SD
Gretchen Meier, M.A.
Ecologist
ASRC Research and Technology Solutions
Sioux Falls, SD

Tiffany Schriever
Doctoral Candidate
Sioux Falls, SD

John T. Whitney, M.D.
Physician
Rapid City, SD

TENNESSEE

John Andes, M.A.
Regional Fire Management Specialist
Mount Juliet, TN

Gerald Bettice, M.A.
Instructor
Memphis, TN

Gordon M. Burghardt, Ph.D.
Professor
Knoxville, TN

Robin Byrne, M.A.
Associate Professor
Department of Science
Northeast State Community College
Erwin, TN

Robin L. Cuany, Ph.D.
Professor Emeritus
Department of Soil and Crop Sciences
Colorado State University
Knoxville, TN

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

John K. Folger, Ph.D.
Professor Emeritus
Nashville, TN

Richard Douglas Foster, M.A.
Madisonville, TN

Timothy J. Gaudin, Ph.D.
Foundation Professor
Department of Biological and Environmental Sciences
University of Tennessee, Chattanooga
Hixson, TN

Mark A. Heald, Ph.D.
Emeritus
Pleasant Hill, TN

Bruce L. Henschen, M.D.
Statcare Pulmonary Consultants
Knoxville, TN

Louis J. Jisonna, Ph.D.
Science Teacher
Nashville, TN

David H. Kesler, Ph.D.
Memphis, TN

Daniel Lindstrom, Ph.D.
Nashville, TN

Greg Loflin
Senior Engineer
Ameresco
Knoxville, TN

W. Ross McCluney, Ph.D.
Research Physicist
SunPine Consulting
Chattanooga, TN

Joan Mitchell, M.P.H.
Hermitage, TN

Liane Brauch Russell, Ph.D.
Oak Ridge, TN

Phil H. Schoggen, Ph.D.
Professor Emeritus
Department of Human Development
Cornell University
Nashville, TN

Edward Sommer, Ph.D.
Nashville, TN

David M. Trayer, M.A.
Hixson, TN

Jeff G. Wardeska, Ph.D.
Professor Emeritus
Johnson City, TN

Kenneth Young, Ph.D.
Franklin, TN

TEXAS

Robert S. Agatston, Ph.D.
Dallas, TX

Frederic Allegrini, Ph.D.
Principal Scientist
San Antonio, TX

A. Thornburg Ansevin, Ph.D.
Houston, TX

Thomas L. Arsuffi, Ph.D.
Director
Llano River Field Station
Texas Tech University
Junction, TX

Mary Bakatsa
Consulting Engineer
Austin, TX

E. William Behrens, Ph.D.
Port Aransas, TX

Ronald Benton, M.A.
Livingston, TX

Robert L. Bighouse, M.A.
Houston, TX

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Nicole L. Bjorklund, Ph.D.
Webster, TX

William B. Brogden, Ph.D.
Leander, TX

Stephen Burton, Ph.D.
Houston, TX

John Calomeni, M.D.
Lajitas, TX

Tracey Chance, M.A.
Austin, TX

Phillip J. Crabill, M.A.
Lewisville, TX

Carmen Druke, M.A.
Houston, TX

Amy E. Dunham, Ph.D.
Assistant Professor
Department of Ecology and Evolutionary Biology
Rice University
Houston, TX

Kristi Fazioli, M.A.
Seabrook, TX

Paul Fitzpatrick, Ph.D.
San Antonio, TX

Joseph L. Goldman, Ph.D.
Alpine, TX

Emmanuel Grotheer
Doctoral Candidate
San Antonio, TX

Felix D. Guerrero, Ph.D.
Boerne, TX

W. James Hadden Jr., Ph.D.
Austin, TX

Todd T. Hahn, M.A.
Software Design Engineer
Sugar Land, TX

Carol Hayman, M.A.
Professor
Austin, TX

Thomas W. Hill, Ph.D.
Professor
Department of Physics and Astronomy
Rice University
Houston, TX

Gerald E. Hite, Ph.D.
Professor
Galveston, TX

Jed Holtzman, M.A.
Houston, TX

Rodney James Hoover, M.A.
Arlington, TX

Robert Klug, Ph.D.
Engineer
Owner
RC Klug Metallurgical Consulting
Dallas, TX

Myron Kuhlman, Ph.D.
Owner
MK Tech Solutions, Inc.
Houston, TX

Thomas W. La Point, Ph.D.
Senior Scientist
Professor
Department of Biology
University of North Texas
Denton, TX

Troy A. Ladine, Ph.D.
Professor
Department of Biology
East Texas Baptist University
Marshall, TX

Robert Garland Landolt, Ph.D.
Arlington, TX

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Mathew A. Leibold, Ph.D.
Regents Professor
Section of Integrative Biology
University of Texas Austin
Dripping Springs, TX

Craig R. Linder, Ph.D.
Associate Professor
Department of Integrative Biology
University of Texas Austin
Austin, TX

Jerry Lobdill
Doctoral Candidate
Fort Worth, TX

Rafael Lopez-Mobilia, Ph.D.
Professor
San Antonio, TX

Steven M. Lucas
Master's Candidate
Austin, TX

Paul Mayer, M.D.
Livingston, TX

Mike Michael McNamara
The Woodlands, TX

Bruce Craig Melton
Austin, TX

Kat Milacek, M.A.
Environmental Health and Safety
Little Elm, TX

David Miller, M.D.
Professor
Director and Dallas Foundation
Department of Obstetrics and Gynecology
University of Texas Southwestern Medical Center
Dallas, TX

Joe Muscara, M.A.
Houston, TX

Rael Nidess, M.D.
Marshall, TX

Ronald John Parry, Ph.D.
Professor
Department of Chemistry
Rice University
Houston, TX

Nancy H. Peterson, M.A.
San Antonio, TX

Ronald Ribble, Ph.D.
Psychological
Psychiatric Forensics
Towers and Rushing Ltd
San Antonio, TX

Kevin Rolfes, M.A.
Engineer
Austin, TX

Matthew Rowe, Ph.D.
Professor of Biology
Department of Biological Science
Sam Houston State University
Huntsville, TX

Volker H.W. Rudolf, Ph.D.
Assistant Professor
Department of Ecology and Evolutionary Biology
Rice University
Houston, TX

Vicki Schaefers Ramirez, M.A.
San Antonio, TX
Asit Kumar K. Sen, Ph.D.
Austin, TX

Brian R. Shmaefsky, Ph.D.
Professor
Department of Biology
Lone Star College, Kingwood
Kingwood, TX

Joseph F. Siebert
Consulting Partner
Orange, TX

Lloyd Slevc, Ph.D.
Houston, TX

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Laurel Ann Smith, Ph.D.
Houston Urban Gardeners
Houston, TX

Louis C. Smith, Ph.D.
Houston, TX

Jane Spaeth, M.D.
New Braunfels, TX

Kimberly Taylor, Ph.D.
Galveston, TX

Ray C. Telfair II, Ph.D.
Whitehouse, TX

Don Tucker, M.A.
Austin, TX

Michael J. Tuvim, Ph.D.
Houston, TX

Albert R. Utzig, M.A.
El Paso, TX

Tom Van Wagoner, M.A.
Senior Geophysicist
San Ramon, TX

Lorin Vant-hull, Ph.D.
Professor Emeritus
Department of Physics
University of Houston
Elgin, TX
Douglas P. Verret, Ph.D.
Texas Instruments Fellow
Sugar Land, TX

Leslie Beauchamp Wang, M.A.
Adjunct Professor
Houston, TX

Joe Watt, Ph.D.
Beaumont, TX

Clark Wilkinson
Austin, TX

David Rowe Wood, Ph.D.
Professor
Department of Academic Affairs
Department of Biology
Collin College
Cedar Hill, TX

Charles P. Zeller
Austin, TX

UTAH

Sherman Bloom, M.D.
Salt Lake City, UT

Elisabeth Cohen, M.A.
Princeton, UT

Laura A. Cotts, M.A.
Assistant Professor
Cedar City, UT

Byron L. Davis, Ph.D.
Staff Consultant
Professor
The Center for High Performance Computing
The Department of Family and Consumer Studies
University of Utah
Salt Lake City, UT

Dirk R. Davis, M.D.
Logan, UT

Jack Greene, M.A.
Smithfield, UT
Richard E. Kanner, M.D.
Professor
Department of Internal Medicine Pulmonary Division
University of Utah School of Medicine
Salt Lake City, UT

John Mull, Ph.D.
Professor
Department of Zoology
Weber State University
Ogden, UT

William Newmark, Ph.D.
Research Curator
Salt Lake City, UT

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Robert Robbins, Ph.D.
Orem, UT

Sam Rushforth, Ph.D.
Orem, UT

Phyllis Safman, Ph.D.
Assistant Commissioner for Academic Affairs
Salt Lake City, UT

Jack W. Sites Jr., Ph.D.
Maeser Professor of Biology
Department of Biology
Brigham Young University
Provo, UT

Daniel P. Stormont
Doctoral Candidate
Electrical Engineer
Brigham City, UT

John M. Veranth, Ph.D.
Research Associate Professor
Department of Pharmacology and Toxicology
University of Utah
Salt Lake City, UT

James Viney, M.D.
Salt Lake Cty, UT

Erica von Allmen, M.A.
Salt Lake City, UT

James A. Wechsler, Ph.D.
Salt Lake City, UT

William Lee White
Master's Candidate
Salt Lake City, UT

Becky L. Williams, Ph.D.
Provo, UT

Thomas M. Yuill, Ph.D.
Director
Professor Emeritus
Department of Pathobiological Sciences
University of Wisconsin, Madison
Mapleton, UT

VERMONT

Rosemary D. Bevan, M.D.
Professor Emeritus
Department of Pharmacology
University of Vermont
Charlotte, VT

Virginia M. Clarke, D.V.M.
Veterinarian
Co-owner
Richmond Animal Hospital
Richmond, VT

Erin A. Cleere, M.A.
Burlington, VT

Liesi E. Hebert, Ph.D.
Chelsea, VT

William L. Johnson, Ph.D.
Professor Emeritus
Department of Animal Science
North Carolina State University
W Dummerston, VT

John W. Lamperti, Ph.D.
Professor Emeritus
Department of Mathematics
Dartmouth College
Norwich, VT

Paul Damian Manganiello, M.D.
Professor
Obstetrics and Gynecology
Dartmouth Hitchcock Medical Center
Norwich, VT

Lance Polya, Ph.D.
Lecturer
Environmental Program
University of Vermont
Jericho, VT

Adina Roskies, Ph.D.
Post Mills, VT

Donald S. Ross, Ph.D.
Burlington, VT

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2,505 Endorsers

Peter B. Smith, Ph.D.
Adjunct Professor
Department of Environment and Liberal Arts
Green Mountain College
Belmont, VT

Rachel Smolker, Ph.D.
Co-director
Biofuel watch
Hinesburg, VT

Deane Wang, Ph.D.
Associate Professor
Department of Environment and Natural Resources
University of Vermont
Shelburne, VT

Richard Wolfson, Ph.D.
Professor
Department of Physics
Middlebury College
Middlebury, VT

VIRGINIA

Richard H. Ball, Ph.D.
Physical Scientist (Retired)
U.S. Department of Energy
Annandale, VA

Raul A. Baragiola, Ph.D.
Professor
Charlottesville, VA

Virginia G. Barber, M.D.
Crozet, VA

Pamela J. Barton, M.A.
Falls Church, VA

Keith F. Brill, M.A.
Arlington, VA

Beth Cady, Ph.D.
Alexandria, VA

John Cairns, Ph.D.
Distinguished Professor Emeritus
Blacksburg, VA

Karen Cairns, Ph.D.
Blacksburg, VA

Richard H. Chapman, Ph.D.
Alexandria, VA
Matt J. Cormons, M.A.
Parksley, VA

Becky Daiss, M.A.
Arlington, VA

Peter L. Derks, Ph.D.
Williamsburg, VA

Norman E. Dowling, Ph.D.
Blacksburg, VA

Dianne L. Dulicai, Ph.D.
Senior Consultant, CAT program
Department of Health Sciences
Drexel University
Fairfax Station, VA

Howard Epstein, Ph.D.
Professor
Environmental Science
University of Virginia
Charlottesville, VA

Anna B. Estes
Doctoral Candidate
Department of Environmental Sciences
University of Virginia
Charlottesville, VA

Felicia Etzkorn, Ph.D.
Professor
Department of Chemistry
Virginia Tech
Blacksburg, VA

Paul M. Fawcett, Ph.D.
Director of Research Resources
Office of the Vice President of Research
Virginia Commonwealth University
Richmond, VA

Quentin Fischer, Ph.D.
Roanoke, VA

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Ken A. Gigliello, M.A.
Centreville, VA

Ellen Carol Halbert, M.A.
Centreville, VA
Kenneth G. Hoffmann
Engineer
Alexandria, VA

George M. Hoke, M.D.
Charlottesvle, VA

Claudia C. Holland, M.A.
Fairfax, VA

Sophia C. Hughes, Ph.D.
Charlottesvle, VA

Carol Johnson
Doctoral Candidate
Department of Geosciences
Virginia Tech
Blacksburg, VA

Barry A. Klinger, Ph.D.
Fairfax, VA

Bret W. Leslie, Ph.D.
Geologist
Vienna, VA

Lembit U. Lilleleht, Ph.D.
Professor Emeritus
Department of Chemical Engineering
Retired
Charlottesville, VA

Christine Hartman Llewellyn, M.D.
Williamsburg, VA

Diane Alison Lowe, M.D.
Roanoke, VA

Jian Lu, Ph.D.
Assistant Professor
Department of Atmosphere, Ocean and Earth Science
George Mason University
Fairfax, VA

Joseph Luchman
Doctoral Candidate
Research Associate
Department of Psychology
George Mason University
Burke, VA

Paxton Marshall, Ph.D.
Professor
Department of Electrical and Computer Engineering
University of Virginia
Charlottesville, VA
Fred E. Maus, Ph.D.
Earlysville, VA

Robert Maybury, Ph.D.
Executive Director Emeritus
Falls Church, VA

Sandra F. McDonald, Ph.D.
Hampton, VA

Larry D. Mesner, Ph.D.
Assistant Professor
Department of Biochemistry and Molecular Genetics
University of Virginia
Charlottesville, VA

Mark Allen Minton, Ph.D.
Linville, VA

David M. Mog, Ph.D.
Arlington, VA

Julia Moriarty
Master's Candidate
Gloucester Point, VA

Francis E. Munley, Ph.D.
Salem, VA

Robert L. Nadeau, Ph.D.
Professor
Department of Environmental Science and Public Policy
George Mason University
Fairfax Station, VA

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Rekha Prakash Nadkarni, M.A.
McLean, VA

John C. Nemeth, Ph.D.
Christiansburg, VA

John Nezlek, Ph.D.
Professor
Department of Psychology
College of William and Mary
Gloucester, VA

Benjamin D. Owen, M.A.
Roanoke, VA

Bruce H. Parker, M.A.
Alexandria, VA

Lydia Patton, Ph.D.
Assistant Professor
Department of Philosophy
Virginia Tech
Blacksburg, VA
Jerome Paulson, M.D.
Alexandria, VA

Christopher D. Peloso, M.A.
Arlington, VA

Mary Picardi, M.D.
Virginia beach, VA

Robert Poignant, M.P.H.
Lynchburg, VA

Ana Prados, Ph.D.
Research Assistant Professor
University of Maryland, Baltimore County
Springfield, VA

Charles Pruett, Ph.D.
Harrisonburg, VA

James Read, Ph.D.
Professor Emeritus
Blacksburg, VA

Diane Rosin, Ph.D.
Charlottesville, VA

Susy Rothschild, Ph.D.
Program Manager
Mclean, VA

Virginia G. Rovnyak, Ph.D.
Crozet, VA

Charles Sharpless, Ph.D.
Associate Professor
Department of Chemistry
University of Mary Washington
Fredericksburg, VA

Beverly Pleasants Silver, Ph.D.
Associate Professor Emerita
Harrisonburg, VA

Stephen J. Simon, Ph.D.
Consultant
Independent Consultant
Oakton, VA

Lowell Smith, Ph.D.
Senior Scientist
Berryville, VA

Tricia A. Smith, Ph.D.
Postdoctoral Research Fellow
Department of Pharmacology and Toxicology
Virginia Commonwealth University
Richmond, VA

George Spagna, Ph.D.
Associate Professor
Department of Physics
Randolph-Macon College
Ashland, VA

David P. Stanford, Ph.D.
Professor
Williamsburg, VA

Carey Stronach, Ph.D.
Professor Emeritus
Petersburg, VA

John Summerville, M.D.
Midlothian, VA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Melanie Szulczewski, Ph.D.
Assistant Professor
Department of Earth and Environmental Sciences
University of Mary Washington
Fredericksburg, VA

Brian Turner, Ph.D.
Professor and Chair
Department of Political Science
Randolph-Macon College
Ashland, VA

Robert L. Van de Castle, Ph.D.
Professor Emeritus
Health Sciences
University of Virginia
Charlottesville, VA

David Williams, M.D.
Assistant Professor
Pathology
Virginia Commonwealth University
Richmond, VA

David Wotton, Ph.D.
Charlottesville, VA

WASHINGTON

Margaret Alic, Ph.D.
Eastsound, WA

Charles D. Anderson, Ph.D.
Professor Emeritus
Department of Chemistry
Pacific Lutheran University
Gig Harbor, WA

Martha Atkinson, M.A.
Biologist
Valley, WA

Dominique Bachelet, Ph.D.
Senior Climate Change Scientist
Olympia, WA

Benjamin J. Belzer, Ph.D.
Associate Professor
Department of Electrical Engineering and Computer Science
Washington State University
Pullman, WA

David B. Benson, Ph.D.
Professor (Retired)
Pullman, WA

Sara Bhakti, Ph.D.
Kirkland, WA

Cecilia M. Bitz, Ph.D.
Associate Professor
Seattle, WA

David Bixler, M.D.
Intensive Care Unit
Harrison Critical Care
Lake Forest Park, WA

John Chambers, Ph.D.
Port Angeles, WA

Richard M. Conrey, Ph.D.
Research Technologist III
School of Earth and Environmental Sciences
GeoAnalytical Lab
Washington State University
Pullman, WA

David Cosman, Ph.D.
Bainbridge Island, WA

Herbert Curl Jr., Ph.D.
Seattle, WA

David L. Daggett, Ph.D.
Technical Fellow
Airplane Environmental Performance
The Boeing Company
Seattle, WA

Anita Das, M.A.
Seattle, WA

February 2011

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2,505 Endorsers

James E. Davis, Ph.D.
Scientist Director (Retired)
U.S. Public Health Service
Wenatchee, WA

Lisa Davison, M.D.
Seattle, WA

Roger de Roos, Ph.D.
Friday Harbor, WA

Stephanie Roemer Develle, M.D.
Kirkland, WA

Joseph P. Dray
Systems Development Engineer
Edmonds, WA

Keith B. Elkon, M.D.
Professor of Medicine
Seattle, WA

Carla Schlatter Ellis, Ph.D.
Professor Emerita
Port Townsend, WA

Richard L. Ellison, M.A.
Adjunct Professor
Department of Science
North Seattle Community College
Seattle, WA

David Fish, Ph.D.
Senior Research Scientist
Bellevue, WA

Robert Fleagle, Ph.D.
Professor Emeritus
Department of Atmospheric Sciences
University Washington
Seattle, WA

Earl N. Forsman, Ph.D.
Professor (Retired)
Department of Physics
Spokane, WA

Diego Gabrieli, M.A.
Seattle, WA

Richard H. Gammon, Ph.D.
Professor Emeritus
Department of Chemistry and Oceanography
University of Washington
Shoreline, WA

Edward W. Geller, M.A.
Mercer Island, WA

Bob L. Gillespie, Ph.D.
Professor
Department of Agriculture and Natural Resources
Wenatchee Valley College
Wenatchee, WA

Nancy C. Gleason, M.A.
Fish Biologist
Seattle, WA

Kathie Sue Golden, Ph.D.
Marysville, WA

Beatrice Greenwald, Ph.D.
Seattle, WA

Chris Guthrie, Ph.D.
Research Scientist
Veterans Affairs Puget Sound Health Care System
Brier, WA

Charles B. Halpern, Ph.D.
Seattle, WA

James Harsh, Ph.D.
Pullman, WA

Michael J. Healy, M.A.
Senior Research Scholar
Electrical and Computer Engineering
University of New Mexico
Seattle, WA

Tim C. Hesterberg, Ph.D.
Senior Statistician
Google
Seattle, WA

February 2011

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2,505 Endorsers

Herbert W. Hethcote, Ph.D.
Professor Emeritus
Department of Mathematics
University of Iowa
Bainbridge Island, WA

Frederick Stanton Hillier, Ph.D.
Professor
Department of Management Science and Engineering
Stanford University
Redmond, WA

Ralph Hochendoner, M.A.
White Salmon, WA

William Joseph Hoffer
Professional Engineer
Department of Engineering
Sunergy Engineering Services PLLC
East Wenatchee, WA

Elton Homan, Ph.D.
Visiting Fellow
Department of Entomology
Cornell University
Port Angees, WA

Jeff Johnston, Ph.D.
Olympia, WA

Carol Z. Jolles, Ph.D.
Seattle, WA

Dorothy Jordan, D.V.M.
Lynden, WA

Robert B. Kaplan, Ph.D.
Professor Emeritus
Port Angeles, WA

Eugene Kiver, Ph.D.
Professor Emeritus
Department of Geology
Retired
Anacortes, WA

Steve Kohl, M.D.
Brush Prairie, WA

Jeffrey Paul LaGasse, M.D.
Freeland, WA

William R. Larson, Ph.D.
Professor Emeritus
Department of Behavioral Science
California Polytechnic University, Pomona
Port Angeles, WA

Cathy Lindsay, M.D.
Seattle, WA

Alan Q. Lippert, M.A.
Mercer Island, WA

Deirdre Lockwood
Doctoral Candidate
Department of Oceanography
University of Washington
Seattle, WA

Virginia I. Lohr, M.A.
Pullman, WA

Norman Y. Luther, Ph.D.
Underwood, WA

Ro W. Marks
Project Manager
Bellevue, WA

Leslie B. Marshall, Ph.D.
Bainbridge Island, WA

Laureen Martin, Ph.D.
Senior Research Scientist
Port Townsend, WA

Alec McDougall, M.A.
Adjunct Professor
Mount Vernon, WA

Melissa M. McKay, M.A.
Faculty
Department of Environmental Science
Edmonds Community College, Washington
Lynnwood, WA

Katharine A. Miller, Ph.D.
Seattle, WA

February 2011

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2,505 Endorsers

Edward L. Mills, M.A.
Bellevue, WA

Steven J. Monahan, Ph.D.
Director
Kenmore, WA

Robert T. Moore, Ph.D.
Associate Professor Emeritus
Department of Mathematics
University of Washington
Lake Forest Park, WA

Jeffrey Morris, Ph.D.
Economist
Sound Resource Management
Olympia, WA

Gary Nelson, Ph.D.
(Retired)
Port Townsend, WA

Elaine A. Nelson, Ph.D.
Port Townsend, WA

Karl A. Ostrom, Ph.D.
Co-Director
Network for Business Innovation and Sustainability
Kirkland, WA

Tracy Jenkins Ouellette, M.D.
Bow, WA

Gary Pascoe, Ph.D.
Principal
Port Townsend, WA

Kenneth W. Porter
Master's Candidate
Mercer Island, WA

John D. Potter, Ph.D.
Member and Senior Advisor
Division of Public Health Sciences
Fred Hutchinson Cancer Research Center
Seattle, WA

Gregory V. Priestley
Research Scientist (Retired)
Department of Hematology
University of Washington
Renton, WA

Scott Ramos, Ph.D.
Seattle, WA

Resa Eileen Raven, Ph.D.
Olympia, WA

Fred M. Reinman, Ph.D.
Fox Island, WA

Louis P. Richard, M.A.
Bainbridge Island, WA

Peter G. Rimbos, M.A.
Principal Engineer
Maple Valley, WA

Kit Robinson, M.A.
Woodinville, WA

Stan Fay Robinson, Ph.D.
Seattle, WA

Anne Roda, Ph.D.
Seattle, WA

Stephen Rosenman, Ph.D.
Mercer Island, WA

Scott John Rozenbaum, M.A.
Certified Professor
Wetland Scientist
Rozewood Environmental Services, Inc.
Lopez Island, WA

Elizabeth R. Schermer, Ph.D.
Bellingham, WA

Richard Dean Schwartz, Ph.D.
Professor Emeritus
Department of Physics and Astronomy
University of Missouri, St. Louis
Sequim, WA

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Ruth W. Shearer, Ph.D.
Retired Consultant in Toxicology
Lacey, WA

M. Kent Shellenberger, Ph.D.
Sequim, WA

Richard T. Shield, Ph.D.
Shelton, WA

Peter Smith, M.A.
Aerospace Consultant
Peter Smith and Associates
Issaquah, WA

Robert G. Stagman, M.D.
Mercer Island, WA

Edward A. Stern, Ph.D.
Emeritus Professor
Department of Physics
University of Washington
Seattle, WA

James Stewart, Ph.D.
Professor
Department of Physics
Western Washington University
Ferndale, WA

Patricia Szot, Ph.D.
Senior Lecturer
Psychiatry and Behavioral Science
University of Washington
Auburn, WA

David Bartlett Thomas, M.D.
Member
Department of Epidemiology
Fred Hutchinson Cancer Research Center
Seattle, WA

Patricia A. Townsend
Doctoral Candidate
Seattle, WA

John E. Vinson, M.A.
Shelton, WA

Robert W. Vocke, Ph.D.
Husum, WA

Bruce B. von Borstel, M.A.
Sequim, WA

Robert von Tobel, M.A.
Bellevue, WA

John Fredric Wagenknecht
Master's Candidate
Roslyn, WA

Richard E. Wallace, Ph.D.
Chief Engineer of Computer-Aided
Engineering (Retired)
Boeing
Issaquah, WA

John M. Wallace, Ph.D.
Professor
Department of Atmospheric Sciences
University of Washington
Seattle, WA

Stacey L. Weiss, Ph.D.
Associate Professor
Tacoma, WA

Stanley G. Willard, M.A.
Professor Chemistry (Retired)
Department of Science
Shoreline College
Port Townsend, WA

Elaine Willey, M.A.
Seattle, WA

Marian Wineman, M.A.
Seattle, WA

Charles F. Wurster, Ph.D.
Professor Emeritus
Marine Sciences Research Center
State University of New York
Seattle, WA

WEST VIRGINIA

Jim Culberson, Ph.D.
Morgantown, WV

February 2011

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2,505 Endorsers

John E. Hall, Ph.D.
Professor Emeritus
Morgantown, WV

Eric Hopkins, M.A.
GIS Specialist
Morgantown, WV

Sarah S. Knox, Ph.D.
Professor
Director Program in Epigenetics
Department of Community Medicine
Mary Babb Randolph Cancer Center
West Virginia University Medical School
Morgantown, WV

Robert Agustus Mertz, M.A.
Science Teacher
Spencer, WV

John Thomas Peterson, M.A.
Certified Registered Nurse Anesthetists
Kingwood, WV

Charles Pique, Ph.D.
Electronic Engineer
Professor (Retired)
Charleston, WV

G. Paul Richter, Ph.D.
Buckhannon, WV

Robert Bruce Weiser, Ph.D.
Parkersburg, WV

Paul E. Wilson, M.A.
Charles Town, WV

WISCONSIN

Joseph E. Ancel, M.A.
Wisconsin Rapids, WI

James E. Boulter, Ph.D.
Associate Professor
Department of Chemistry
University of Wisconsin, Eau Claire
Eau Claire, WI

Bjorn Brooks, Ph.D.
Postdoctoral Research Scientist
Department of Atmospheric Oceanic and Space Sciences
University of Wisconsin, Madison
Madison, WI

James H. Campbell, M.A.
Madison, WI

Donald Harvey Campbell, Ph.D.
Principal Geologist
Research
Campbell Petrographics
Dodgeville, WI

Anders Carlson, Ph.D.
Assistant Professor
Department of Geosciences
University of Wisconsin
Madison, WI

Derek Clevidence, M.D.
Cottage Grove, WI

Susan M. De Vos, Ph.D.
Madison, WI

Regiis P. DiGiacomo, M.A.
Consultant
Electrical and Computer Engineering
Marquette University
Wauwatosa, WI

Tracy S. Feldman, Ph.D.
Assistant Professor
Stevens Point, WI

Maria L. Fernandez-Medina, Ph.D.
Verona, WI

Gerald K. Flakas, M.A.
Engineer (Retired)
Delafield, WI

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Wesley K. Foell, Ph.D.
(Retired)
College of Engineering and Institute for Environmental Studies
University of Wisconsin, Madison
Madison, WI

Brian L. Frey, Ph.D.
Senior Scientist
Department of Chemistry
University of Wisconsin
Madison, WI

Thomas C. Friedrich, Ph.D.
Madison, WI

Mark G. Friesen, Ph.D.
Associate Scientist
Department of Physics
University of Wisconsin, Madison
Madison, WI

Christina D. Gallup, Ph.D.
Associate Professor
Department of Geological Sciences
University of Minnesota Duluth
Superior, WI

Mary I. Graziano, M.A.
Galesville, WI

Michael Green
Doctoral Candidate
Madison, WI

Scott L. Halberg, M.A.
Hudson, WI

Bernadine Hoeft, M.A.
Teacher (Retired)
Milwaukee Public Schools
Milwaukee, WI

Monika Ivancic, Ph.D.
Associate NMR Director
Department of Chemistry
University of Wisconsin
Madison, WI

Sharon L. Knopp, Ph.D.
Eau Claire, WI

David Knutzen, M.D.
Waunakee, WI

James A. Koelbl, M.A.
Scientist II
Cross Plains, WI

Bruce Krawisz, M.D.
Marshfield, WI

Dubear Kroening, Ph.D.
Menasha, WI

Max Lagally, Ph.D.
Madison, WI

Richard L. Lindroth, Ph.D.
Professor
Department of Entomology
University of Wisconsin, Madison
Madison, WI

Olvi L. Mangasarian, Ph.D.
Professor Emeritus
Department of Computer Science
University of Wisconsin Madison
Madison, WI

Kathleen M. Marr, Ph.D.
Chair Natural Sciences
Sheboygan, WI

Constance McCarty, M.D.
Professor
Medicine (Rheumatology)
Medical College of Wisconsin
Hartland, WI

Galen Mckinley, Ph.D.
Madison, WI

Hans Meyer
Pewaukee, WI

Robert Molthen, Ph.D.
Brookfield, WI

February 2011

Scientists' Statement on the Clean Air Act
2,505 Endorsers

Colleen Mouw, Ph.D.
Fitchburg, WI

Susan M. Nossal, Ph.D.
Associate Scientist
Department of Physics
University of Wisconsin, Madison
Madison, WI

John Reisel, Ph.D.
Associate Professor
Department of Mechanical Engineering
University of Wisconsin, Milwaukee
Milwaukee, WI

James A. Rossmanith, Ph.D.
Madison, WI

Dennis K. Ryan, M.D.
La Crosse, WI

Eric M. Sanden, Ph.D.
Professor
Department of Plant and Earth Science
University of Wisconsin
River Falls, WI

Robert B. Scheele, Ph.D.
Madison, WI

Peter Sigmann, M.D.
Sturgeon Bay, WI

Richard Spindler, Ph.D.
Eau Claire, WI

Yoyi Steele, M.A.
Wildlife Biologist
Madison, WI

Erika M. Voss, M.D.
Wauwatosa, WI

Daniel N. Weber, Ph.D.
Senior Scientist
Children's Environmental Health Science Center
University of Wisconsin, Milwaukee
Milwaukee, WI

WYOMING

Stephen T. Jackson, Ph.D.
Professor and Director
Department of Botany and Ecology
University of Wyoming
Laramie, WY

U.S. TERRITORIES

American Samoa
Douglas Fenner, Ph.D.
Pago Pago, AS

Puerto Rico

Jonathan S. Friedman, Ph.D.
Senior Research Associate
National Astronomy and Ionosphere Center
Cornell University
Arecibo, PR

Carlos R. Lugo, Ph.D.
Auxiliary Professor
Department of Biology
Pontifical Catholic University
San German, PR

U.S. Virgin Islands

Catherine A. Childs, M.A.
Executive Director
Island Offsets
Christiansted, VI

October 21, 2009

- American Association for the Advancement of Science
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- American Geophysical Union
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- American Society of Agronomy
- American Society of Plant Biologists
- American Statistical Association
- Association of Ecosystem Research Centers
- Botanical Society of America
- Crop Science Society of America
- Ecological Society of America
- Natural Science Collections Alliance
- Organization of Biological Field Stations
- Society for Industrial and Applied Mathematics
- Society of Systematic Biologists
- Soil Science Society of America
- University Corporation for Atmospheric Research

Dear Senator:

As you consider climate change legislation, we, as leaders of scientific organizations, write to state the consensus scientific view.

Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver. These conclusions are based on multiple independent lines of evidence, and contrary assertions are inconsistent with an objective assessment of the vast body of peer-reviewed science. Moreover, there is strong evidence that ongoing climate change will have broad impacts on society, including the global economy and on the environment. For the United States, climate change impacts include sea level rise for coastal states, greater threats of extreme weather events, and increased risk of regional water scarcity, urban heat waves, western wildfires, and the disturbance of biological systems throughout the country. The severity of climate change impacts is expected to increase substantially in the coming decades.[1]

If we are to avoid the most severe impacts of climate change, emissions of greenhouse gases must be dramatically reduced. In addition, adaptation will be necessary to address those impacts that are already unavoidable. Adaptation efforts include improved infrastructure design, more sustainable management of water and other natural resources, modified agricultural practices, and improved emergency responses to storms, floods, fires and heat waves.

We in the scientific community offer our assistance to inform your deliberations as you seek to address the impacts of climate change.

[1] The conclusions in this paragraph reflect the scientific consensus represented by, for example, the Intergovernmental Panel on Climate Change and U.S. Global Change Research Program. Many scientific societies have endorsed these findings in their own statements, including the American Association for the Advancement of Science, American Chemical Society, American Geophysical Union, American Meteorological Society, and American Statistical Association.

American Association for the Advancement of Science
1200 New York Avenue, NW, Washington, DC 20005 USA
Tel: 202 326 6600 Fax: 202 289 4950 www.aaas.org

Alan I. Leshner
Executive Director
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The US Economic Impacts of Climate Change and the Costs of Inaction

A Review and Assessment by
the Center for Integrative Environmental Research (CIER)
at the University of Maryland

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Contributors to the Report

Matthias Ruth
Director, Center for Integrative Environmental Research, and Roy F. Weston Chair for Natural Economics

Dana Coelho
Research Associate, Center for Integrative Environmental Research

Daria Karetnikov
Research Assistant, Center for Integrative Environmental Research

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For additional information on this report, please contact:
Matthias Ruth at cier@umd.edu

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1 Executive Summary

1.1 Introduction

As science continues to bring clarity to present and future global climate change, policymakers are beginning to respond in earnest and proposing policies that aim to curb greenhouse gas emissions and help society adapt to the impending impacts triggered by past emissions. Although these policies are gaining momentum, their importance is not understood by many, including Congress, the public and the media. All too frequently, inaction is motivated by the perceived high cost of reducing greenhouse gas emissions. The costs of not taking on the challenges posed by climate change are frequently neglected and typically not calculated.

The range of climatic changes anticipated in the United States – from rising sea levels to stronger and more frequent storms and extreme temperature events – will have real impacts on the natural environment as well as human-made infrastructure and their ability to contribute to economic activity and quality of life. These impacts will vary across regions and sectors of the economy, leaving future governments, the private sector and citizens to face the full spectrum of direct and indirect costs accrued from increasing environmental damage and disruption.

This report presents a review of economic studies for the United States and relates them to predicted impacts of climate change. The summary findings are organized by region and identify the key sectors likely affected by climate change, the main impacts to be expected, as well as estimates of costs. The report builds on the 2000 Global Change Research Program National Assessment, using additional regional and local studies, as well as new calculations derived from federal, state and industry data sources. From this review and quantification, five key lessons emerge:

1. Economic impacts of climate change will occur throughout the country.
2. Economic impacts will be unevenly distributed across regions and within the economy and society.
3. Negative climate impacts will outweigh benefits for most sectors that provide essential goods and services to society.
4. Climate change impacts will place immense strains on public sector budgets.
5. Secondary effects of climate impacts can include higher prices, reduced income and job losses.

These lessons are supported in much greater detail in the full report. In their totality, the data and information in this report strongly support a call for action to avoid the most severe impacts of climate change, as well as to prepare for and adapt to those impacts that are unavoidable.

LESSON 1: Economic impacts of climate change will occur throughout the country.

The effects of climate change will be felt by the entire nation:

- all sectors of the economy - most notably agriculture, energy, and transportation - will be affected;
- essential infrastructures that afford us reliable services and high standards of living (such as water supply and water treatment) will be impacted; and
- ecosystems, on which quality of life relies (such as forests, rivers, and lakes), will suffer.

In the West and Northwest, climate change is expected to alter precipitation patterns and snow pack, thereby increasing the risk of forest fires. Forest fires cost billions of dollars to suppress, and can result in significant loss of property. The Oakland, California fire of 1991 and the fires in San Diego and San Bernardino Counties in 2003 each cost over $2 billion. Every year for the past four years, over 7 million acres of forests in the National Forest System have burned with annual suppression costs of $1.3 billion or more.

The Great Plains and the Midwest will suffer particularly from increased frequency and severity of flooding and drought events, causing billions of dollars in damages to crops and property. For example, the North Dakota Red River floods in

1997 caused $1 billion in agricultural production losses, and the Midwest floods of 1993 inflicted $6-8 billion in damages to farmers alone.

The Northeast and Mid-Atlantic region will see increased vulnerability to sea level rise and storms. Depending on the category of the event, evacuation costs for the Northeast region may range, for a single event, between $2 and $6.5 billion. Since 1980, there have been 70 natural weather-caused disasters, with damages to coastal infrastructure exceeding $1 billion per event. Taken together, their combined impact surpassed $560 billion in damages.

Decreased precipitation levels in the South and Southwest will strain water resources for agriculture, industry and households. For the agriculturally productive Central Valley in California alone, the estimated economy-wide loss during the driest years is predicted to be around $6 billion per year. Net agricultural income for the San Antonio Texas Edwards Aquifer region is predicted to decline by 16-29% by 2030 and by 30-45% by 2090 because of competing uses for an increasingly scarce resource – water.

The true economic impact of climate change is fraught with "hidden" costs. Besides the replacement value of infrastructure, for example, there are real costs of re-routing traffic, workdays and productivity lost, provision of temporary shelter and supplies, potential relocation and re-training costs, and others. Likewise, the increased levels of uncertainty and risk, brought about by climate change, impose new costs on the insurance, banking, and investment industries, as well as complicate the planning processes for the agricultural and manufacturing sectors and for public works projects.

Since the early 1990s, and especially during the 21st century, significant progress has been made in understanding the impacts of climate change at national, regional, and local scales. These studies, many of which are discussed in the pages that follow, highlight physical processes that influence transportation, energy and water supply systems, agriculture and forestry, fisheries, tourism, and other important economic sectors. There is, however, a lack of research that quantifies and compares these impacts, and a deficiency in using what is known about climate impacts to guide adaptation actions from the national level down to the local level. Thus, the full economic costs will likely be much higher than what is reported currently.

LESSON 2. Economic impacts will be unevenly distributed across regions and within the economy and society.

Not all regions or sectors of the country will be equally affected by climate impacts because of differences in climatic, economic and social conditions whose interplay influences coping capacities. For example, in the Northeast, the maple sugar industry – a $31 million industry - is expected to suffer losses of between 15 and 40% ($5-12 million) in annual revenue due to decreased sap flow. The region can expect a decrease of 10-20% in skiing days, resulting in a loss of $405-810 million per year. The dairy industry is also highly sensitive to temperature changes, since the dairy cows' productivity starts decreasing above 77°F (25°C). In California, an annual loss of $287-902 million is expected for this $4.1 billion industry. Losses are expected to the $3.2 billion California wine industry as well, since grape quality diminishes with higher temperatures. In each case, these may be considered small niche sectors in their respective economies – accounting for less than one-tenth of gross state product – yet they are an essential element of local employment, history, culture and landscape.

Changes in climate conditions may foster the spread of pests and diseases. For example, spruce bark beetle outbreaks in Alaska could cause a 50% loss of harvestable timber, resulting in a $332 million annual loss (less than one-tenth of gross state product). The recent spread of Southern Pine beetle attributable in part to climate change, has affected sawtimber and pulpwood production in Alabama, Louisiana, Mississippi, Tennessee, Kentucky and the Carolinas. On average, annual losses have reached over 1% of gross state product.

It's hard to imagine another natural catastrophe on the scale of Hurricane Katrina. The economic cost estimates from Katrina range upward of $200 billion, or over 1% of US gross domestic product. Yet climate change may already be affecting the strength and length of tropical storms and hurricanes, and is expected to contribute to an increase in hurricane intensity and duration. With 53 percent of the total population in the US close to major bodies of water, people and infrastructure increasingly lie in harm's way.

Not only are sectors and regions impacted differently, climate change will also take its toll, in varied ways, on the nation's population. For example, temperatures are expected to increase across the country, resulting in an increase of extreme heat events. Events like the Chicago heat wave of 1995, which lasted for five days, could become more frequent. This event resulted in an 85% increase in heat-related mortality and an 11% increase in heat-related hospitalizations. Many of the affected were elderly or poor. Similarly, it is projected that by 2100, temperatures in Boston, MA, will be similar to those of today's Richmond, VA or Atlanta, GA. The number of days above 90°F may rise from the current 13 day average to over 30 days per year within the next 25 years. These are clearly trends that significantly affect local populations and will result in individual- and community-level hardship.

LESSON 3. Negative climate impacts will outweigh benefits for most sectors that provide essential goods and services to society.

For some sectors of the economy and some regions, climate change may temporarily be beneficial. For example, Mid-Atlantic States' agricultural yields are likely to benefit from slightly higher temperatures temporarily. However, additional warming and the movement of agricultural areas mean not only economic losses for farms that lose production. They also add costs to farms that benefit from improved growing conditions because cultivation of new crops and changing farming practices may make prior investments in technology obsolete. More importantly, although the factors that provide temporary gains to some are the same that cause losses to others, overall, everyone suffers from the introduction of new pests and the spread of existing ones, disruption of the hydrological cycle, and the impacts of severe weather events. For example, New York State's agricultural yield may be reduced by as much as 40%, resulting in $1.2 billion in annual damages. Expected water shortages in California's Central Valley are likely to affect the agricultural sector in the area. The economy-wide annual losses generated are expected to be around $6 billion during particularly dry years. Agriculture around the San Antonio Texas Edwards Aquifer region is likely to suffer a similar fate. The regional impact may reach losses of $3.6-6.5 billion by 2030 and $6.75-10.13 billion by 2090. Even those farms and regions that temporarily benefit from altered environmental conditions (e.g., carbon fertilization and extended growing season) risk economic losses if temperatures exceed those preferred by the crops they currently produce.

Climate change will trigger increases in energy demand for cooling and will outpace declines in heating requirements. For example, electricity demand in Massachusetts may increase by 40% in 2030 because of climate change alone, most of which will occur in summer months and require significant investment in peak load capacity and energy efficiency measures. Nationwide, the required investment may exceed $300 billion by the middle of this century. Given the long lead times of capacity expansion in the energy sector, little time remains to act on anticipated warming trends.

LESSON 4. Climate change impacts will place immense strains on public sector budgets.

The effects of climate change will likely place immense strains on public budgets, particularly as the cost of infrastructure maintenance and replacement increases. At the same time, economic losses may translate into lost tax revenues. As a result, public officials may need to raise taxes or cut services. For example, climate change is expected to add $5-10 billion to Alaska's infrastructure maintenance budget through 2080, depending on the climate change scenario under consideration, because of major replacement costs and service disruptions generated by climate change effects. Recent estimates indicate that a sea-level rise of nearly 20 inches (50 cm) by 2100 would cause $23-170 billion in damages to coastal property throughout the US. In Hawaii, sea level rise will require upgrades to the drinking and wastewater infrastructures -- at a cost that exceeds $1.9 billion over the next 20 years.

In addition, managed ecosystems and the communities they border will require increased resources for their protection. In 2006, $1.5 billion in federal funds was used to protect over 9.3 million acres of forest land and adjacent communities. Climate change-induced warming will mean that Washington State, for instance, will face fire-suppression cost increases of over 50% by 2020 and over 100% by 2040, raising the expenses to $93 and $124 million respectively.

Federal insurance programs' funds are strained because of the increasing trends of adverse weather events. From 1980 to 2005, federal insurance agencies paid out more than $76 billion in claims. The overall risk exposure of the National Flood Insurance Program increased four-fold from 1980 to $1 trillion in 2005, and the Federal Crop Insurance Corporation's exposure reached $44 billion.

Planning and public policies that promote adaptation and occur in anticipation of climate change impacts are essential to reduce strain on budgets. For example, building codes and land use planning typically reflect historical experiences. With future climate conditions quite different from the past, many of those codes and standards are becoming obsolete. Yet, because we continue to build on the basis of these standards, infrastructures that are expected to last many decades may be outdated, requiring retrofits and upgrades shortly after they have been built. Thus, investments assumed to be completed will require additional resources far sooner than planned.

LESSON 5. Secondary effects of climate impacts can include higher prices, reduced income and job loss.

The indirect effects of climate change have rarely been quantified, yet they are likely substantial. Such effects may be present in the form of higher prices for products, because the prices of raw materials and energy, transport, insurance and taxes increase. As the costs for doing business increase, competitiveness of individual firms, entire sectors or regions may decline. With this decline may come a loss of employment and overall economic security. As climate change affects jobs and household income in the United States, and as resources are increasingly diverted to help maintain safety and adequate supply of goods and services, national security may be weakened.

For example, a 1988 Midwest drought cost the region over $49 billion – in part because river-borne commercial shipping routes had to be replaced by more expensive railroad transport due to Mississippi River's reduced water levels. The costs of future droughts are likely to extend beyond requirements to meet public and agricultural water needs, with the region's manufacturing sector incurring costs as well. Around 60,000 jobs and $3 billion annually depend on the movement of goods within the Great Lakes-St. Lawrence route. Drought could lower water levels in the Great Lakes, requiring additional dredging of sediments at an annual cost of between $85 and $142 million, simply to maintain shipping lanes; and overall decreases in connectivity flow are estimated to cost the manufacturing sector $850 million per year.

Damages from severe hurricanes can span many economic sectors. Hurricane Katrina, for example, damaged not only hundreds of thousands of housing units and other urban infrastructure, but it also affected as many as 2,100 oil platforms and damaged over 15,000 miles of pipelines. Lost revenues due to these damages amounted to nearly $11 billion.

1.2 Conclusions and Recommendations

Scientific evidence is mounting that climate change will directly or indirectly affect all economic sectors and regions of the country, though not all equally. Although there may be temporary benefits from a changing climate, the costs of climate change rapidly exceed benefits and place major strains on public sector budgets, personal income and job security. Because of the economic costs of climate change, we conclude that delayed action (or inaction) on global climate change will likely be the most expensive policy option. **A national policy for immediate action to mitigate emissions coupled with efforts to adapt to unavoidable impacts will significantly reduce the overall costs of continued climate change.**

Climate change will pose major challenges for the country as a whole. At the same time, the very nature of climate impacts and adaptation options requires focus on issues at regional and sectoral scales. The number, breadth and sophistication of case studies estimating economic costs of impacts are increasing. Yet, coverage continues to be limited to some of the main sectors of the economy and discrete regions or even single states, with little attention to their interdependencies. Furthermore, most estimates of the economic cost of climate impacts are for direct impacts, and few consider indirect and induced impacts. By virtue of neglecting the adverse economic ripple effects throughout the regional and national economy, many of the direct impacts listed here may be low estimates of total impacts.

The dominant methodology to judge adaptation options is to calculate the benefits associated with incremental expansion of adaptation actions and suggest that an optimum level of adaptation is reached once these benefits are equal to the marginal cost of adaptation. Many of the adaptation studies on which this report is based employ such a marginalist approach. A more adequate methodology would treat adaptation actions as bulky investments in natural, human-made and social capital, with the goal of maintaining or enhancing the services they provide. A methodological approach consistent with that viewpoint will need to rest in portfolio choice theory (i.e. how rational investors will use diversification to optimize their portfolios, and how a risky asset should be priced or valued) and needs to include methods and tools from the theory of investment and finance under risk and uncertainty. Here lies a methodological frontier to be explored in future research.

Because improved understanding of climate impacts, and the costs and benefits of these impacts, is in the national interest, **the federal government should organize and finance a set of region- and sector-specific studies that help guide climate policy and investment, using appropriate methodologies.** A wide range of resources should be brought to bear on the problem – it should be a multi-agency effort that mobilizes universities, research centers and national laboratories. Although Congressional oversight of such studies would be necessary, the intellectual power of the nation's universities and labs should be set free to do cutting-edge, original research and help to inform policy and investment decision making while we can still avoid the high cost of inaction.

2 Introduction

As science continues to bring clarity to present and future global climate change, policymakers are beginning to debate and consider various options for a national response that achieves a range of beneficial outcomes. All too frequently, inaction is motivated by the perceived high cost of mitigation and adaptation and becomes the default policy option. The direct costs of not taking on the challenges posed by climate change are often neglected – and typically not calculated. The indirect effects of climate change are considered even less frequently, yet they are likely substantial.

The true economic impact of climate change is fraught with "hidden" costs. Besides the replacement value of infrastructure, for example, there are real costs of re-routing traffic, workdays and productivity lost, provision of temporary shelter and supplies, potential relocation and re-training costs, and others. Likewise, the increased levels of uncertainty and risk, brought about by climate change, impose new costs on the insurance, banking, and investment industries, as well as complicate the planning processes for the agricultural and manufacturing sectors and for public works projects.

The range of climatic changes anticipated in the United States – from rising sea levels to stronger and more frequent storms and extreme temperature events – will have real impacts on the natural environment as well as human-made infrastructures and their abilities to contribute to economic activity and quality of life. These impacts will vary across regions and across sectors of the economy, and in many cases are intricately linked with each other. For example, just at the time when a heat wave reduces stream flow and increases water temperatures, energy demand for cooling will increase, yet power generation must be curtailed because of limitations on the use of cooling water.

Not all environmentally induced impacts on infrastructures, economy, society and ecosystems reported here can be directly or unequivocally related to climate change. However, historical as well as modeled future environmental conditions are consistent with a world experiencing changing climate. Models illustrate what may happen if we do not act now to effectively address climate change and if adaptation efforts are inadequate.

Estimates of the costs of adapting environmental and infrastructure goods and services to climate change can provide insight into the very real costs of inaction, or conversely, the benefits of maintaining and protecting societal goods and services through effective policies that avoid the most severe climate impacts. Since it is typically at the sectoral and local levels where those costs are borne and benefits are received, cost estimates can provide powerful means for galvanizing the discussion about climate change policy and investment decision-making.

Two kinds of quantifications of climate change costs and benefits typically can be found in the literature. One stems from standard microeconomic theory and assumes that adaptation actions would be taken as long as those actions increase consumer welfare. Since taking those actions also has associated costs, it is in society's best interest to halt expansion of adaptive measures at the point at which the benefits from another unit of action are equal to the cost of the next unit of adaptation. For example, increasing the height of dikes to protect against sea level rise would stop at the point at which the cost of the next inch of dike elevation would equal the benefits from that next inch.

Key underlying assumptions necessary for the standard economics approach to work include the notion that adaptation measures can be perceived as "marginal" and separable projects where benefits increase at a decreasing rate. This is the approach most frequently chosen in economic assessments of the optimal levels of mitigation and adaptation. An alternative viewpoint posits that adaptation costs are investments in the preservation of natural, human-made and social capital, and that they are "bulky", i.e. they can often not be carried out meaningfully in small increments. Adaptation, so the argument goes, would then be best understood as part of a larger portfolio, with decisions guided towards the maintenance or improvement of the quality of life. The size of dikes, for example, would be determined by the effectiveness with which wetlands, emergency preparedness, land use and development codes, and other measures and strategies interact to reduce vulnerability to sea level rise impacts down to a socially accepted level. In this context, issues of distributional impacts of climate change begin to play a role not seen in standard economic analysis.

In this report, we present estimates of climate impacts on the US, using information from case studies and modeling exercises that fall into one of these two quantification schemes. Where prior research enables us to numerically illustrate adaptation costs, we will use them as proxies for costs of impacts of climate change. Since adaptation costs are borne by specific localities and individual entities in the public, private and non-profit sectors, they are more tangible than gross economic measures of impacts. Adaptation costs might include repair of infrastructure affected by storms or sea level rise, investment in new power generation capacity to meet cooling energy needs, and investment in water storage and irrigation systems for municipalities and agriculture affected by drought.

In the following section we will use the 2000 Global Change Research Program National Assessment as a starting point for discussing regional and local climate change, impacts and adaptation options. More details are presented for specific geographic regions, including: the Northeast and Mid-Atlantic, Midwest, West, Great Plains, Southeast, Pacific Northwest, Alaska, and Hawaii and US Affiliated Islands. Where the National Assessment explored economic impacts, we report and expand upon them with results from additional regional and local studies, as well as new calculations using federal, state and industry data sources. Additionally, to standardize the results, all of the figures used in this report have been converted to 2005 dollars (Inflation Calculator 2007).

The definitive total cost of inaction is lacking due to the diversity of methodological approaches in estimating impact and adaptation cost, and the diversity of climate-induced challenges faced by society. Despite such gaps, it is clear from available information that climate change impacts are real and significant. National action to avoid the most severe impacts must be taken. The report, therefore, closes with recommendations for regional, multi-agency and multi-jurisdictional investigations that are based on a consistent and theoretically sound methodology, utilize state-of-the-art data acquisition and analysis, and present a comprehensive portrait of adaptation.

3 A Summary of US Impacts and Cross-Cutting Issues

The impacts of climate change will vary greatly across the US due to the country's size, diverse topography, ecosystems, climates and economies, and its dispersed populations and lifestyles. How this large and diverse nation, which generates a GDP of more than $13.6 trillion (current dollars, BEA 2007) and is home to more than 302 million people (US Census Bureau 2007), responds to climate change will depend on many factors. The severity of impacts is among those factors, as are the ability to understand the full implications of impacts, and the extent to which that knowledge is reflected in investment and policy decisions.

Since the early 1990s, and especially during the 21st century, significant progress has been made in understanding the impacts of climate change at national, regional, and local scales. These studies, many of which are discussed in the pages that follow, highlight physical processes that influence transportation, energy, water supply systems, agriculture and forestry, fisheries, tourism, and other important economic sectors. There persists, however, a lack of research that quantifies and compares these impacts and a deficiency in using what is known about climate impacts to guide adaptation actions, from the national down to the local level.

3.1 Water Supply and Agriculture

One of the most significant impacts of climate change in the US may be related to water supply. Surface and subsurface water flow and storage already are stressed by natural and anthropogenic causes. As a result, availability for human consumption, irrigation, energy production and industry may be reduced (Groisman et al. 2004). Climate change will exacerbate existing and future stresses placed on supplies by continued economic and population growth.

The uneven nature of climate change impacts throughout the country make the net impacts of global warming on the agricultural sector uncertain. Some northern regions are likely to experience fleeting economic benefits with more profitable crops migrating there (as the climate becomes hospitable to those crops). As climate conditions continue to change, however, those temporary benefits may be lost. Other regions, such as the Southeast, West, and southern Great Plains, may face challenges from increased temperatures, water stress, saltwater intrusion, and the potential increase in invasive species and pests – the impacts of which may cause costs to outweigh benefits.

Certain areas will experience greater precipitation levels, while others are likely to undergo prolonged droughts. In cases where more precipitation may occur in the future, damage to agricultural production may be considerable. For example, the US Midwest floods of 1993 inflicted $6-8 billion in damages to farmers. The North Dakota Red River floods in 1997 caused $1 billion in agricultural production losses. One study estimates that extreme weather-related damages to US agricultural crops are on the order of $1.5 billion per year. Expected increases in excess soil moisture conditions likely will result in an increase of their annual loss to $3 billion by the 2030s (Rosenzweig et al. 2002).

Economic impacts on the agricultural sector will vary by region. In the areas where precipitation levels are likely to stay constant or diminish, warmer temperatures may lead to increased risk of severe drought by increasing the rate of evaporation. The effects of future drought and decreased soil moisture on agriculture and natural vegetation (such as forests) are uncertain and may, at least in part, be temporarily offset by fertilization effects of higher atmospheric concentrations of CO_2 (Triggs et al. 2004). Nonetheless, the net impacts of global warming on the agricultural sector are, at least for the short- to medium-term, uncertain. Some northern regions are likely to temporarily see benefits, as more agriculturally valuable crops migrate there. However, that migration may also mean loss to some southern regions in which growing conditions may no longer be favorable for currently profitable crops. As climate continues to change, benefits from expanded production opportunities in the north may be lost as well.

Other regions, such as the Southeast, West, and southern Great Plains, may already in the short-term face challenges from increased temperatures, water stress, saltwater intrusions, and the potential increase in invasive species and pests (NAST 2001). The success of adaptation to the negative effects will likely be dependent on water availability, which already is overextended in many areas.

3.2 Coastal Impacts

With a majority of US cities and people located along the coasts (over 153 million people in 673 counties), significant and costly impacts to coastal infrastructure from storms and sea level rise are likely (Höppe and Pielke 2006). The number of people in coastal areas may grow another 7 million by 2008 (NOAA 2004). This growth, in turn, will likely increase the value of personal property and public infrastructure investment in coastal areas. As the number and intensity of adverse weather events will likely continue to increase in the future (NAST 2001), costs of climate change impacts will likely rise. Whether the surge of hurricane activity during the 2005 Atlantic Hurricane Season was due in any way to climate change is debatable (Webster et al. 2005; Hoyos et al. 2006; Kossin et al. 2007; Landsea et al. 2006), but it does provide a striking example of the costs associated with landfall of a major hurricane in a large, unprepared urban area. Real and perceived increases in the social vulnerability of coastal areas is affecting insurance coverage and rates along the Gulf and Atlantic Coasts (Mills 2005). The present rate of sea level rise is 0.08-0.12 inches per year for most of the US coast, and taking into account local subsidence, a 1-3 foot sea level rise is anticipated over the next century (Zervas 2001; IPCC 2001a). Loss of wetlands and developable land to sea level rise and erosion, as well as increased salinity of groundwater supplies and estuaries, affect agriculture and commercial fisheries, in addition to residential and economic development.

3.3 Energy

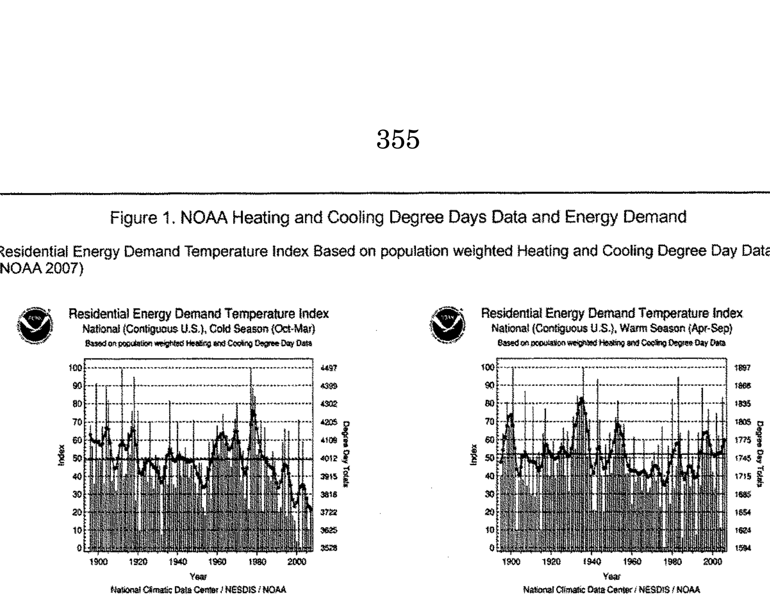
Future changes in energy supply and demand are also projected. Actual changes in production, use, and utility bills in urban areas will vary seasonally and by region (Hadley et al. 2006; Scott et al. 2005). Analysis of heating and cooling degree days, which are highly correlated with energy consumption, helps explain these changes in demand (NOAA 2007). A national trend in residential energy demand for cooling during the summer months is less apparent (no clear increase or decrease) than a national trend in heating degree days and energy use during the winter months over the last century (Figure 1). Region-specific studies, however, show very clear trends. For example an analysis of changes in heating and cooling demand in Boston, Massachusetts indicates that, depending on the climate scenario, household electricity consumption in peak summer months may be nearly three times that of the 1960-2000 average, with over 25% of the increase directly attributable to climate change (Amato et al. 2005). Similarly, Ruth and Lin (2006) show that for Maryland, approximately 24% of the increase in household electricity use and almost 10% of the increases in industrial electricity use by the year 2025, compared with the 1977-2000 average, are attributable to climate change. Such significant increases over only a few decades may render current planning for peak load capacity inadequate and may require more investment in the energy sector of those states and, likely, elsewhere in the nation.

Energy demand may also increase for irrigation (pumping water) as temperatures rise and local hydrology shifts (Peart et al. 1995; IPCC 2001b).

Conservation may become an important adaptation tactic to balance increased demand and decreased supply (Franco and Sanstad 2006; CEPA 2006). But this may also impose significant program implementation costs, such as expenditures on educational campaigns and monitoring systems.

Figure 1. NOAA Heating and Cooling Degree Days Data and Energy Demand

Residential Energy Demand Temperature Index Based on population weighted Heating and Cooling Degree Day Data (NOAA 2007)



3.4 Human Health

Impacts to human health also will vary regionally, as prevalence and susceptibility to certain diseases and health conditions vary with local climate, demographics and capacity to adapt to climate change (Rose et al. 2001). Many recent studies have linked high temperatures with increased mortality in the United States (Kalkstein 1993; Kalkstein et al. In Print), particularly in northern cities where residents are less accustomed to extremely warm weather (Table 1). Following extreme temperatures the death toll may increase as much as 85%, as it did in Chicago after a 5-day heat wave in 1995 (CDC 1995; Semenza et al. 1996, 1999). The impact of increased temperatures on morbidity and hospitalization is less clear than the mortality relationship, but a 1982 study by Jones et al. observed a 5% increase in hospital admissions during a 1980 heat wave in Kansas City (Jones et a. 1982). An 11% increase in hospitalizations was observed in Chicago following the 1995 heat wave (Semenza 1996). Increased incidence of death from heart diseases and diabetes, accidents, violence (including homicides), and suicide also have been associated with heat waves for a long time (Ellis 1972; Ellis et al. 1978).

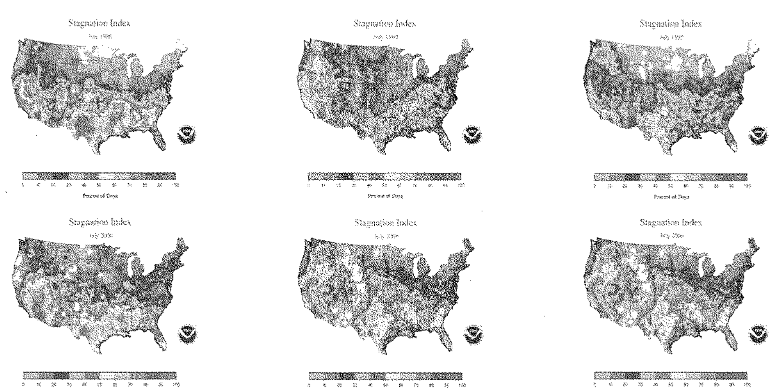
At the same time, warmer temperatures create ideal conditions for the development of stagnant air masses (Figure 2) that reduce air quality, trapping pollution and raising morbidity rates. Moreover, increased air pollution and allergens (CO_2 fertilization may lead to increased pollen production) may aggravate existing, and introduce new, respiratory ailments (Wayne et al. 2002). Stagnant air masses may also introduce travel hazards due to storms and unstable weather patterns (EPA 2003), and contribute to the spread of infectious diseases via habitat and genetic shifts in rodent and insect populations (Bradshaw and Holzapfel 2001). Although our health care infrastructure is capable of minimizing the worst effects of these impacts, the costs of adapting the infrastructure to changing conditions will be significant. In addition, any of these health-related impacts may lead to noticeable personal and insurance cost increases.

Table 1. Estimates of Total Heat-related Mortality for Average Summer on Three Climate Change Scenarios

City	Present total	Estimated deaths on non-acclimatized (and climatized) basis for (*)					
		A. GISS Trans A		B. GISS 2 × CO_2		C. GISS +2°C	
Atlanta	18	45	(23)	159	(79)	203	(148)
Chicago	173	295	(145)	412	(622)	177	(88)
Cincinnati	42	93	(83)	226	(195)	378	(189)
Dallas	19	61	(61)	309	(244)	158	(79)
Detroit	118	201	(152)	592	(295)	302	(152)
Kansas City	31	33	(40)	60	(100)	330	(212)
Los Angeles	84	153	(81)	1654	(824)	164	(82)
Memphis	20	28	(14)	177	(88)	480	(229)
Minneapolis	46	96	(47)	142	(186)	209	(105)
New York	320	777	(386)	1743	(880)	577	(289)
Philadelphia	145	288	(142)	938	(700)	441	(220)
St Louis	113	325	(162)	744	(372)	749	(275)
San Francisco	27	44	(23)	246	(202)	66	(49)

(*) Full report has five scenarios: 1) Goddard Institute of Space Studies (GISS) Trans A (A in this table), 2) another modified scenario, 3) GISS 2 × CO_2 (B here), and 4) temperature rises of 3.6°F (2°C) (C here) and 5) 7.2°F (4°C). Source: Kalkstein 1993

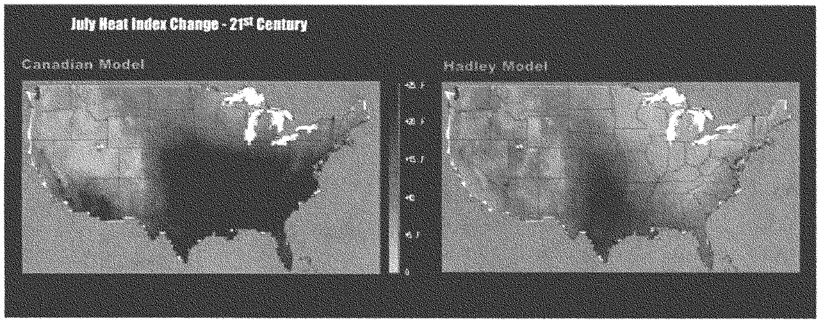
Figure 2. Air Stagnation Maps, June 1980-2006



The July heat index is predicted to increase by over 25°F (13.9°C) in some areas. The degree to which regions are likely to be affected by these increases varies, depending on the climate change model in use (see Figure 3). Both models, however, predict the greatest changes in the Southeastern region. For example, a day in Atlanta with the current heat index of 105°F (40.6°C) would reach a heat index of 115°F (46.1°C) under the Hadley Centre model, and 130°F (54.4°C) under the Canadian Climate Centre model (USGCRP 2001).

Figure 3. July Heat Index Increases in the United States.

July Heat Index Change – 21st Century. The color spectrum ranges from 0°F to +25°F in projected increase in average daily July heat index (USGCRP 2001).



Adaptation options include increasing the proportion of buildings (residences, offices and retail locations) with air-conditioning. Though it varies regionally, as of 2001, more than 70% of US residences have air-conditioning (27% in the Northeast, 88% in the South) (McGeehin and Mirabelli 2001). Other adaptation measures include changes in the built environment and use of materials that are less heat absorbing.

Hot Weather—Health Watch/Warning Systems (warning systems) have also been implemented in several US cities as a means of alerting residents of risky days.[1] First implemented in Philadelphia (called Heatline) in the summer of 1995, the warning systems have proven to be both effective and low cost (Kalkstein et al. 1996). A 2004 study by Ebi et al. quantified the costs of implementing the warning system in Philadelphia and compared those costs to the value of the lives saved (Ebi et al 2004). They estimated the total benefits from the system between 1995 and 1998 to be about $468 million.[2] The estimated wage costs for implementing the warning system were on the order of $5,000 per day on weekdays and $7,000 per day on weekends for Heatline operators and EMS crews. Other direct costs likely increased the costs of operation to $10,000 per day during a heat wave warning. With 21 warning days during 1995-98, the estimated costs of the Philadelphia system were about $210,000. The total cost of the system is likely much higher and includes expenses related to job absenteeism and lost economic productivity.

3.5 Forest Fires

More frequent and severe occurrence of forest fires may increase nationwide with climate change. Costs of suppressing fires increase with fire intensity and under certain climate conditions. Anticipated warmer and drier conditions in many areas, as well as earlier melting of snow-covered surfaces, are likely to extend the fire seasons and may increase fire intensity. A recent study analyzing wildfire trends in the western US found a six-fold increase

[1] There are presently warning systems in Seattle, Washington; Dallas and Fort Worth, Texas; Phoenix and Yuma, Arizona; Washington, DC: Chicago, Illinois; St. Louis, Missouri; Cincinnati and Dayton, Ohio; New Orleans and Shreveport, Louisiana; Little Rock, Arkansas; Memphis, Tennessee; Lake Charles and Jackson Mississippi (NOAA 2004).

[2] 117 lives saved, $4 million per "statistical life" based on EPA estimates (Smith et al. 2001).

in the area of forest burned since 1986 compared with the 1970-1986 period. The average duration of fires increased from 7.5 to 37.1 days – mostly because of an increase in spring and summer temperatures and earlier thawing of snowpacks (Westerling et al. 2006). In general, there has been an increasing trend in the annual number of acres succumbing to fire in the National Forest System (NFS) since the early 1980s (USFS 2006). For example, with 1.2 million acres burned, 1987 marked the first year since 1919 when more than 1 million acres were affected. More than 1 million acres were ablaze again in 1988, 1994, and 1996 (USFS 2000). The most acres burned in 2006, when $1.5 billion in federal funds was used to protect over 9.3 million acres. Overall, over 7 million acres have burned every year for the past four years – with annual suppression costs amounting to $1.3 billion (USFS 2006).

Catastrophic forest fires account for 2.3% of the nation's insured losses (USFS 2006). The full cost of wildfires is vastly underestimated, however, since federal and state agencies only track suppression costs, structures lost, and acres burned. Other expenditures including loss of property and human life, public health needs, restoration of federal and private lands, impacts to local watersheds, or lost tourist revenue are not reported. There are additional indirect costs related to fires. For example, a study conducted for Alberta, Canada following a two-day forest fire in the town of Edmonton indicated that in addition to the $10 million spent on direct costs of fighting the fire, an additional expense of $10-12 million was accrued in lost wages, decreased productivity, and increased medical care (USFS 2006).

3.6 Insurance Claims

The increasing trends of adverse weather events, particularly in coastal areas, are predicted to continue (NAST 2001). Claims made to private and public insurers are expected to climb with them. From 1980 to 2005, private and federal insurance agencies distributed more than $320 billion in claims. Private insurers paid out 76% of the total, followed by the federal crop and flood insurance programs. The overall risk exposure of insurers' has grown considerably. The National Flood Insurance Program's exposure increased four-fold since 1980 to $1 trillion in 2005, and the Federal Crop Insurance Corporation's (FCIC) exposure grew to $44 billion (US GAO 2007a).[5]

In summary, the effects of climate change are expected to cross regional boundaries and exert negative impacts throughout the United States. These include stress to water supply networks, changes to the agricultural sector, threats to coastal infrastructure from storms and sea level rise, effects on energy supply and demand, increased risk to human health, more frequent and extensive forest fires, and additional impacts related to an increase in adverse weather events. Additional disconcerting trends relevant to specific regions in the United States are outlined in the rest of the report.

[5] Expansion of FCIC's program contributed to the increase, as well as increases in portfolio holdings in hazard-prone areas.

4 Regional Summaries

4.1 Northeast and Mid-Atlantic

4.1.1 Overview

The Northeast and Mid-Atlantic regions include the most populated coastline in the country. Four out of the ten largest U.S. metropolitan areas are located within the region – New York, Washington DC/Baltimore, Philadelphia, and Boston (NOAA 2004). Figure 4 outlines predicted population changes in the region. Maryland and Virginia are predicted to experience the greatest percent of coastal population change in the United States. The major economic sectors include services, followed by manufacturing, finance, insurance and real estate, and trade. Agriculture, fisheries and resource extraction are also prominent industries in the region.

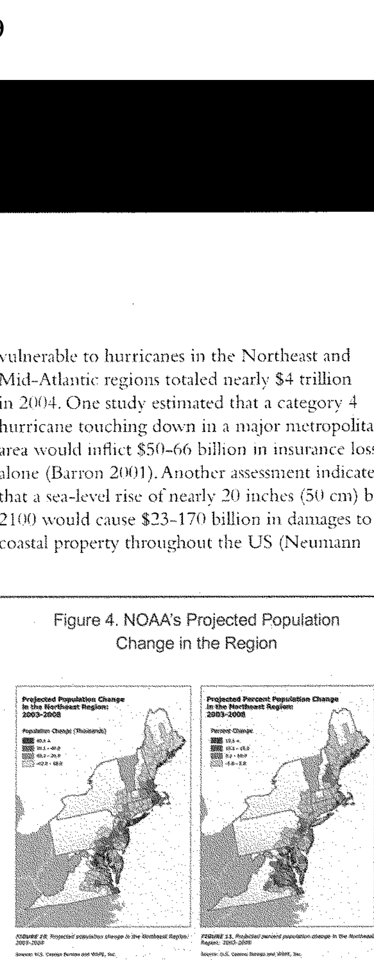
In the last century, the Northeast and Mid-Atlantic region has experienced significant increases in major weather events (from 12 to 20%), with the largest increases in very severe events. A warming of 4°F (2.2°C) has been observed along the coast from the Chesapeake Bay to Maine. Climate change scenarios for the next 90 years predict continued warming trends in the region, coupled with increases in precipitation levels (Barron 2001; Frumhoff et al. 2007).[4] The region's extensive coastal infrastructure – including transportation and energy supply networks and coastal developments – will likely endure the greatest portion of total economic impacts of climate change in the region.

4.1.2 Major Impacts

4.1.2.1 Coastal Infrastructure

Coastal developments, transportation facilities and infrastructure, as well as many energy and water supply systems are at risk of coastal storm surges. The Insurance Information Institute (2007) estimates that the value of insured properties vulnerable to hurricanes in the Northeast and Mid-Atlantic regions totaled nearly $4 trillion in 2004. One study estimated that a category 4 hurricane touching down in a major metropolitan area would inflict $50-66 billion in insurance losses alone (Barron 2001). Another assessment indicated that a sea-level rise of nearly 20 inches (50 cm) by 2100 would cause $23-170 billion in damages to coastal property throughout the US (Neumann 2000). With 34% of coastal properties located in the Northeast (NOAA 2004), the local costs of sea level rise are likely to amount to around $8-58 billion.

Figure 4. NOAA's Projected Population Change in the Region



(Source: NOAA 2004)

Transportation infrastructure in the region is especially vulnerable. In the New York metropolitan area alone, there are 48 major transit facilities at 10 feet or less above sea level. All of the City's four airports also are at risk. The area's 2,200 bridges will likely be used as alternate routes and may become overstressed as a result (Zimmerman 2002). The scale of cost to repair or overhaul the system can be gleaned from the expenditures accrued after the attacks on September 11, 2001. Since that time, reconstruction costs of the transportation system in Lower Manhattan and the surrounding areas have amounted to over $7 billion (Zimmerman 2002).

[4] Hadley Climate Model predicts a 25% increase in precipitation and a 5°F (2.8°C) average temperature rise. Canadian Climate Model predicts a 5-10% increase in precipitation and a 9°F (5°C) average temperature rise.

Table 2. Insured and Uninsured Losses from Coastal Surge, Flooding and Wind Damage in the Metropolitan East Coast Region

Storm Category	Surge Height	Average Recurrence Period (in years) in 2100	Estimated Total Losses (billions $2005)	Annualized Losses (million $2005)
Extratropical storm	8	6	1.13	57-193
1	10	15	5.7	113-374
2	11	30	11	-
3	13	150	57	-
3-4	14	300	113	-
4	16	800	>283	-

Source: Jacob et al. 2000

Similarly, flooding of the Boston subway system in 1996 inflicted over $92 million in damages (Frumhoff et al. 2007).

It is difficult to estimate how vulnerable roads are in the region. The length of rural and urban roads in the coastal states of the Northeast and Mid-Atlantic regions (all except Pennsylvania) extends 17,748 miles (US DOT 2005). Assuming that the density of urban roads is proportional to population density (77% of the population lives in coastal counties), then 7,439 miles of urban roads are potentially at risk.

In the Metropolitan East Coast Region, the expected insured and uninsured losses from coastal surge, flooding and wind damage expected with climate change range from $1.13 billion to over $283 billion, as outlined in Table 2 above. The estimated recurrence period is derived by averaging four commonly used climate change models (Jacob et al. 2000).[5]

Predictably, building protective structures along the coastline may become one option for mitigating the impacts. Constructing sea wall and bulkhead protection for just 25% of the length of the region's coastline would cost from around $300 million and just under $8 billion. Putting up dikes or levees to protect against a one-meter rise in sea level would run from $300 million to just over $1.5 billion for a quarter of the coastline.[6]

A major expenditure during a storm event is evacuation of the residents. According to NOAA (2004), the 2003 coastal population in the Northeast totaled 52.6 million people, comprising around 20.5 million households (US Census Bureau 2006).[7] Using data from a study that analyzed evacuation practices following the 1998 Hurricane Bonnie in North Carolina, the estimated direct costs of the evacuation ranged from $212 to $292 in 1998 dollars per household, depending on storm category (Whitehead 2000). Assuming the same evacuation trends and household costs, direct

[5] The four scenarios used are: 1. HCGG=Hadley Centre Greenhouse Gases; 2. HCGS=Hadley Centre Greenhouse gases and Sulfate aerosols; 3. CCGG=Canadian Centre Greenhouse Gases; 4. CCGS=Canadian Centre Greenhouse gases and Sulfate aerosols.

[6] It is estimated that, in 2005 dollars, sea wall and bulkhead construction would cost $227-6,069 per linear foot and construction of dikes or levees to protect against 3.28 feet (1 meter) rise in sea level would cost $227-1,214 per linear foot (Neumann et al. 2000). NOAA puts the entire length of the region's coastline at 996 miles (or 5,258,880 feet) (CRS 2006).

[7] Census estimates the average number of people in a household to equal 2.57 (US Census Bureau 2006).

Table 3. Total Cost of an Evacuation in the Northeast States

Storm Category	% of Evacuees*	Cost per Household ($)**	# of Evacuee Households***	Total Cost ($)
1	37.91	247	7,759,539	1,916,606,015
2	44.68	271	9,145,594	2,478,455,884
3	63.68	317	13,032,518	4,131,308,363
4	75.70	298	15,494,256	4,617,288,343
5	94.21	340	19,282,233	6,555,959,211

* Source: Whitehead 2000

** Source: Whitehead 2000, converted to 2005 dollars

*** Source: US Census Bureau 2006 and NOAA 2004

costs of an evacuation effort for the Northeastern coastal region ranges from nearly $2 billion to over $6.5 billion. Table 3 summarizes the findings.

4.1.3 Other Impacts

Other industries in the region are expected to experience potentially deleterious effects stemming from global climate change as well. Changes in water quality and water temperature on the coasts may negatively affect the $63 billion ocean economy sector,[8] which employs 1.1 million people in the region (NOEP 2004; BEA 2005; Barron 2001; Frumhoff et al. 2007). The **skiing industry** also stands to become less viable. The region is home to 138 skiing facilities, whose annual revenues amount to nearly half a billion dollars (US Census Bureau 2002). The New Hampshire Department of Environmental Services estimates that direct and indirect spending in the New Hampshire skiing industry amounts to over 8 times the annual revenue (New Hampshire Department of Environmental Services 2005). If the same pattern holds for other states, direct and indirect spending for the industry in the entire region totals $4.05 billion. A decrease of 10-20% in skiing days will result in a loss of $405-810 million per year.

[8] This is defined as any economic activity, which directly or indirectly uses the ocean or the Great Lakes. Six sectors are included in the "ocean economy" – marine construction, living resources, minerals, ship and boat building, tourism and recreation, and transportation (NOEP 2004).

Other tourism industries, such as **snowmobiling and beach-related sectors**, which are primarily located in the vulnerable coastal communities, are likely to experience declines, as well (Frumhoff et al. 2007).

The **forest industry** will likely face declines in productivity as high as 17% (Barron 2001). Changes in forest composition and disturbances from pests, fire, and extreme weather events are likely to further jeopardize this economic sector, which generates over 300,000 jobs in New England and New York (Frumhoff et al. 2007). **Maple syrup** production may also suffer. Sap flow is predicted to fall by 17-39%, inflicting a loss of $5.3-12.1 million in annual revenue to this $31 million industry (Barron 2001).

Because the region spans a wide geographical and ecological area, economic effects on **agriculture** are expected to be mixed – at least for the short- to medium-term. For example, New York's agricultural yield may be reduced by as much as 40%, causing $1.2 billion in annual damages. On the other hand, Mid-Atlantic States' agricultural yields are likely to temporarily benefit from warmer temperatures (Barron 2001). The majority of annual losses suffered by the livestock industry will be due to warmer temperatures and heat stress on the animals. Annual losses of $50.8 million in Pennsylvania, $24.9 million in New York, and $5.4 million in Vermont mostly occur in the dairy industry, whose annual production value is $3.6 billion in the region (Frumhoff et al. 2007). Given the predicted disruptions from extreme weather events and warmer temperatures increasing the need for more irrigation, additional losses and the net effects on agriculture in the region are at present unknown. However, as an example of the potential magnitude, the 1999 nation-wide drought cost the Northeast region around $973 million in net farm-income losses (Frumhoff et al. 2007).

There are likely to be adverse **health impacts** on the population of the region. Floods and sea-level rise in estuaries and bays increase the presence of many water-borne pathogens, while higher temperatures may allow them to flourish and spread (Barron 2001). Heat-related illnesses and deaths may also increase. For example, it is estimated that an increase from the current 13 days above 90°F (32.2°C) to 16-32 days predicted by the climate change models may result in a five-fold increase in heat-related mortality in New York City (Barron 2001). The number of ozone-related deaths in the New York Metropolitan Region is predicted to increase by 53.8-63.8% by 2050, relative to 1990, assuming a scenario with continued high CO_2 emissions (30 gt/yr max) and significant population increases (15 billion by 2100; Kinney et al. 2006).

Additional effects to the infrastructure include those on **water and energy systems**. The Mid-Atlantic states are particularly vulnerable to potential disruptions to surface water recharges, since 95% of all water withdrawals are highly dependent on surface water flow (Barron 2001). Energy transmission infrastructure could itself be disrupted as a result of more severe weather occurrences or become overstressed during such events.

4.1.4 Missing Information and Research Needs

Economic impacts from climate change on coastal and urban infrastructures in the Northeast and Mid-Atlantic region likely dominate in magnitude the impacts on many of the other sectors of the region. At the same time, a reliable infrastructure is essential for performance of the other sectors. Consequently, prioritizing data collection and research may require a particular focus on the vulnerability of existing infrastructures in coastal areas (especially transportation and energy systems). Since infrastructures are often interdependent in their performance, research will need to account specifically for those interdependencies, lest important determinants of their individual performances are overlooked. For example, adequate flood control will be key to reliable transportation, reliable cooling water supply will be essential for electricity generation, and reliable electricity and water supply will contribute to public health. Similarly, investment and policy-making need to be cognizant of, and explicitly deal with, those interdependencies in order to reduce the region's overall vulnerability to climate change.

4.2 Southeast

4.2.1 Overview

The Southeast states – Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North and South Carolina, Tennessee, Virginia, and the Gulf Coast of Texas – may be some of the hardest hit by climate change in the US. By value, the region produces about one quarter of US agricultural products; half of US timber supplies; and much of the nation's fish, poultry, tobacco, oil, coal and natural gas (Burkett et al. 2001). As such, the state economies are intricately tied to the condition of their natural resources. Having undergone rapid population growth during the 1970s-1990s (30%), the region is expected to continue growing, perhaps another 40% between 2000 and 2025. The climate in the Southeast has gone through a warm period during the 1920s-40s, a cool period from 1950-1960, and is presently in another warm period that began in the 1970s. There has been a 20-30% increase in precipitation over the last 100 years. The Canadian Climate Centre (CCC) model scenarios show continued warming through the 2090s, whereas the Hadley Centre model scenarios project less warming (Burkett et al. 2001) and about a 20% increase in precipitation throughout the region by 2100. Both models predict an increase in the heat index greater in the Southeast than in other US regions, 8-15°F

(4.5°C-8.4°C) or more (Burkett et al. 2001). With warmer weather and warmer water in the Atlantic and the Gulf of Mexico, the region may experience an increased frequency and intensity of storms, sea level rise, and the loss of important agricultural areas, crops and timber species.

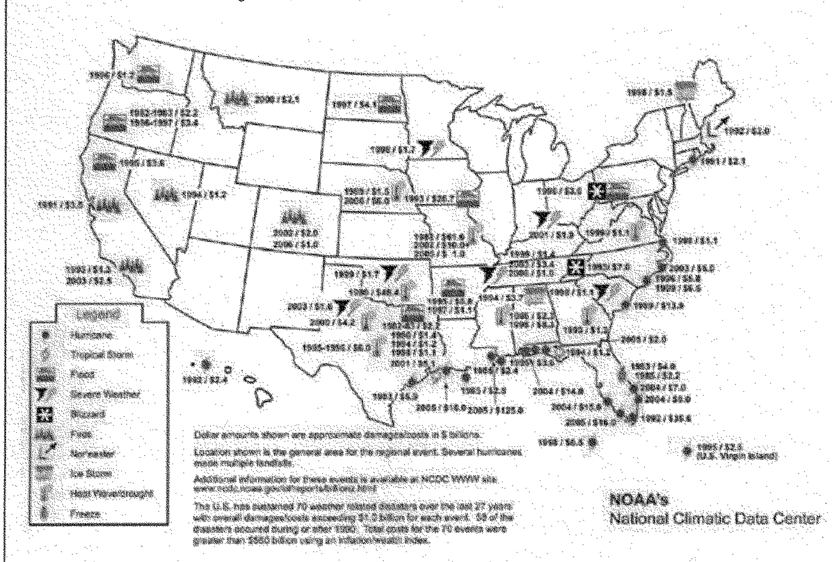
4.2.2 Major Impacts

4.2.2.1 Coastal Infrastructure

Since 1980, the United States has witnessed 70 natural disasters – including hurricanes, floods, heat waves, and droughts – each causing over $1 billion in damages (Figure 5). Fifty-eight of these events have occurred since 1990 and 29 have been in the Southeast. Total estimated damages from all of the billion-dollar events are more than $540 billion (Lott and Ross 2006).

Hurricanes and tropical storms are by far the most frequent and destructive of the natural disasters documented by the National Climatic Data Center at NOAA. Other disasters include non-tropical floods, heatwaves and drought, severe weather, fires, freezes, blizzards, ice storms and nor'easters, accounting for 24 of the 70 events and $308 billion in damages (Figure 6). The Southeast states were hit hardest by these natural disasters, with each state,

Figure 5. Billion Dollar Weather Disasters, 1980 - 2006



(Source: NCDC 2007)

Figure 6. Billion Dollar Weather Disasters by Type

DISASTER TYPE	NUMBER OF EVENTS	PERCENT FREQUENCY	NORMALIZED DAMAGES (Billions of Dollars)	PERCENT DAMAGE
Tropical Storms/Hurricanes	24	34.2%	308	54.6%
Non-Tropical Floods	12	17.1%	55	9.8%
Heatwaves/Droughts	12	17.1%	151	26.8%
Severe Weather	8	11.5%	14	2.4%
Fires	7	10.0%	14	2.4%
Freezes	2	2.9%	6	1.1%
Blizzards	2	2.9%	9	1.6%
Ice Storms	2	2.9%	5	~0.9%
Noreaster	1	1.4%	2	~0.3%
	70		564	

(Source: NCDC 2007)

except Kentucky, experiencing at least 16 events that caused over $1 billion in damages each. Texas, Alabama, Georgia, Florida, and North Carolina each experienced 21-25 natural disasters from 1980-2006 (Lott and Ross 2006).

In 2005, the nation was made painfully aware of the damages possible from extreme storm events when Hurricanes Katrina and Rita struck. A total of 90,000 square miles was declared a federal disaster area following Hurricane Katrina, covering four states and 23 coastal counties and parishes. Eighty percent of the City of New Orleans was flooded, and more than 1,700 lives were lost. More than 350,000 homes were destroyed and another 146,000 seriously damaged. A total of 850,791 housing units were damaged. At an estimated $100,000 repair cost per unit, the total cost to rebuild what was lost could exceed $85 billion (Petterson et al. 2006). In addition to the urban infrastructure damaged by the storms, Petterson et al. (2006) estimated that 2,100 oil platforms and over 15,000 miles of pipeline were damaged. Lost revenue due to the damages amounted to almost $11 billion – 153 million barrels of oil (of an annual total of 547 million) at approximately $70 per barrel at the time of the hurricanes. The questions of what to rebuild, when, and at what cost have spurred debates locally, regionally and nationally, and have stirred deep-seated environmental justice concerns.

4.2.3 Other Impacts

Not all of the impacts from climate change in the Southeast pertain to coastal infrastructure. Forests, agriculture and fisheries, water quality, and energy may be subject to notable change and damages as well.

Forestry is a major economic sector in the Southeast. For example, the state of South Carolina boasts 60% forest cover and forestry is, after tourism, the second largest economic sector (South Carolina State Climatology Office 2007). Given the diversity of species and environmental conditions, short- to medium-term impacts on forests are uncertain. Sea level rise resulting in salt water intrusion may damage forests, particularly in southern Florida and Louisiana (Burkett et al. 2001). Higher temperatures, decreased soil moisture, and more frequent fires may stress forest ecosystems and ultimately may lead to a conversion from forest to savannah and grassland (Burkett et al. 2001). However, some species may see, at least temporarily, increases in productivity and forested acreage due to a longer growing season, CO_2 fertilization, and a switch from stressed to more acclimatized species. For examples, southern loblolly pine plantations may experience yield increases of 11% by 2040, and 18% by 2040, raising the expenses to $93 and $124 million respectively. Hardwood and mixed pine-hardwood forests (64% total forested area) will likely increase in acreage by 22% by 2040, and 25% by 2100, compared with 1990 base levels. (Burkett et al. 2001).

As increased storm frequency and intensity impact coastal infrastructure, they may also reduce **water quality** and harm **fish** populations. Fish and shellfish are at risk in warmer waters and when exposed to increased pollution following major storm events (Burkett et al. 2001). Much of this pollution will come from stronger storms stressing water management systems and causing sewer systems to overflow, as well as increased nutrient runoff from agricultural lands.

Energy demand will also change in the Southeast as temperatures increase, though not as much as in more northern regions. The majority of homes and offices already are equipped with air conditioning, and will face fewer expenses upgrading compared with cities in the Northeast that have fewer structures with central air conditioning. However, increased energy demand to meet cooling needs may add stress on the energy supply system and waste heat may exacerbate urban heat island effects and their associated human and environmental health impacts.

4.2.4 Missing Information and Research Needs

The high density of infrastructure in coastal regions of the Southeast, combined with high rates of sea level rise and subsidence, as well as exposure to hurricanes, make preparedness to coastal storms a high priority for research. As in the Northeast and Mid-Atlantic (and for that matter, much of the US), regional infrastructure systems are closely tied to each others' performance – for example, energy supply depends on cooling water availability; transportation on flood control; communication on energy; emergency preparedness on transportation, energy supply, resilient communication systems, water availability and more. Only a few of these interrelationships typically enter economic impact and cost assessment, and significant room persists to substantiate those relationships and make them an integral part of regional and local investment and policy decisions.

4.3 Midwest

4.3.1 Overview

Within the eight states of the Midwest region – Illinois, Wisconsin, Indiana, Ohio, Iowa, Minnesota, Missouri, and Michigan – lies the largest group of freshwater lakes in the country and the world. Long accustomed to utilizing this unique natural resource for shipping and manufacturing purposes, the Midwest produces 40% of the US industrial output and provides 30% of the US foreign agricultural exports. Observed climate change effects in the region include increases in temperatures – 4°F (2.2°C) in the North and 1°F (.6°C) in the South (Easterling and Karl 2001). A big concern in the region is drought-like conditions resulting from elevated temperatures, which increases levels of evaporation, contributing to decreases in soil moisture and reductions in lake and river levels.

4.3.2 Major Impacts

4.3.2.1 Manufacturing and Shipping

Around $3.4 billion and 60,000 jobs rely on the movement of goods within the Great Lakes-St. Lawrence shipping route annually (Easterling and Karl 2001). In 2004, over 42 billion ton-mileage[9] of overseas and Canadian goods was shipped through the Great Lakes, and 65 billion ton-mileage of goods destined for domestic distribution were carried as freight on the Lakes in 2004 (US ACOE 2004). Table 4 below outlines the geographic distribution of the domestic freight within the shipping route area, which is dominated by Lake Erie and Lake Hurron.

[9] Ton-mileage is obtained by multiplying the tons of commerce being shipped by the actual distance (in miles) moved on the water-route. It is a measure of total activity on the water channel (US ACOE 2004).

Table 4. Ton-mileage of US Freight Carried on the Great Lakes, 2004

	Foreign	Domestic			
		Lakewise		Internal	
Area	In/Out & Through	In/Out	Through	In/Out	Through
Detroit River, MI	987,882	244,388	798,663	964	619
Lake Erie	9,198,033	3,373,510	383,806	2,737	368
Lake Huron	8,689,854	5,528,978	11,713,970	431	10,560
Lake Michigan	5,427,209	15,152,655	2,664,119	49,170	-
Lake Ontario	6,561,832	1	-	-	2,848
Lake Superior	6,209,531	20,008,653	75	0	-
St Clair River, MI	1,239,096	173,588	1,404,363	40	1,212
St Lawrence River	1,718,865	0	-	-	813
St Mary's River, MI	1,332,787	44,495	3,567,924	-	-
Welland Canal, Canada	671,246	-	-	-	198
Net United States Traffic on the Great Lakes	42,036,335	65,210,549 (figure includes intraport freight, not detailed above)			

Any decline in water levels along the system could jeopardize this relatively inexpensive and effective method of transporting manufactured goods. If water levels drop significantly, a scenario described by the Canadian Climate Centre Model, dredging may be the only alternative to salvage this system. It is estimated that between 7.5 and 12.5 million cubic yards would need to be dredged annually at a cost of $85-142 million (Great Lakes Regional Assessment Group 2000). System connectivity is predicted to become 25% impaired, causing a loss of $850 million annually (Easterling and Karl 2001). Increased incidences of drought will likely place an additional stress on the water conveyance system. For example, a 1988 Midwest drought cost the region over $49 billion, in part because riverine commercial shipping had to be replaced by more expensive railroad transport due to the Mississippi River's reduced water levels (Easterling and Karl 2001).

4.3.3 Other Impaacts

Forestry is an integral part of the economic structure in the Midwest. Over 90% of forestland is used for commercial forestry, resulting in economic activity valued at $41.6 billion (Great Lakes Regional Assessment Group 2000). The sector employs 200,000 people and produces $27 billion in forest products. Many of the economically valuable timber species – aspen, jack pine, red pine, and white pine – may be lost due to warming of the climate (Easterling and Karl 2001). The virgin pulping/wood fiber industry may be eliminated entirely as the forested landscape shifts toward oak and hickory species.

Potentially negative impacts are expected to the $5.7 billion **dairy industry**, since milk production by dairy cows is temperature sensitive and declines once temperatures advance beyond a certain threshold (Great Lakes Regional Assessment Group 2000). The **agriculture** sector also may experience losses similar to the 1988 drought, which cut production of grain by 31% and production of corn by 45% (Easterling and Karl 2001). The variability and spectrum of potential impacts make it difficult to predict the economic effect on agriculture. Some of these impacts include: increases in soil erosion, increases in severe weather events, increases in use of herbicides, and an extended growing season with associated changes in water demand and quality, as well as impacts on ecosystems and fisheries (see, e.g. Donaghy et al. 2006).

The region is well-known to **outdoor recreation** enthusiasts and most portions of the industry are likely to suffer because of climate change. For example, the distribution of prominent game and other bird species (e.g. waterfowl, warblers, perching bird species) may be altered, affecting hunting and bird-watching. In Michigan, Minnesota and Wisconsin alone, $4.7 billion was spent in 1996 on hunting, and bird-watching generates $668 million in retail sales and supports 18,000 jobs. **Skiing** is likely to be affected as well. Lighter than usual snowfall during the 1997-1998 season resulted in business losses of $144 million (Great Lakes Regional Assessment Group 2000). **Boating** is another favorite pastime – 4 billion boats are owned in the region. Reduced water levels may require dredging to ensure access to the 1,883 marinas, at a total annual cost of $68 million (Great Lakes Regional Assessment Group 2000).

4.3.4 Missing Information and Research Needs

One of the major impacts of climate change in the region will be on shipping and, as a result, the manufacturing base that depends on reliable supply of inputs into the production process, as well as shipment of products to markets, will be affected. Little information is currently available to assess the broader logistics and supply chain implications of climate change in the region, as well as the associated costs to businesses in transport and manufacturing sectors, employment and costs to end consumers. Data collection and research to fill this knowledge gap and guide policy and investment decision-making will need to combine climate science with business decision-making and regional economic impact assessment. Information on re-routing the shipments and the cost incurred by the industry would be helpful in evaluating the larger picture.

4.4 The Great Plains

4.4.1 Overview

The Great Plains region includes Texas and New Mexico in the south and all the states spanning to Montana and North Dakota to the north.[10] Its economic base is formed primarily by the service sector, but includes manufacturing, government, finance, and insurance and real estate industries (Joyce et al. 2001). Although agriculture's overall economic contribution to the gross regional product is fairly small (see Table 5), 90% of the land in the region is used for agriculture (Ojima 2002). The region has already witnessed increased temperatures and precipitation, as well as decreased snowpack (Joyce et al. 2001). The average temperatures are predicted to increase by around 3°F (1.7°C) by 2030 and increases up to 11°F (6.1°C) by 2090 may be expected. Although average precipitation may slightly decline by 2030, it is predicted to increase by almost 5 inches per year by 2090 (Ojima 2002). Despite predicted precipitation increases, higher temperatures throughout the region are likely to result in net soil moisture declines because of water loss through evaporation (Joyce et al. 2001). Competing uses for water could result in re-prioritization of land use and economic sectors.

4.4.2 Major Impacts

4.4.2.1 Agriculture and Water

The agricultural sector in the region contributes $22.5 billion annually in market value of products – 35% of which is attributed to crops and the rest to livestock (Ojima 2002). The sector already uses 40% of the total water in the region and, although there is some evidence that productivity of certain crops may temporarily benefit from warmer temperature, decreased availability of water for agricultural purposes may pose a more significant economic hurdle (Joyce et al. 2001). Long-term increases in temperatures may overwhelm agricultural coping mechanisms. The consumptive demand for water of some crops (especially grass and alfalfa) may increase by 50% by 2090, further straining water resources in the region (Joyce et al. 2001). One study estimated that net agricultural income will decrease by 16-29% by 2030 and by 30-45% by 2090 because of

[10] CO and WY are also included in the "West" Assessment; and MT is also included in the "Pacific Northwest" assessment.

Table 5. Selected Industries and Their Contribution to State Domestic Product in Millions of Dollars, 2005

State	Crop and Animal Production ($)	Forestry, Fishing, and Related Activities ($)	Manufacturing ($)	Information ($)
Colorado	1,705	236	14,393	18,164
Kansas	2,784	248	14,092	6,555
Montana	1,091	204	1,383	859
Nebraska	3,186	194	8,344	2,413
New Mexico	1,056	140	6,639	1,698
North Dakota	1,484	107	2,351	886
Oklahoma	1,961	193	12,625	4,055
South Dakota	1,855	100	3,104	824
Texas	6,899	1,573	127,435	40,274
Wyoming	405	50	910	404

Source: BEA 2005

conflicting water uses around the San Antonio Texas Edwards Aquifer region (Chen and McCarl 2000). If similar trends hold for the entire region, the agricultural sector stands to lose $3.6-6.5 billion by 2030 and $6.75-10.13 billion by 2090on an annual basis.

The agricultural sector is vulnerable to projected increases in disturbances, such as drought and invasive species. A year-long drought in 1995 cost the Southern Great Plains agricultural sector $5.81 billion (Joyce et al. 2001). Stressed ecosystems are more susceptible to invasive species; control costs and weed-associated losses due to invasives amount to $15 billion annually nationwide. The region is home to 23.4% of the nation's crop and animal production (BEA 2005). Under the assumption that costs to control invasive species are distributed evenly throughout the country, the region expends $3.51 billion annually in invasive species control costs. This figure may increase dramatically, as damaging invasive species migrate north with warmer temperatures.

Changes in crop productivity are likely to be both positive and negative, at least in the short- to medium-term. However, in the long run, if temperatures continue to increase and water availability continues to change seasonally and in total, even some of the better adjusted crop types may no longer be able to cope. The Southern and Plains regions are likely to experience a decline in productivity – by as much as 70% for soybeans and 10-50% for wheat (Reilly et al. 2003). Crops in other areas may temporarily increase their yields (see Table 6). The crops around the Edwards Aquifer Region, however, are expected to have lower yields (Chen and McCarl 2000). Table 7 outlines the predicted changes.

An additional burden on the agricultural sector may be an increased resilience of insects to pesticides. Pesticide use and the associated costs are estimated to increase by 10-20% for corn; 5-15% for potatoes; 2-5% for cotton and soybeans; and 15% for wheat (although pesticide expenditures for wheat may also decrease by 15%; Reilly et al. 2003).

4.4.3 Other Impacts

Water demand for municipal uses will likely increase as regional temperatures continue to rise. A study of the San Antonio Texas Edwards Aquifer region estimates municipal water demand to increase by 1.5-3.5% (Chen and McCarl 2000). As supplies of freshwater diminish, quality of water is likely to suffer. Increased contamination of water has been estimated to raise the cost of water treatment by 27% from around $75 to $95 per million gallons in Texas (Dearmont et al. 1997).

Table 6. Predicted Percentage Changes in Yield Variability for 2090 in Selected States Under the Canadian Climate Centre and Hadley Centre Models

	Maize	Soybeans	Cotton	Wheat	Sorghum
Colorado	-	-	-	-10.60 to +34.43	-
Montana	-	-	-	-6.36 to +32.86	-
Nebraska	-15.05 to +15.30	-4.74 to + 11.65	-	-5.75 to +48.22	-16.15 to -1.72
Oklahoma	-	-	-	-17.07 to +16.34	-9.27 to +2.83
South Dakota [11]	-21.75	-24.37	-	-6.94	-19.10
Texas	-	-	-13.21 to -8.05	+2.26 to +27.86	-10.83 to -3.10

Source: Reilly et al. 2003

Table 7. Predicted Percentage Changes in Crop Yield in the Edwards Aquifer Region Based on the Hadley Centre and Canadian Climate Centre Models

Crop	Irrigated Corn	Dryland Corn	Irrigated Sorghum	Dryland Sorghum	Irrigated Cotton	Dryland Cotton	Irrigated Cantaloupe	Irrigated Cabbage
2030	-1.93 to -4.26	-3.93 to -8.17	-1.75 to -2.79	-5.93 to -10.82	-9.06 to -19.80	-7.13 to -13.95	-1.34 to -1.86	-5.57 to -9.63
2090	-3.47 to -5.61	-6.78 to -10.79	-3.35 to -4.17	-13.07 to -16.76	-11.60 to -17.76	-11.60 to -17.76	-2.33 to -3.58	-12.05 to -14.72

Source: Chen and McCarl 2000

Higher incidences of **severe weather** events are likely to cause major damage to the region's infrastructure. For example, a 1999 outbreak of tornadoes in the Great Plains caused $1.16 billion in damages and 54 deaths; and an extreme flooding event in 1998 in southeast Texas inflicted $1.16 billion in damages and caused 31 deaths (Joyce et al. 2001).

4.4.4 Missing Information and Research Needs

The agricultural sector of the Great Plains, because of its dominance in the region and its dependency on water resources, may be significantly affected by climate change. Major research efforts are under way to estimate the cost and benefits to agriculture from changes in temperatures and precipitation patterns. Whether climate change may be beneficial to the agricultural sector overall, however, depends on a range of issues, from the ability of crops to react to the full range of possible changes in the climate, to the technologies and practices employed in growing food, to the range of climate conditions that are considered. In the short- to medium-term, production of several crops will show increased yield. However, for the more distant future, some of those crops, too, may be stressed as temperatures increase and water becomes scarce. One of the areas in need of significant attention by researchers is the identification of long-term transition strategies for the agricultural sector to make it less vulnerable to climate change. Exploration of how best to develop transition strategies into action at the regional, local and farm level is needed.

[11] Note: For South Dakota, the Canadian Center Model was used to estimate loss of productivity for maize and wheat production only; and the Hadley Centre Model was used to assess soybeans and sorghum production only.

4.5 West

4.5.1 Overview

The Western region of the country stretches from desert plateaus of Arizona and New Mexico to the mountainous ranges of Colorado and Northern California, all the way north to Wyoming. Climatically sensitive sectors – agriculture, mining, construction, and tourism – account for nearly one-eighth of the region's economy.[12] The sprouting population of the region greatly influences the flow and allocation of resources. Temperatures have already increased 2-5°F (1.1-2.8°C) within the past century and the snow season is now shorter by 16 days in California and Nevada (Smith et al. 2001). The Central Valley of California, southeastern California, south-central Utah, northeastern Arizona and western Colorado all experienced more drought as compared with the rest of the region (Smith et al. 2001). The predicted impacts of climate change on the region include wetter winters and drier summers, as well as sea level rise of 6–37 inches by 2100 (Smith et al. 2001). Similar to the Great Plains, meeting the competing needs and uses for water resources will be a major challenge as decreased winter snowpack contributes to changes in water flow, both in quantity and timing.

4.5.2 Major Impacts

4.5.2.1 Water System and Agriculture

The use of water in the area is highly regulated and apportioned between many stakeholders through interstate and international agreements. This system is the product of past population and climatic pressures. The Colorado River Compact of 1922, for example, handles the water-distribution networks among several States in the West, including Arizona, California, Nevada, New Mexico, and Utah (Konieczki et al. 2004). Many argue that the system is already overstressed (Smith et al. 2001). Satisfying the legal requirements currently in place, meeting additional demand, maintaining the physical infrastructure, and juggling competing uses will become more challenging and costly if climate change advances and stores of water are depleted. Major climate change models predict winter snowpack will decline and snowmelt will occur earlier, resulting in greater runoff.[13] Storing water in aquifers for later withdrawal, which is the practice currently used to manage the resource, may be compromised (Smith et al. 2001).

The demand for water is rising in the region. Withdrawals for all purposes – domestic, agricultural, and industrial – have increased 58% to 62.8 million acre-feet from 1950 to 2000 in Arizona, California, Nevada, New Mexico, and Utah. Domestic water use has grown 410%, with population growth reaching 250%. Ground-water withdrawals increased dramatically in most States – 324% in Nevada, 147% in New Mexico, 208% in Utah, and 52% in California, although they decreased 15% in Arizona (Konieczki et al. 2004). While the demand for water has steadily increased, there is evidence that the supply is drying up. For example, the total annual streamflow of the San Pedro River in southeastern Arizona has experienced a drop of about 66% from 1913 to 2002 (Thomas 2006).

One study predicts that in the years 2070-2099, an additional 254,000 acres now producing crops will have to be fallowed because of water shortages around the Central Valley, which will generate an annual loss of $278.5 million (9% of net revenue). However, during especially dry years – which are estimated to occur 15% of the time – 29.1% of the land will have to be fallowed, resulting in an annual loss of $829 million (26.4% of total revenue). Considering multiplier effects on the overall well-being of the economy and applying an output multiplier of 2.1, the estimated economy-wide loss will be $6 billion during dry years (Hanemann et

[12] Economic sector sensitivity to climate change is determined by modeling historical economic and weather data and analyzing how economic output in each of the sectors fluctuates as a result of weather variation (Lazo et al. 2006).

[13] Runoff is the portion of precipitation that escapes managed water cycles in uncontrolled surface streams, rivers, drains, or sewers.

al. 2006). On an individual farm level, decreased supplies of water will likely reduce the value of affected farmland by around 36% of the overall area-weighted, per-acre value of the farm, which on average equals $1,700 (Schlenker et al. 2005). Other agricultural activities may be impacted, as well. The value of wine production in California is $3.2 billion (California Climate Change Center 2006). Grape quality will likely diminish with higher temperatures, causing losses to this sector (PNAS 2007). A decline in dairy cow productivity is correlated with higher temperatures as well. An annual loss of $287-902 million is expected to this $4.1 billion industry in California (PNAS 2007).

Agricultural water use is only part of the picture; urban and industrial uses and needs should be considered also. It is estimated that the predicted growing population in California will raise urban demand for water by 62% by 2085. Meeting this increased demand will run the state $316 million per year. However, for 35% of the driest years, the costs are likely to be on the order of $5 billion per year (Hanemann 2006). Some climate scenarios suggest that the amount delivered to the West Side of the San Joaquin Basin may be reduced by 50% (Hidalgo 2006). Other studies indicate decreases in deliveries of 11 and 14.5% (depending on the provider - Central Valley Project and State Water Project, respectively) to the region between 2035-2064, and 27.3 and 31.4% between 2070-2099 (Hanemann 2006). Considering that the annual agricultural receipts for the Central Valley total more than $4.9 billion (California Water Plan Update 2005), reducing water deliveries to this profitable sector will likely affect the whole area.

Water procurement in Arizona, Nevada, and New Mexico is already a controversial issue. Strained supply of water will likely increase the cost of living in the major metropolitan areas of those states.

4.5.3 Other Impacts

Sea level rise and flooding are likely to affect Southwest coastal areas. For example, to protect the San Francisco Bay Area and the stretch of coast south of Santa Barbara from a 3.28 feet (1 meter) rise in sea level, an initial investment of $1.52 billion, plus $152 million in annual maintenance costs, will be required (Smith et al. 2001). The probability of a major flood event there is predicted to increase to a 2-in-5 chance of an event occurring in the next 50 years (Franco et al. 2005).

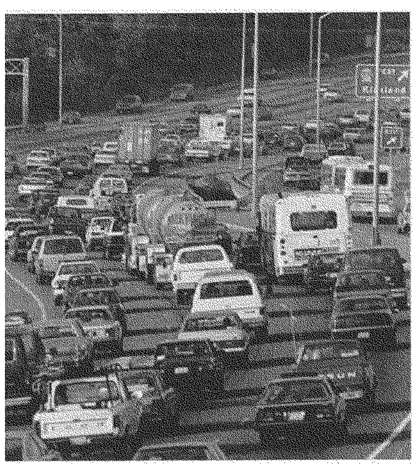
Energy infrastructure will also be affected. Under extreme heat events, the increase in net energy expenses in California is expected to rise by $2 billion (Franco et al. 2005). Other studies predict yet more severe increases in energy expenditure for residential and commercial buildings. Under the mildest warming scenario of 2.7°F (1.5°C), the annual costs are predicted to increase by $1.37 to 3.7 billion by 2100. Under scenarios of an extreme 9°F (5°C) warming, annual costs increase by $8.11 and 18.7 billion (Mendelsohn 2003). Another potential source of expenditure may come from the need to obtain energy from sources other than hydropower, which relies on high water levels. If energy generated from hydropower sources is reduced by 10%, making up the deficit through other supplies will cost $3.5 billion/year for California (Franco 2005).

About 45% of land in California is covered with **forest.** Thirty-five percent of this is commercial forest. Effects of climate change are predicted to reduce the productivity of mixed conifer stands by 18%, and productivity of pine plantations by 30%. Additional stresses on forests, such as the expected 55% increase in forest fires, will also damage this resource (California Climate Change Center 2006). Economic damages inflicted from increased incidences in fires will likely be far-reaching. The 1991 Oakland fire caused losses of about $2.2 billion (in 2005 dollars), and the 2003 wildfires in San Diego and San Bernardino Counties damaged $2 billion worth of property and infrastructure (Insurance Information Institute 2007).

The recreation industry is also likely to suffer. **Skiing**, for example, is worth around $1 billion for the entire region (US Census Bureau 2005a), not considering indirect spending. Climate change is predicted to alter precipitation patterns and decrease snowpack, thereby decreasing the number of snow days that will likely dramatically affect this industry.

4.5.4 Missing Information and Research Needs

The West will likely experience significant climate impacts on the hydrological cycle, water supply systems, and water demand in the years to come. There is very active research into the associated climatological, agricultural, technological, socioeconomic, institutional and legal implications. However, few efforts, if any, exist to systematically estimate costs of meeting water demands for the various uses in the region. Identification of costs of alternative strategies could provide the basis for investment and policy that increase the resilience of the region in light of climate change.



4.6 Pacific Northwest

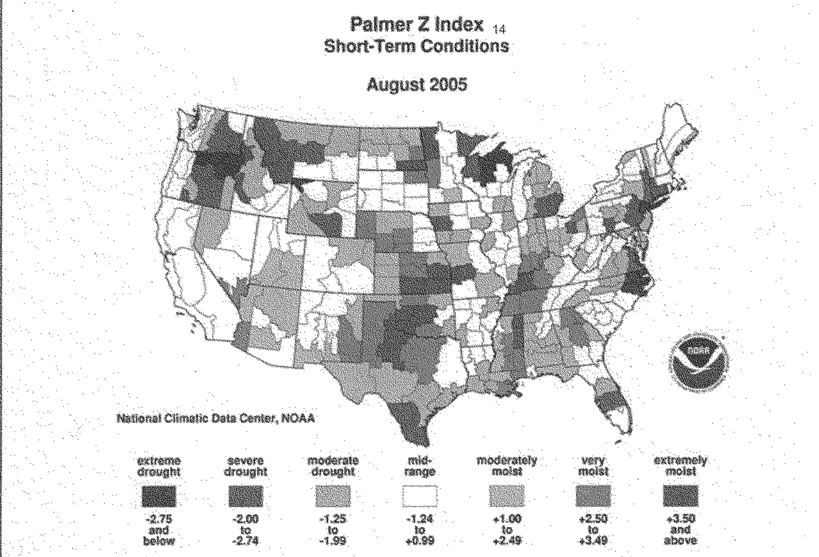
4.6.1 Overview

A large region consisting of Washington, Oregon, Idaho and Montana, the Pacific Northwest has undergone rapid urban growth (twice the national average) since the 1970s. Much of the region is forested and approximately 50% of the land area is federally owned (Parson et al. 2001a). The economy is characterized by a heavy reliance on agriculture, fisheries, and natural resource extraction (forestry and mining). Tourism, particularly visitation to national parks, also makes a significant contribution to the regional economy. The greatest threats from climate change come from increased temperatures and decreased precipitation in summer, contributing to water shortages and increased forest fires.

The climate of the Pacific Northwest is heavily influenced by the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), bringing alternating warm-wet and cool-dry seasons to the region. The past century has seen an increase in average air temperatures of 1-3°F (.6-1.7°C), roughly uniform across the seasons. The warming trend is anticipated to continue, with temperatures rising another 3°F (1.7°C) by the 2020s and 5°F (2.8°C) by the 2050s. Precipitation has increased, on average, 11% in the region over the last century, with the greatest increases in northeast Washington and southwest Montana (up to a 50% increase). The future direction and magnitude of changes in precipitation are uncertain, but likely between a small decrease (of 7% or 2 inches, mostly during summer) and a slightly larger increase (of 13% or 4 inches, mostly during winter; Parson et al. 2001a).

Despite the modest increases in precipitation, higher temperatures have, and are likely to continue to contribute to decreased snowpack and earlier spring melting that could lead to severe droughts (Figure 7), jeopardize regional water supplies and make forests more vulnerable to fire and pest outbreaks (Parson et al. 2001a; Epstein et al. 1997).

Figure 7. US Drought, 2005



(Source: NOAA 2007)

4.6.2 Major Impacts

4.6.2.1 Water Supply

Despite increases in winter precipitation, in many places a large percentage of the traditionally snow-covered areas of the northwestern United States have experienced a decline in spring snowpack, especially since the middle of the 20th century (Mote et al. 2005). The largest decreases have occurred at lower elevations where snowpack is most sensitive to temperature and in regions where winter temperatures are mild. The peak streamflow in Pacific Northwest basins dominated by snowmelt has advanced by 1–2 weeks (Groisman et al. 2004; Hodgkins et al. 2003), thereby providing less river runoff during late spring and summer.

Climate projections suggest a 30% decline in snowpack over the Northern Rockies and a 50% decline over the Cascades by 2050 with a doubling of CO_2 (Parson et al. 2001a). This would lead to a 10% reduction in annual average stream flows and reduced peak spring flows across the region (Parson et al. 2001a). A 2004 study by the University of Washington Climate Impacts Group estimates that by 2090, snowpack will be 72% below the 1960-90 average, which would not only diminish water supplies but could lead to a loss of lower elevation skiing destinations (Jolly et al. 2004). The secure supply, or firm yield, of water to the region may fall by as much as 6.1 million gallons per day for every ten years of climate change (Washington Department of Ecology 2006).

[14] The Palmer Z Index measures the variance from normal climate moisture (NCDC 2007). Red color indicates dryer conditions than normal, and green corresponds to more moist conditions.

As supplies decrease, water demand will continue to grow because of continued population and economic growth in the region. In Washington State, the growth in annual demand attributable to population growth will be about 4.1 billion gallons by 2020 and 5.5 billion gallons by 2040 (Washington Department of Ecology 2006). This growth in demand will be exacerbated by climate change, adding another 5-8% onto the already large 50% projected increase in demand on summer municipal water supplies by 2050 (Parson et al. 2001a). According to the study by the Washington Department of Ecology (2006), impacts from climate change - such as a decrease in snowpack duration - will alter the hydrology of water storage in the state by 1.3 billion gallons annually. With the projected demand for water increasing by 1.5 billion gallons annually, a 2.8 billion gallon per year increase in storage capacity will be required. This number could jump to 5.5 billion gallons in a particularly dry year. Combined with increases from population growth, the total increase in water demand may be as large as 8.0 billion gallons in 2020 and 9.6 billion gallons in 2040 (Washington Department of Ecology 2006).

The water supply problem is further complicated because the Columbia River – one of the region's primary sources – is nationally one of the most developed and heavily managed river systems for purposes of electricity generation, flood control, water supply, irrigation, wildlife habitat, navigation and recreation. There is little to no room to increase supply. Instead, water conservation measures will need to be put into place. Such measures could cost more than $8 million per year by the 2020s, perhaps $16 million by the 2040s (Washington Department of Ecology 2006).

4.6.2.2 Forests

The indirect effect of climate change on forests is also related to projected water shortages throughout the region. While average precipitation levels are predicted to increase, the actual rainfall events are projected to vary seasonally, resulting in wetter winters and drier summers. This variation, in turn, decreases water availability. As trees become more stressed from lack of water they are more vulnerable to pest outbreaks, disease and fire. At the same time, younger and thicker managed forest ecosystems are more vulnerable to catastrophic fire than are older, thinner pine stands (Parson et al. 2001a). These factors are contributing to an overall increase in the number of acres of forest burned each year in the Pacific Northwest and in the US as a whole (USFS 2000). Other climate change effects, such as increases in spring and summer temperatures and earlier melting of snowpacks, were found to have contributed to the six fold spike in the area of forest burned since 1986, compared with the 1970-1986 period. Moreover, the average duration of fires increased from 7.5 to 37.1 days since 1986 (Westerling et al. 2006). In 1987, 1.2 million acres of forest burned throughout the US, the first time since 1919 that more than one million acres burned in one year. 1988, 1994 and 1996 also saw one million or more acres burned. In 2000, 2.14 million acres burned (mostly in the West), raising fire suppression costs to $1 billion, or about $480 per acre (USFS 2000).

State and federal spending on fire suppression in the state is projected to increase to more than $93 million per year by the 2020s with a 2°F (1.1°C) warming in the Pacific Northwest – 50% more than current spending (Washington Department of Ecology 2006). A 50% increase in the number of acres burned is expected by 2020, and a 100% increase by 2040, raising the suppression bill to $124 million.[15] As an order of magnitude estimate, these numbers are useful, but may in fact turn out to be low if both the number of acres burned and the cost of suppression per acre continue to increase, as they have done in the past (Table 8).

[15] Dollar figures for fire suppression in the State of Washington are based on present expenditure for 1) Department of Natural Resources direct costs for fire preparedness ($12 million), 2) other state expenditures ($26 million), and 3) federal expenditures on fire preparedness and suppression ($24 million; Washington Department of Ecology 2006).

Table 8. Service Expenditures for Emergency Fire Suppression

Year	Cost per acre burned*
1980	$418.60
1981	$681.77
1982	$700.58
1983	$812.16
1984	$635.77
1985	$390.19
1986	$479.14
1987	$333.73
1988	$450.54
1989	$859.15
1990	$632.72
1991	$949.70
1992	$565.57
1993	$722.77
1994	$668.01
1995	$1,081.75
1996	$436.30
1997	$742.43
1998	$831.34
1999	$1,133.16

* All dollar amounts in 2005 dollars (converted from 1999 dollars)

Source: USFS 2000

4.6.3 Other Impacts

In addition to impacts to the water supply and forests of the Pacific Northwest, the region's **coastal infrastructure** may likely be at risk from sea level rise, and climate change is projected to affect agriculture, electricity supply and demand, and human health.

As air and water temperatures warm, sea level is expected to rise in the Pacific Northwest. Although this will not affect the high rocky shores, there are numerous cities and towns in tidal areas, such as the Puget Sound in Washington. Sea level rise will be compounded by land subsidence. Currently, land in the Puget Sound is subsiding 0.3-0.8 inches per year (Parson et al. 2001a). A two-foot rise in sea level would inundate approximately 56 square miles in Washington, affecting more than 44,000 people (Washington Department of Ecology 2006). This kind of change could happen in Tacoma within the next 50 years. In order to protect coastal settlements, expensive infrastructure will need to be designed and re-designed, built and re-built. One estimate of the costs of redesigning the Alaskan Way seawall increases project costs 5-10% ($500 million) when protection from sea level rise is considered (Washington Department of Ecology 2006).

Agriculture in the Pacific Northwest may benefit from a longer growing season, but these benefits may be offset by higher maximum temperatures and water shortages. Expected annual crop losses from water shortages are projected to rise from $13 million at present to $79 million by mid-century (1.4 to 8.8% of $901 million total output). Higher temperatures are also expected to reduce dairy output 3-6% and may allow new insect pests, weeds and crop diseases to flourish (Washington Department of Ecology 2006).

Warmer temperatures, particularly in urban areas, mean shifts in **energy** demand peaks (higher and earlier in the summer, lower in the winter) and decreases in air quality that may affect human health. Although the overall change in energy revenue and expenditure in the Pacific Northwest may be marginal (less than +/- 5%)[16], peak shifts may pose supply problems, especially to the extent that peak power is provided by hydroelectric plants that will be affected by decreased streamflows.

Human health may be affected by increased air pollution that increases asthma and other respiratory diseases; warmer weather may also support the introduction of infectious diseases into previously unaffected areas. Some of these problems will be magnified during periods of electricity supply interruptions, raising the vulnerability of particularly the elderly, sick and less affluent. Asthma already costs the state of Washington over $400

[16] The Washington Department of Ecology (2006) estimates impacts to the state energy budget of +/- 5%, or $165 million annually. This proportional change may be relevant to other states in the region.

million per year and over $120 million was spent on medical and non-medical direct costs in Colorado over a five-year period to combat West Nile Virus, a mosquito-borne disease making its way through the United States (Washington Department of Ecology 2006).

4.6.4 Missing Information and Research Needs

Perhaps the most striking impacts of climate change on the Pacific Northwest concern those on forests and wildfires. Many of the other impacts, such as on water supply and infrastructure will be, in principal at least, similar to those in other regions. Nevertheless, few studies exist on each of those impacts, and where quantification of cost has been attempted, prior research often simply estimated and presented those costs on the basis of percentage changes or overall decreases or increases in, for example, energy demand, agricultural production, and water availability. Rigorous and detailed economic analysis of impacts is sparse. Significant opportunities exist to fill the void in quantitative assessments for the region.

4.7 Alaska

4.7.1 Overview

Alaska's ecology, climate, geography, and its size give it characteristics distinct from the lower 48 states. With its almost year-round cold temperatures, upwards of 85% of the state rests upon permafrost, a layer of frozen soil that ranges from 10-300 feet deep in some places (Parson et al. 2001b). Its $40 billion economy is supported primarily by resource (oil and gas) extraction, fisheries, and government and military employment (Table 9). The Alaska Permanent Fund distributes petroleum revenues to state residents, $300-2000 per person each year since 1982 (Alaska Permanent Fund Corporation 2007).

The nation's largest state, Alaska covers an area of 570,380 square miles and supports a population of approximately 641,724 – only a 2% increase from 2000 (US Census Bureau 2005b). The majority of Alaska's population resides along the southern coast, including Anchorage, the largest city and the only one with a population greater than 100,000 people. Unlike the arctic interior of the state, these coastal regions (and almost 34,000 total miles of tidal shoreline including the islands) are vulnerable to sea level rise and storms. Precipitation varies widely, even in this relatively small area of the state, with some localities receiving 10 inches of precipitation annually and others up to 100 inches. The state's transportation infrastructure is limited and relies heavily on a system of ferries and airports. The Alaska Highway is the principal roadway through the state and the Alaska Railroad runs from Seward to Fairbanks.

4.7.2 Major Impacts

4.7.2.1 Public Infrastructure

The northernmost state in the US, Alaska has experienced and is projected to experience climate change double that experienced in other US regions. Since the 1950s, the average air temperature has risen 4°F (2.2°C), 7°F (3.9°C) in the

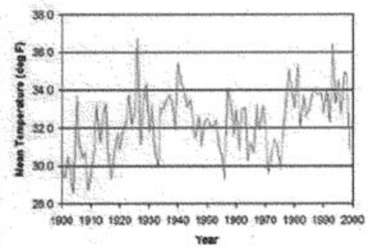
Table 9. Economic Sectors/Sources of Income for Alaska

Economic sector/source of income	Percent of total
Government/military/State Permanent Fund	44
North slope oil production	35
Fisheries	7
Tourism	5
Timber	2
Mining	2
Agriculture	0.1
Other	4.9

Source: Parson et al. 2001b

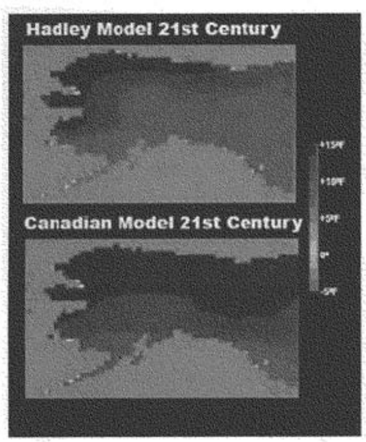
winter. Much of the warming occurred during a major climate regime shift around 1977 (Figure 8). Warming is expected to continue – 1.5-5°F

Figure 8. Alaska Average Annual Temperature



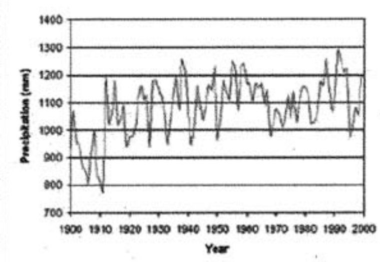
(Source: Parson et al. 2001b)

Figure 9. Alaska Winter Temperature Change by 2100



(Source: Parson et al. 2001b)

Figure 10. Alaska Precipitation 1900-2000



(Source: Parson et al. 2001b)

(.9-2.8°C) by 2030 and 5-18°F (2.8-10°C) by 2100 – and will be strongest in the winter months (Figure 8, Figure 9). Observed average precipitation increased 30% between 1968 and 1990 (Figure 10). This trend is expected to continue, with an additional 20-25% increase in the north and northwest. Precipitation may decrease somewhat in the southeast.

With higher temperatures, much of the additional precipitation will be falling as rain and Alaska's extensive permafrost layer will be subject to major changes in freeze-thaw cycles. Thawing permafrost will place the state's infrastructure – its network of roads, rail, airports, and energy and water supply which depends on permafrost as a foundation – at risk. Warmer temperatures and warmer oceans may also lead to more intense coastal storms and sea level rise that will affect coastal cities and towns.

A recent study by Larsen et al. (2007) attempted to quantify the potential impacts of climate change on Alaska's public infrastructure. In total, climate change is expected to add $5-10 billion to an already $32-56 billion infrastructure maintenance budget through 2080,[17] depending on the climate

[17] Alaska's budget for infrastructure damage (to buildings, roads, airports, pipelines, etc.) is already about $35 million per year. The most resources are directed towards rebuilding heaved roads. At about $2 million per mile, annual road repair amounts to approximately 1.4% of the total state budget (Cole et al. 1999).

change scenario under consideration (Arnold 2007; Rosenberg 2007). The study by Larsen et al. (2007), the first of its kind for Alaska and one of the most thorough state-level assessments in the US, used estimates of lifetime and replacement costs for 19 types of infrastructure elements along with climate change scenarios to project future costs (Table 10). Larsen et al. (2007) observed that climate of change may benefit construction, land and sea transportation in the long-run by allowing the use of more conventional construction techniques and opening new shipping and travel routes; however, short-term damages will be significant and will likely persist through the century, generating major costs and service disruptions.

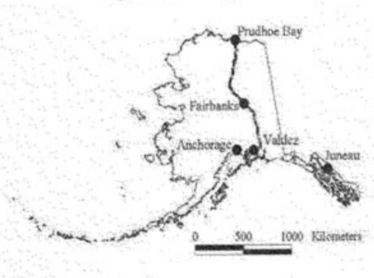
Table 10. Estimated Life Expectancies and Replacement Costs for 19 Types of Public Infrastructure

Type of Infrastructure	Count/Length	Useful Life (years)	Replacement Cost per unit ($2006)	Units	Total Replacement Costs Today ($2006)
Airports	253	20	20 million	Whole	5.06 billion
Bridges	823 31.4 miles	40	10,000	Per foot	1.7 billion
Court facilities	42	40	16 million	Whole	678 million
Defense facilities*	178	40	305,000	Whole	54 million
Emergency services (fire stations, other)	233	20	467,000	Whole	108 million
Energy (fuel tanks, other structures off power grid)	234	30	32,000	Whole	7 million
Misc. government buildings	1,571	30	1 million	Whole	1.6 billion
Power grid (lines, transformers, substations)*	68 768 miles of line	15	100,000	Per mile	77 million
Misc. health buildings (clinics, other non-hospital facilities)	346	30	1.6 million	Whole	565 million
Harbors	131	30	10 million	Whole	1.3 billion
Public hospitals	18	40	44.7 million	Whole	806 million
Law enforcement facilities (police and trooper stations, prisons, other correctional)	66	30	4 million	Whole	259 million
Alaska Railroad	45 structures 819 miles track	30	2.8 million	Per mile	2.3 billion
Roads	10,476 roads 4,564 miles (paved) 5,000 miles (unpaved)	20	1 million (unpaved) 3 million (paved)	Per mile	18.7 billion
Schools	520	40	2.5 million	Whole	1.3 billion
Sewer systems	124	20	30 million	Whole	3.7 billion
Telecommunications (towers, satellites, other)	275	10	300,000	Whole	82 million
Telephone lines*	20 222 miles	15	50,000	Per mile	11.1 million
Water systems	242	20	5 million	Whole	1.2 billion
Totals	15,665				39.4 billion

* The counts and the replacement costs in these categories are low because of limited data availability, especially for defense facilities. In part for security reasons, little public information is available about the size and value of defense facilities.

Source: Larsen 2007

Figure 11. TAP Pipeline

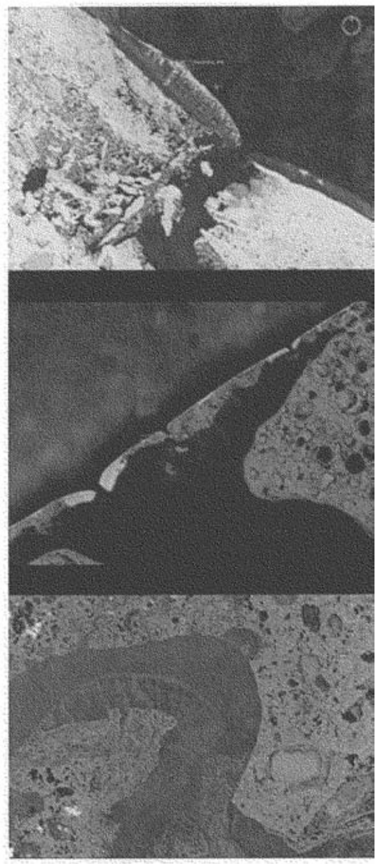


(Source: McBeath 2006)

McBeath (2006) evaluated potential climate impacts on the Trans-Alaska Pipeline (TAP). An 800-mile, 48-inch diameter warm oil pipeline, the TAP crosses nearly the entire state, north to south from Prudhoe Bay oil field to the Port ofValdez (Figure 11). The pipeline cost approximately $8 billion to construct, and approximately $800 million of those construction costs were due to the need to elevate the pipeline above permafrost over half its length. Since its construction, the thawing of permafrost has reduced structural integrity, which leads to spills (McBeath 2006).

In addition to disruptions to Alaska's infrastructure network from thawing permafrost, significant impacts are predicted for human settlements, particularly coastal towns and villages vulnerable to sea level rise and more frequent and intense storms. Cost estimates of shoreline protection and village relocation continue to rise. In 1998, the Army Corps of Engineers estimated construction costs of $5-7 million (converted to 2005 dollars) for a sea wall in Shismaref, located along Alaska's northwest coast, and costs of $64 million (converted to 2005 dollars) to relocate the town of Kivalina, 100 miles north (US ACOE 1998). The most recent estimates by the US Army Corps of Engineers (US ACOE) are up to $450 million in relocation costs for Shismaref, Kivalina and the village of Newtok – see Figure 12 for their locations. (Larsen et al. 2007).

Figure 12. Alaska's Coastal Towns



(Source: Google Earth 2007)

4.7.3 Other Impacts

Other sectors of Alaska's economy could be negatively affected by climate change, especially **forestry** and **fisheries**. In the long run a warmer climate may bring benefits to forestry and agriculture, but short-term vulnerabilities pose significant costs resulting from thawing permafrost and unstable soils, increased fire and insect outbreaks.

Roughly one-third of the state (129 million acres) is forested, and, of this, 4 million acres are located outside of protected areas; these support commercial harvests and road construction.[18] Increased occurrence of fire and pest outbreaks put both natural and managed **forests** at risk. An example of the kind of damages that may be expected in warmer and more vulnerable forests is the spruce bark beetle outbreak. In 1992 the outbreak – the largest documented in North America – damaged over 2.3 million acres on Kenai Peninsula. Additional insect outbreaks in the 1990s damaged over 800,000 acres of forest (Parson et al. 2001b). If an outbreak of this scale were to hit the state's commercial forests, upwards of 50% of the harvestable forestland area could be lost, causing a $332 million loss to the industry.[19]

Forest fires have also been increasing in recent history, their intensity associated with warm and dry periods in the climatic record. As of 1970, approximately 2.5 million acres burned each year. This number jumped to 7 million acres per year by the 1990s (Nash and Duffy 1997). In 1996, a 37,000 acre forest and peat fire caused $96 million in direct losses and destroyed 450 structures (including 200 homes). Based on a median housing value of about $200,000 (US Census Bureau 2005b) today, damage to the housing stock of this magnitude would cost nearly $40 million. As climate changes, more and more settled areas near forests will be at risk.

In 1995, Alaska's **fisheries** brought in 2.1 million tons of fish and $1.64 billion in revenue to fishermen, accounting for 54% of total US catch by volume and 37% by value. The total value of fisheries has since risen to approximately $2.8 billion and employs over 20,000 workers (Parson et al. 2001b). Changes in ocean temperatures, expected to be slower than temperatures over land, may affect spawning and migratory behaviors of many commercially valuable species. Sea level rise may impact harbor infrastructure, requiring retrofits and upgrades to docks. Higher temperatures may increase cooling needs for storage and processing of catch. All of these impacts are likely to add cost to an already vulnerable industry and will likely negatively impact the state economy.

4.7.4 Missing Information and Research Needs

The information contained in this report and indeed the state of knowledge on potential climate impacts to Alaska's resource extraction industries is sparse. Additional research should be directed to (and data openly shared) risks to oil and natural gas extraction, forestry and fisheries. The research efforts underway to quantify the potential impacts to Alaska's public infrastructure should continue and be intensified.

4.8 Hawaii and US Affiliated Islands

4.8.1 Overview

Hawaii and the US affiliated islands cover a large area throughout the Pacific and the Caribbean, including Puerto Rico and the US Virgin Islands in the Caribbean, the Hawaiian Islands, American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, the Federated States of Micronesia, the Republic of the Marshall Islands,

[18] The productivity of these 4 million acres of forest land is roughly 50 cubic feet per acre per year (Parson et al. 2001b).

[19] Calculation based on forestry's contribution to the state economy. $33.2 billion Gross State Product × 2% contribution of timber × 50% loss in forested area = $332 million. (Bureau of Economic Analysis 2007).

and the Republic of Palau in the Pacific. The economies of these island states and territories are dominated by agriculture, fishing and processing, tourism, and some high-tech industries (Carter et al. 2001). They have unique geological features and rich economic and cultural diversity. These island states will be most vulnerable to sea level rise and storms that will threaten coastal infrastructure and drinking water supplies.

Over the past century, average temperatures have increased 1°F (.6°C) in the Caribbean and 0.4°F (.2°C) in the Pacific. Global average sea level has risen 4-8 inches over the last century, though with significant local variation. The rate of sea level rise in the Gulf of Mexico is presently 3.9 inches per century. Their climates are significantly affected by ENSO, storm surges, and extreme lunar tides. Future trends in air temperature are much less important than sea level rise, changes in ENSO, storm cycles, and ocean temperature and circulation (Carter et al. 2001).

4.8.2 Major Impacts

4.8.2.1 Coastal Infrastructure

Climate change will likely stress already deficient infrastructure on the islands. According to the American Society of Civil Engineers, 47% of Hawaii's bridges are structurally deficient or functionally obsolete (ASCE 2005). The state also has 77 high hazard dams, whose failure would lead to loss of life and property damage. Repairs (not including those due to climate change) to Hawaii's drinking water infrastructure could exceed $146 million over the next 20 years; its wastewater infrastructure, $1.74 billion. The biggest threats to this already burdened infrastructure will be sea level rise and tropical storms.

There have been a number of destructive hurricanes to hit the US islands in recent years. Hurricane Marilyn, in the US Virgin Islands, caused as much as $4 billion in damages (see Figure 13,

Table 11. Breakdown of Estimated Damages from Hurricane Marilyn in the US Virgin Islands

Category of Damage	Estimated Costs
Sewage Treatment Facilities	1,000,000
Roads and Bridges	1,000,000
Damage to Manufacturing	1,000,000
Agriculture	1,000,000
Water	3,000,000
Protective Measures	10,000,000
Debris Removal	18,000,000
Telephones	30,000,000
Electrical	70,000,000
Lost Employment	80,000,000
Public Buildings	210,000,000
Damage to Hotels	253,000,000
Lost Tourist Revenue	293,000,000
Private Housing	1,300,000,000
Total	2,271,000,000

Source: The Virgin Islands Natural Hazard Mitigation Plan, Potter et al. 1995

Potter et al. 1995; National Hurricane Center 1996). Hurricane damages in Hawaii from 1957-1995 topped $2.7 billion (Pielke 2001). Hurricane Iniki, the most powerful hurricane (category 4) to hit Hawaii, caused 7 deaths, $2 billion in damages, and leveraged $295 million FEMA disaster relief in 1992 (Hamnett et al. 1999; Carter et al. 2001). It was part of the strong 1991-1994 El Niño cycle that produced some 11 powerful tropical cyclones in the Central Pacific.

Hurricane Georges hit Puerto Rico in 1998, bringing 26 inches of rain in 24 hours that caused major flooding, landslides, infrastructure and agricultural damages, and left 12 people dead. Puerto Rico lost 75% of its water and sewer infrastructure. Ninety-six percent of its electrical power network, 50% of its utility poles and cables, and 33,100 homes were damaged or destroyed. Road damages exceeded $25 million, and damage to public schools was about $23-29 million. Its agricultural areas were also affected, with 75% of the coffee crop, 95% of the plantain and banana crops, and 65% of all poultry production temporarily lost (USGS 1999; NOAA 1999). In total, Hurricane Georges cost Puerto Rico $2.3 billion in damages; damages to the US mainland damages were $6.9 billion (Carter et al. 2001).

With storms and sea level rise come beach erosion, which occurs 150 times faster than the rate of sea level rise (Carter et al. 2001). Some Caribbean islands are already losing 9 feet of coastline each decade due to erosion and the projected rate of sea level rise would erode more than 33 feet of coastline per decade in the foreseeable future.

4.8.3 Other Impaacts

Climate impacts on coastal infrastructure, particularly roads, bridges, docks, water supply systems, and hotels will reduce the attractiveness of islands to **tourism**, as well as impact local ecosystems, from tropical forests to coral reefs. Changes in temperature and precipitation may make additional locations unattractive to visitors.

4.8.4 Missing Information and Research Needs

Although the climatic and socioeconomic situation differs considerably among Hawaii and the various US affiliated islands, by virtue of their size and location, they all exhibit vulnerability to sea level rise. With the bulk of their infrastructures, populations and economic activities located along coast lines, these islands will benefit from adaptive capacity that reduces vulnerability to gradual sea level rise as well as helps prepare them for extreme events. A series of case studies for various islands, strategically chosen, may provide a basis on which to identify, in those locations and many of the others, investment and policy options that reduce vulnerabilities and cost.

5 Conclusions and Recommendations

The nation already experiences a wide range of adverse economic impacts of climate change itself, as well as changed environmental conditions whose frequency and severity are consistent with those under a changed climate. Examples include sea level rise and its impacts on coastal economies; droughts and heat waves with their impacts on agriculture, forestry, energy systems and public health; and severe rainfall events with their impacts on transportation and other infrastructure systems.

Directly or indirectly, Climate change will continue to affect all sectors and regions of the country, though not all of them equally or at the same time. There will temporarily be winners and losers from climate change, but the long-term economic cost of climate change rapidly exceeds benefits and places major strains on public sector budgets, personal income and job security. Because of the higher economic costs of climate change, we conclude that delayed (or inaction) action on global climate change will likely be the most expensive policy option. **A national policy for immediate action to mitigate emissions coupled with efforts to adapt to unavoidable impacts will significantly reduce the overall costs of continued climate change.**

Providing adequate information and support for climate change policy requires that models and assessments of mitigation and adaptation options reflect both the costs of environmental investments and policy as well as the benefits of such policies. To achieve such a balanced perspective, in turn, necessitates a concerted effort by the scientific and stakeholder communities along the following three dimensions:

1. Adequate choice of methodologies.
2. Expansion of regional and sectoral case studies.
3. Implementation of adaptive and anticipatory management.

5.1 Choice of Methodologies

Much of the economic analysis of climate change impacts and adaptation has been guided by the notion that adaptation options can be carried out incrementally and that their extent must be limited to the point at which the cost of an extra unit of adaptive measures equals the cost of that extra unit. This is the traditional microeconomic approach to identifying, for example, optimal levels of production, now applied to the production of "care" for environmental goods and services. As such, it rests on more than 100 years of economic theory, has led to myriad economic assessments of optimal investment and policy, and, unfortunately, is utterly inadequate to address all but the narrowest of climate mitigation and adaptation issues. Many of the assumptions underlying the traditional microeconomic approach do not hold in the climate change context, such as the assumption of homothetic consumer preferences, concave benefit functions and infinitesimally divisible levels of action.[20] In fact, a recent report by the U.S. Government Accountability Office on climate change and federal land management stressed precisely this point by asserting that "resource managers lack specific guidance for incorporating climate change into their management actions and planning efforts. The report further concludes that in light of the missing information managers cannot plan for upcoming changes and are left only to respond to already-observed climate change impacts (US GAO 2007b).

An alternative approach treats mitigation and adaptation actions as investments in natural, human-made and social capital, with the goal of maintaining or enhancing the services they provide. A methodological approach consistent with that viewpoint will need to rest in portfolio choice theory. It needs to include methods and tools from the theory of investment and finance under risk and uncertainty.

The current, rather inadequate, theoretical and conceptual foundation is resulting in a hodge-podge of empirical and modeling studies with often incongruous results. We recommend that one consistent assessment be carried out across major regions of the US and across major sectors in those regions. Key features of that assessment should be:

(a) Recognition of the complementary and non-marginal

[20] For a concise presentation of standard economic approaches to adaptation cost estimation see Callaway et al. 1998; for a non-technical rebuke of those assumptions see Dore and Burton 2000.

nature of investments in climate change solutions: Adequate preparation to deal with climate impacts requires that investments into human-made infrastructures (such as dikes and levies) are coupled with corresponding investments in social capital (such as local knowledge about disaster preparedness and institutions to manage infrastructures and communicate with local populations) and natural capital (such as flood plains and coastal ecosystems). Investment in one, without corresponding recognition of the performance of the other factors that influence overall "system performance," will likely be misguided and wasteful. And since investment in either will likely need to be significant (non-"marginal") to have any noticeable impact, the methodological approach needs to adequately capture the investment decision as one of portfolio choice, rather than be based on traditional benefit cost analysis.

(b) Use of cutting-edge data acquisition and visualization: The spatial nature of infrastructures, settlements, economic activity and climate impacts all call for the use of the best available spatial data, such as satellite imagery and Geographic Information Systems. The recursive nature of climate impact and socioeconomic adjustment, in turn, calls for the application of computer modeling tools that help play out the dynamic nature of adaptation to climate change. Although pilots are trained on flight simulators to improve safety of their equipment and passengers, investment and policy-making often lacks corresponding tools for information processing and learning. Adequate capture and visualization of cutting-edge scientific information will be an important contributor to proper investment and policy decision-making.

(c) Modular, hierarchical approach to filling knowledge gaps: The extent of the problem and dearth of consistent and detailed information will require an approach that allows scientists to first cover large regions and highly aggregate sectors, but then to remove and replace initially coarse assessments with finer ones as new data and information are generated. Sequential movement towards higher-resolution studies that will require strict adherence to research protocols as new modules are developed. A detailed listing of underlying assumptions will be needed to enhance follow-up research and enable comparison to other cases or locations.

(d) Tight coupling of environmental, economic and social information for specific sectors and regions: The interdependencies among sectors and regions in the US, and the potentially significant ripple effects of the cost of climate impacts and the benefits of adaptation require that data, models and analyses adequately reflect those interdependencies. This will be a clear break from current practice, where focused sectoral and regional assessments are typically carried out in isolation of each other, or – when they are connected – the studies are of such coarse temporal and spatial resolution as to offer only very general guidance for investment and policy-making.

5.2 Regional and Sectoral Case Studies

Adaptation actions typically are carried out in individual sectors within specific regions with the goal of reducing the vulnerabilities of environmental, social and economic systems at particular locations. As a consequence, an assessment of the benefits of various adaptation actions and options will require place-specific information. Therefore, we highly recommend to successively move from the large regional assessments currently available to ever finer scales of resolution of the actions taken across the US. To ensure that the different regional and sectoral case studies remain comparable and that knowledge can be effectively transferred from one place to another will require, as discussed above, that a consistent methodology be applied and that data acquisition, analysis and reporting follow protocols that are common and consistent across case studies.

One novel approach to organizing the potentially large number of the very heterogeneous case studies is akin to the development of open source software. There, many different developers and users provide modules to an evolving product whose features reflect changes in the state-of-technology and user preferences, while at the same time providing consistency and coherence for the system as a whole to optimally function.

A consistent nation-wide, regional and sectoral case studies approach will enable systematic comparison of the underlying reasons why, in some cases, a particular adaptation strategy was chosen, yet not in others, and why some of these strategies were successful while others failed. On the basis of detailed comparative studies, general guiding principles and policies may be derived that are meaningful nationally. Such an approach to policy design would be quite different from the one where a universally applicable economic theory is combined with broad legal direction to inform policy with the understanding that regional and sectoral processes will follow suite to generate locally appropriate investment in mitigation and adaptation actions.

Because improved understanding of climate impacts, and the costs and benefits of those impacts, is in the national interest, the **federal government should organize and finance a set of region- and sector-specific studies that help guide climate policy and investment, using appropriate methodologies.** Fortunately, large amounts of data and studies are already available in the scientific literature, as well as reports by various agencies and non-governmental entities, that can provide solid starting points for the assessment of mitigation and adaptation benefits. It will be prudent to systematically evaluate those assessments and build on them; it will not be necessary to start from scratch in many cases. Although Congressional oversight of the process of information assembly and new analysis would be necessary, the intellectual power of the nation's labs and universities should be set free to do this cutting-edge research.

5.3 Adaptive and Anticipatory Management

The climate is not constant, and the local economies and societies that attempt to adapt to it are not static. We are neither ignorant of the risks associated with climate change, nor has the nation implemented the necessary strategies to mitigate, prepare for, and adapt to climate change. A new management approach is required that helps society and the economy adapt to the changes in environmental, technological, social and economic circumstances, and that responds to new knowledge that is gained as management approaches are implemented.

Consequently, management ideally anticipates likely future conditions and sets in place strategies that answer to those conditions when they are met. Since considerable uncertainty will always prevail about possible future environ-mental, technological, social and economic condi-tions, management and policy need to identify robust strategies – portfolios of investment and policy decisions that lead to desired outcomes under a wide range of potential future states of the world.

Advanced computer simulation may provide one piece of valuable input into the identification of robust strategies. To date, the climate change research and policy communities have benefited much from computer models developed in the natural sciences to better understand the biogeochemical cycles, especially the cycles of carbon and other greenhouse gases, and how those cycles are altered under different socioeconomic activities. No comparable funding has been provided or similar effort has been made to improve the tools for quantitative analysis of the human activities that lead to climate change, their interdependency with changes in the natural world, and the associated mitigation and adaptation options.

Computer models can only provide one kind of input into the management process. Another very important contribution must come from the various stakeholder communities which are affected by climate change and which ultimately choose among alternative mitigation and adaptation actions. The choice of methodology and case study approaches outlined above may render stakeholder involvement a more doable and more productive component in the assessment process and may foster implementation of sustainable climate mitigation and adaptation strategies.

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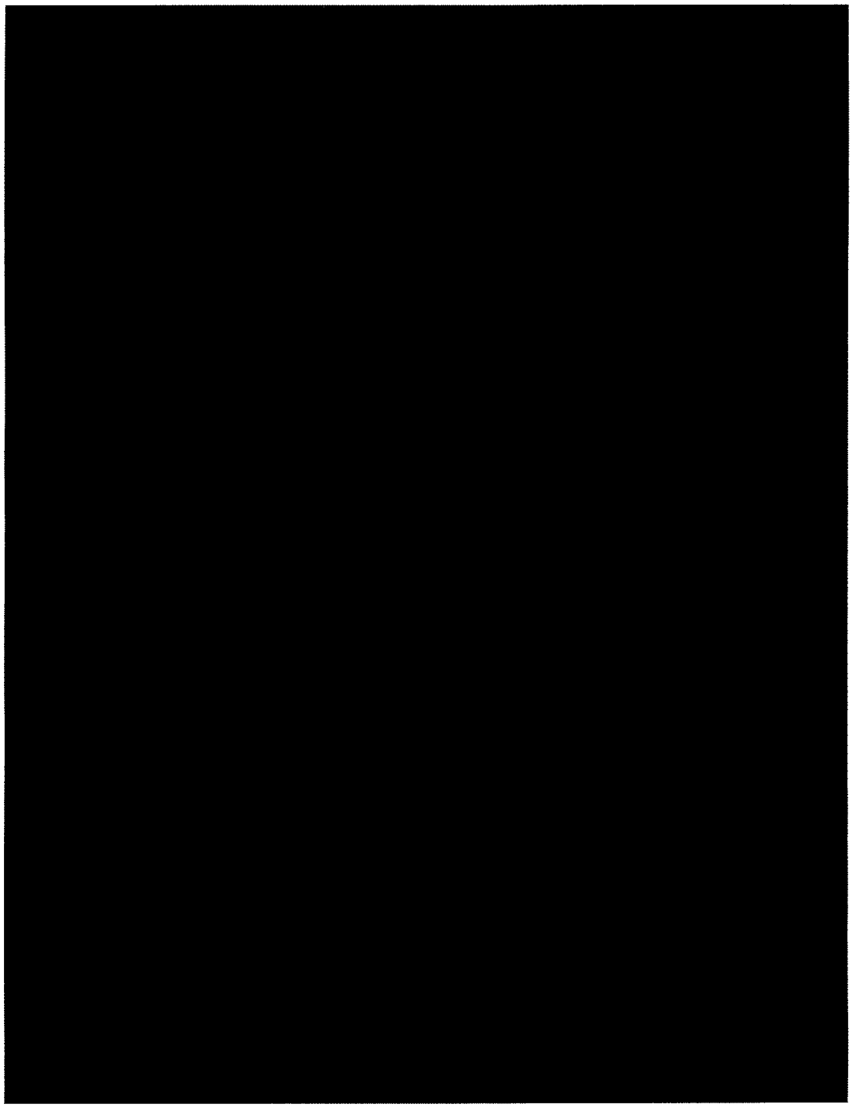

CIER
Center for Integrative Environmental Research

Center for Integrative Environmental Research
University of Maryland
2101 Van Munching Hall
College Park, Maryland 20742
email: cier@umd.edu
www.cier.umd.edu

Federal Climate Change Legislation

October 11, 2009

To: Wisconsin's Congressional Delegation
From: University of Wisconsin and partner's researchers
RE: Legislation to address greenhouse gas emissions

We are writing to you as scientists in colleges and universities across the state of Wisconsin to urge the Wisconsin Congressional delegation to support strong federal policies for rapid and deep reductions in emissions of carbon dioxide and other greenhouse gases at least on par with the reductions recommended by the intergovernmental panel on climate change.

The science now convinces us that calls for immediate action are warranted to avoid the worst consequences of global warming on Wisconsin's economy and environment, including the Great Lakes. While slowing the damaging effects of climate change poses challenges, we also believe such action presents Wisconsin with real opportunities to reinvigorate our economy and improve the quality of life for all Wisconsinites.

Controlling carbon emissions will allow for Wisconsin and the United States to take full advantage of the clean renewable resources and energy efficient technologies that are available today. A workable federal policy to combat global warming will also encourage researchers, investors, and businesses to accelerate development and deployment of next generation energy technologies. Putting a price on carbon is a critical step toward building a clean energy future for the US and right here in Wisconsin.

Climate policy at the federal level offers a unique opportunity to protect valuable natural resources and stimulate the economy. A comprehensive federal climate and energy policy can provide the stable regulatory framework, appropriate market signals, and long-term investment commitment necessary to jumpstart new business, transition core industries, and enhance our global competitiveness.

According to "Job Opportunities For The Green Economy: A State-By-State Picture Of Occupations That Gain From Green Investments", there are currently almost 450,000 jobs that would be considered green jobs in Wisconsin. If, as expected, there is an increase in demand for solar, wind, building retrofitting, cellulosic biofuels, more fuel efficient transportation or mass transit options, then it is not unreasonable to expect a 25% increase in the jobs in these areas. A 25% increase would represent an additional 112,500 jobs in Wisconsin, with half of these in the manufacturing area. As an example, Johnson Controls, the largest business in Wisconsin, is a leader in the green jobs field, with expertise in energy efficient building systems and next generation batteries.

Sound climate policy will accelerate this transition – it is a critical part of the stimulus that our struggling economy needs. A recent report from the Apollo Alliance states that a $13 billion investment in clean energy in Wisconsin would yield approximately 93,000 new jobs, with about 27,297 of those in manufacturing and 11,199 in construction.

Doing nothing is not a viable option for Wisconsin. Our state faces serious economic, social, and ecological impacts from global warming. If climate change continues on its present course, not only will we miss out on the new economic opportunities outlined above, but some of Wisconsin's industries, agriculture and tourism, could suffer. Additionally, climate change could seriously impact water quantity and quality in the Great Lakes, leading to greater conflicts over water resources in the region.

Agriculture is a key Wisconsin industry, contributing approximately $59 billion in annual industrial sales to the state, along with 353,991 jobs and $20 billion in income.[1] Many of the jobs and much of the economic impact provided by Wisconsin's agriculture industry could be lost if climate change continues on its present course. Conversely, Wisconsin universities are leaders in agriculture and bioenergy research, and Wisconsin farmers stand to gain from federal policy that promotes renewable energy and caps carbon pollution. Farmers, for instance, could realize new revenue by leasing land for wind turbines and assigning unproductive cropland to carbon offset programs and producing biomass for next generation renewable fuels.

Heat waves and increased ozone concentrations projected with climate change can adversely affect human health, especially the young and the elderly. Intense rainfall and heavy runoff are expected to increase up to 40% by mid-century, markedly raising water quality-related human health risks. Such conditions also decrease crop production. Intense rainstorms during spring planting season and summer droughts, both of which have increased in recent decades, will continue with greater intensity under "business as usual" carbon emissions and will likely reduce

[1] Steven C. Deller, The Contribution of Agriculture to the Wisconsin Economy (2009).

agricultural productivity and pollute our surface waters, including the Great Lakes. Hotter, drier summers and more droughts will require additional irrigation for crops that were previously rain-fed. Warmer winters will favor more southern insects, pests, and plant pathogens. All of these factors could dramatically reduce agricultural production and increase costs for farmers, agri-businesses, and others who have either direct or indirect ties to Wisconsin's agriculture industry.

Left unchecked, climate change will also harm our state's tourism industry. Tourism contributes $13 billion in direct spending each year to Wisconsin's economy, and brings in $2 billion in state and local taxes and provides 310,000 jobs, according to the Wisconsin Department of Tourism.

Winter sports, such as skiing, snowmobiling, ice fishing, and snowboarding will suffer due to shorter, warmer winters. Warmer Great Lakes, rivers, streams, and inland lakes will change the distribution of fish species, and many species of coldwater fish — including three of our trout species (Brook, Rainbow and Brown Trout) — could disappear from our region. Bird-watching activities will slow due to a decline in bird diversity, particularly among waterfowl and songbirds. Longer, hotter summers could increase beach use, but beach recreation could see a decline in activities because of more volatile weather and potential increases in pollution and waterborne- and insect- diseases.

Policymakers have a clear choice: allow climate change to continue on its present path and cause serious long-term damage to Wisconsin's population, natural resources and economy, or embrace an enlightened global warming solutions policy that will protect our air, water, land, and Great Lakes while spurring economic growth at home in Wisconsin. There are even "co-benefits" in pursuing a less carbon-intensive economy. For example, reducing transport trips with internal combustion engines could save our state many lives and health care costs simply by beneficial effects from clearer air quality.

For all these reasons, we strongly urge you to pass without further delay strong global warming policies that can give Wisconsin citizens, businesses, and farmers cost-effective, clean and affordable energy.

Sincerely,

Professor Jonathan Patz
UW–Madison

Professor John Magnuson
UW–Madison

Professor Don Waller
UW–Madison

Dr. Sandra McLellan
Great Lakes WATER Institute
UW-Milwaukee

Dr. Monica G. Turner
UW–Madison

Stephen R. Carpenter
UW-Madison

Thomas L Eggert, Esq
UW-Madison, School of Business

Additional Signatures as conveyed via the Internet as of October, 2009

George Nicholas Allez, Nelson Institute, SAGE, U. of Wisconsin–Madison
Patrick Anderson, Great Lakes Water Institute
Edward Belongia, MD, Marshfield Clinic Research Foundation
Marcia Bjornerud, Lawrence University
William L. Bland, University of Wisconsin-Madison
Dr. Harvey Bootsma, UW-Milwaukee Great Lakes WATER Institute
Mark A. Borchardt, Marshfield Clinic Research Foundation
Stephen M. Born, UW-Madison
Kenneth M. Cameron, University of Wisconsin, Madison
Stephen R. Carpenter, University of Wisconsin-Madison
Aaron Carrel, MD, University of Wisconsin
Michael J. Carvan, UW-Milwaukee
Megan Christenson, University of Wisconsin-Madison
Dr. James Conway, University of Wisconsin School of Medicine & Public Health
Gregory Davis, UW-Green Bay
Bart De Stasio, Lawrence University
Lori DiPrete Brown, UW Madison Center for Global Health
Tom Eggert, WI School of Business
Maggie Lynn Grabow, University of Wisconsin-Madison
Erin Gutowski, UW-Madison
Micah Hahn, Center for Sustainability and the Global Environment, UW-Madison
Dr. Jill Hapner, Washington County Conservationist
Cynthia Haq, University of Wisconsin, School of Medicine and Public Health
H.J. Harris, UW-Green Bay
Emma Hynes, Population Health Institute
Randall Jackson, University of Wisconsin-Madison
Allen Kahl, UW Population Health Sciences

Betty Kaiser, University of Wisconsin-Madison
Miles Kirby, Wisconsin Department of Health Services - Bureau of Environmental and Occupational Health
George J. Kraft, University of Wisconsin - Stevens Point
Tim Kratz, University of Wisconsin - Madison
John E. Kutzbach, University of Wisconsin-Madison
James A. LaGro, Jr., UW-Madison
Frederick W. Lauing, University of Wisconsin Press
Mark K. Leach, Ph.D., Northland College
David S. Liebl, UW-Madison and UW-Extension
Vijay Limaye, UW-Madison
Sara Lindberg, UW-Madison
Richard L. Lindroth, University of Wisconsin-Madison
Kathleen Madden, University of Wisconsin - Madison
Kristen Malecki, UW Madison
Dave Marshall, Underwater Habitat Investigations LLC
Dr. Karl Martin, WI DNR
Nancy E. Mathews, University of Wisconsin - Madison
Kathi Matthews-Risley, Sauk Prairie River Projects Association, LTD
Marc Mayes, University of Wisconsin-Madison
Sabrina McCormick, George Washington University
Brent McCown, University of Wisconsin-Madison
Galen A. McKinley, University of Wisconsin - Madison, Atmospheric and Oceanic Sciences
Katherine Mitchell, University of Wisconsin-Madison
Claus C. Moberg, University of Wisconsin - Madison
Michael Mossman, Wisconsin Department of Natural Resources
Peter J. Nowak, University of Wisconsin-Madison, Nelson Institute
Sarah Olson, University of Wisconsin - Madison
Steve Plachinski, Center for Sustainability and the Global Environment
Volker Radeloff, University of Wisconsin-Madison
Kenneth Raffa, University Wisconsin - Madison
Dr. James A. Reinartz, Director, UW-Milwaukee, Field Station
Bradford G. Rence, Ph.D., Lawrence University
Susan K. Riesch, UW-Madison
Emily L. Rossi, University of Wisconsin Madison
Annemarie Schneider, University of Wisconsin-Madison
Emily H. Stanley, University of Wisconsin
Yoyi Steele, Wisconsin Department of Natural Resources
Cecilia Stodd, Population Health Sciences, University of Wisconsin
John (Jack) Sullivan, Wisconsin Department of Natural Resources
Philip A. Townsend, University of Wisconsin - Madison
Paula Tran, University of Wisconsin Madison
Professor Monica G. Turner, University of Wisconsin-Madison
J. Val Klump, Great Lakes WATER Institute University of WI-Milwaukee
Stephen J. Ventura, University of Wisconsin-Madison
Carl J. Watras, Wisconsin Department of Natural Resources
Amy Wolf, University of Wisconsin Green Bay
Jerry Woolpy, Earlham College
David Zaks, University of Wisconsin - Madison
Jake Vander Zanden, University of Wisconsin - Madison
Michael Zorn, UW-Green Bay

Here is the reaction of a great scientist, Professor F. Sherwood Rowland, who was later to win a Nobel prize for his work on stratospheric ozone depletion, when he was frustrated by the world's failure in the early 1980s to act to ban the man-made chemicals that cause the Antarctic ozone hole:

"After all, what's the use of having developed a science well enough to make predictions, if in the end all we're willing to do is stand around and wait for them to come true!

(published in an article by Paul Brodeur, *The New Yorker*, June 9, 1986, p. 81).

I have asked Professor Rowland if he feels exactly the same way now about the world's failure to act to avoid man-made climate change. His answer is yes. I agree.

It is safe to say that the international community of scientists is appalled by the attitude and behavior of Republican members of the House Subcommittee on Energy and Power at the March 8, 2011 hearing at which I testified. To illustrate this, I would like to insert into the record the following editorial in its entirety. This was published online on March 16, 2011 in *Nature*, one of the most prestigious science journals in the world.

Into ignorance

Vote to overturn an aspect of climate science marks a worrying trend in US Congress.

As *Nature* went to press, a committee of the US Congress was poised to pass legislation that would overturn a scientific finding on the dangers of global warming. The Republican-sponsored bill is intended to prevent the US Environmental Protection Agency (EPA) from regulating greenhouse-gas emissions, which the agency declared a threat to public welfare in 2009. That assessment serves as the EPA's legal basis for regulation, so repealing the 'endangerment finding' would eliminate its authority over greenhouse gases.

That this finding is scientifically sound had no bearing on the decision to push the legislation, and Republicans on the House of Representatives' energy and commerce committee have made clear their disdain for climate science. At a subcommittee hearing on 14 March, anger and distrust were directed at scientists and respected scientific societies. Misinformation was presented as fact, truth was twisted and nobody showed any inclination to listen to scientists, let alone learn from them. It has been an embarrassing display, not just for the Republican Party but also for Congress and the US citizens it represents.

It is tempting to write all of this off as petty partisanship, a populist knee-jerk reaction to lost jobs and rising energy prices by a well-organized minority of Republican voters. After all, US polling data has consistently shown that, in general, the public accepts climate science. At a hearing last week, even Ed Whitfield (Republican, Kentucky), who chairs the subcommittee, seemed to distance himself from the rhetoric by focusing not on the science but on the economic effects of greenhouse-gas regulation. "One need not be a sceptic of global warming to be a sceptic of the EPA's regulatory agenda," said Whitfield.

Perhaps, but the legislation is fundamentally anti-science, just as the rhetoric that supports it is grounded in wilful ignorance. One lawmaker last week described scientists as "elitist" and "arrogant" creatures who hide behind "discredited" institutions. Another propagated the myth that in the 1970s the scientific community warned of an imminent ice age. Melting ice caps on Mars served to counter evidence of anthropogenic warming on Earth, and Antarctica was falsely said to be gaining ice. Several scientists were on hand — at the behest of Democrats on the subcommittee — to answer questions and clear things up, but many lawmakers weren't interested in answers, only in prejudice.

It is hard to escape the conclusion that the US Congress has entered the intellectual wilderness, a sad state of affairs in a country that has led the world in many scientific arenas for so long. Global warming is a thorny problem, and disagreement about how to deal with it is understandable. It is not always clear how to interpret data or address legitimate questions. Nor is the scientific process, or any given scientist, perfect. But to deny that there is reason to be concerned, given the decades of work by countless scientists, is irresponsible.

That this legislation is unlikely to become law doesn't make it any less dangerous. It is the attitude and ideas behind the bill that are troublesome, and they seem to be spreading. Fred Upton, the Michigan Republican who chairs the full energy and commerce committee, once endorsed climate science, but last month said — after being pinned down by a determined journalist — that he is not convinced that greenhouse-gas emissions contribute to global warming. It was yet another blow to the shrinking minority of moderate centrists in both parties.

One can only assume that Congress will find its way at some point, pressured by voters who expect more from their public servants. In the meantime, as long as it can fend off this and other attacks on the EPA, President Barack Obama's administration should push forward with its entirely reasonable regulatory programme for reducing greenhouse-gas emissions where it can, while looking for ways to work with Congress in other areas. Rising oil prices should increase interest in energy security, a co-benefit of the greenhouse-gas and fuel-efficiency standards for vehicles that were announced by the administration last year. The same advice applies to the rest of the world. Work with the United States where possible, but don't wait for a sudden change of tenor in Washington DC.

One of the scientists testifying before Whitfield's subcommittee was Christopher Field, director of the Carnegie Institution's global ecology department in Stanford, California. Field generously hoped that his testimony at last week's hearing took place "in the spirit of a genuine dialogue that is in the best interests of the country". Maybe one day that hope will be justified.

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The Honorable Edward Markey
1. During the hearing, Dr. Pielke suggested that the statements on climate change made by scientific professional organizations like the American Geophysical Union (AGU) and the American Meteorological Society (AMS) are the work of a small group of scientists and are not representative of the opinion of the members of the societies. In your experience, do societies follow protocols to develop statements like these that are designed to ensure that the final products are representative of the broad membership? Are there ways to amend or update these statements as the scientific understanding of the issues advances?

Dr. Pielke is incorrect, and this suggestion is a gratuitous insult to these organizations and their leadership and membership. Both AGU and AMS, as well as other organizations, have detailed formal procedures for drafting and adopting statements, including soliciting opinions from their membership. It is egregious nonsense to suggest that the statements issued by these organizations, and by many other reputable professional scientific societies, are not based on sound science and would be opposed by majorities of the membership of the societies.

Many leading scientific societies and national academies of science worldwide have endorsed the foundational findings of climate change science, as assessed by the Intergovernmental Panel on Climate Change (IPCC). The notion that all these organizations have acted against the will of their members is not credible. If Dr. Pielke truly believes this notion, that very fact shows the degree to which he has become an outlier in the expert scientific community.

I have inserted below the full AGU procedure and a summary of the AMS procedure, from the websites of these organizations.

Policy on AGU's Role in Advocacy on Public Issues

Adopted by Council May 1982

The American Geophysical Union is an association of scientists, scholars, and interested lay public for the purpose of advancing geophysical science. The Union shares a collateral sense of responsibility to assure that the results of geophysical research are made available to benefit all mankind. The Union encourages its members to exercise their individual sense of responsibility in addressing political and social issues. Should they choose to act collectively on such issues, other organizations exist for such purposes. The American Geophysical Union, as a society, should preserve its unique position as an objective source of analysis and commentary for the full spectrum of geophysical science. Accordingly, the following policies should guide the AGU's role as an advocate.

The American Geophysical Union has a responsibility to its members to adopt a position of advocacy on geophysical science issues based on their intrinsic merits and needs.

To the extent that the understanding and application of geophysical science is relevant to public policy, AGU as a responsible scientific association should make relevant information available to all parties interested in the issue.

As a scientific society, AGU should not take or advocate public positions on judgmental issues that extend beyond the range of available geophysical data or recognized norms of legitimate scientific debate. Public positions adopted by AGU and statements issued on its behalf must be based on sound scientific issues and should reflect the interests of the Union as a whole.

Procedures for Developing Union Positions

Adopted by Council May 1982 Most Recently Revised May 1998

Position statements will be restricted to those issues that fall within the guidelines above which have been approved by the Council. Proposals for position statements can originate from any member or from any Union or Section committee.

Requests for position statements are referred immediately to the Committee on Public Affairs (COPA).

If a request seems to fall within Union guidelines, COPA will recommend that the President of the Union appoint an independent panel charged with drafting a statement. The panel will include at least one member of COPA, the originator of the request, and one Council member.

The Council and the membership will be informed that the panel is working on the issue and that comments are welcome.

The panel will prepare a statement for circulation to the Council of the Union, with an information copy to COPA.

Members of the Council (or Executive Committee when timeliness is critical) will be asked to vote or to comment on the proposed statement. This vote is to be taken at regularly scheduled meetings except where timeliness is critical. Concurrence of two-thirds is required for adoption.

All adopted position statements will be published in Eos as soon as possible.

Once a statement has been approved, the Committee on Public Affairs will endeavor to apply its expertise to making advocacy of its contents as effective as possible.

Public policy statements have a lifetime of no more than four years but can be reaffirmed and thereby extended for an additional four years. Individual statements may be adopted with an earlier expiration date. Additionally, a new statement may be adopted that supersedes and therefore replaces one or more previous statements. The Council may also withdraw a statement at any time by a simple majority vote.

The American Meteorological Society (AMS) promotes the development and dissemination of information and education on the atmospheric and related oceanic and hydrologic sciences and the advancement of their professional applications. Founded in 1919, AMS has a membership of more than 14,000 professionals (in government, the private sector and academia), students and weather enthusiasts. As a service to its members, and in fulfillment of its larger responsibilities to human society, the AMS periodically issues statements on topics that fall within the scope of AMS expertise.

Summary of the process used to create AMS statements
The full process for creating AMS statements of various types is provided in the Guidelines for Statements of the AMS (PDF). A few key components of the process are provided here.

Statements are drafted in a multistep process by a drafting committee composed of volunteers from the AMS who are recognized experts in the subject area of the statement and who bring different perspectives on the subject. The process is overseen and coordinated by the AMS Council, which is the governing body of the AMS that is elected from the membership by the membership. Every statement, after passing review by the AMS Council in draft form, is posted for comments from the AMS membership for a period of not less than 30 days. All comments received during the comment period are evaluated and must be addressed by the drafting committee before the final form of the statement is approved. The final statement is approved by the AMS Council on behalf of the Society only when the Council feels the statement has incorporated appropriately the comments from the membership and that it represents the view of the Society.

The Honorable Morgan Griffith
1. Do we know what the temperatures were during the period in history known as the Great Optimum, which lead to the rise of Mesopotamian and Egyptian cultures? That was a time in history of global warming, but how warm did it get?

Our current understanding and available proxy data do not permit us to provide detailed temperature estimates for particular regions in the distant past. We do know, however, that natural climate variations did have strong effects on these ancient civilizations. The evidence favors the conclusion that it was climatic change rather than a given average temperature that had the greatest effect on humans.

For example, in Mesopotamia, the Akkadian empire abruptly collapsed about 4,150 years ago, at a time of widespread aridification, possibly resulting from sea surface temperature changes in the North Atlantic (P. B. De Menocal (2001): Cultural responses to climate change during the late Holocene, *Science*, vol. 292, pp. 667-673).

As for Egypt, a 2006 study in *Science* (vol. 313, pp. 803-807) concludes, "Radiocarbon data from 150 archaeological excavations in the now hyper-arid Eastern Sahara of Egypt, Sudan, Libya, and Chad reveal close links between climatic variations and prehistoric occupation during the past 12,000 years. Synoptic multiple-indicator views for major time slices demonstrate the transition from initial settlement after the sudden onset of humid conditions at 8500 B.C.E. to the exodus resulting from gradual desiccation since 5300 B.C.E. Southward shifting of the desert margin helped trigger the emergence of pharaonic civilization along the Nile, influenced the spread of pastoralism throughout the continent, and affects sub-Saharan Africa to the present day."

2. How about for the period known as the Lesser Optimum? And how much did the temperature rise then? We know this period led to Vikings dominating Europe.

The Medieval Warm Period or Medieval Climate Optimum (approximately 950 to 1250 AD) appears to have been highly variable geographically, with some regions likely being significantly warmer than at present, but the global average temperature likely having been considerably less than at present. Once again, our ability to estimate temperatures in many regions is limited by the available proxy data. The Vikings apparently took advantage of ice-free seas to colonize Greenland and Newfoundland.

3. Has the IPCC studied why the ice caps on Mars are melting? Do we know whether this is a result of a shift in the orbit of Mars? Or is the Sun is putting out more radiant heat?

First, we should make clear that the IPCC does not carry out or sponsor or direct research. It simply assesses published research results carried out by scientists all over the world.

Second, our understanding of the climate of Mars is far less extensive than our understanding of the climate of the Earth, and we have only very limited observational data for Mars. Third, Mars ice caps are almost certain to be strongly affected by processes that are dominant on Mars but are far less important for the Earth. For example, Mars orbital eccentricity variations are about 5 times greater than those of the Earth. Also, Mars is subject to gigantic dust storms. There are no oceans on Mars, and the Martian atmosphere is thin, so there is much less thermal inertia than on Earth. These factors are of much greater influence on Martian climate than on that of the Earth. We do measure variability of solar luminosity very accurately from satellites, and it is ten times weaker in influencing Earth's climate than the effect of the increase of carbon dioxide. Thus, a large body of scientific evidence leads us to conclude that Mars ice caps do not change for reasons that are significant for changes in the climate of the Earth.

4. Why was I taught in school 40 years ago that greenhouse gases were going to lead to a new ice age?

There is a rather definitive study, "The myth of the 1970s global cooling scientific consensus, " by Thomas C. Peterson, William M. Connelly, and John Fleck. This study refutes the myth that may have crept into the Congressman's education. This study appeared in the peer-reviewed journal *Bulletin of the American Meteorological Society* in the September 2008 issue, pages 1325 - 1337. It concludes, "There was no scientific consensus in the 1970s that the Earth was headed into an imminent ice age. Indeed, the possibility of anthropogenic warming dominated the peer-reviewed literature even then." Perhaps the teachers in the Congressman's school were confused by some hype in portions of the media and in some popular books at that time. They should read this article. In the hearing video recording, Dr. John Christy can be seen shaking his head and signaling his disagreement when I cited this paper in response to the Congressman's description of his education some 40 years ago. I challenge Dr. Christy to produce peer-reviewed studies in reputable journals, refuting the study of Peterson et al. cited above. On this topic and others in climate science, it is facts and evidence that matter, not unfounded allegations and opinions.

5. In regard to radiant heat and the sunspot effects, how could this affect global temperatures?

Changes in the sun could certainly affect the climate. We have had accurate satellite measurements of the variability of the total solar luminosity for about the last 3 decades. During this period, the measurements show that this quantity varies over the 11-year solar cycle by about one tenth of one percent. Translated into the quantitative units appropriate to measuring the effect on climate change, called radiative forcing, measured in Watts per square meter, the effect of these solar changes is about ten times smaller than the effect of man-made carbon dioxide increases in the atmosphere. Furthermore, there is no long-term trend in the solar measurements. Thus, they can be ruled out as a cause of the observed climate warming in recent decades.

6. What is the optimum temperature for man?

I don't know of an optimal temperature for man, and neither does anybody else. Our concern about the effects of man-made climate change is not based on a search for some optimal temperature. It is based on the speed and magnitude of the climate change that is already occurring and that will almost certainly intensify in the future unless serious mitigation measures, such as a large reduction in global emissions of carbon dioxide, are undertaken soon. Global average surface temperature as an indicator for the climate may be thought of as analogous to body temperature for humans, in that a fever is a symptom of a disease, and a larger fever is often associate with a more serious illness. Thus, the larger the climate warming, the more serious are likely to be the climatic consequences, including, but not limited to, rising sea levels, altered precipitation patterns, loss of glaciers and sea ice and ice sheets, and increased intensity and/or frequency of many kinds of extreme weather events.

Global temperatures have been relatively stable during the time that human civilization has developed. The problem we face due to rapid human-induced climate change is that we have designed our society for the climate we have had, not for a rapidly changing one. With our many large coastal cities, and with all of our infrastructure, dams, pipes, pumps, and canals, all built for the climate we have become used to, many careful analyses have shown that any rapid and dramatic climate change is likely to be costly and dangerous.

7 . You indicated pre-1900 industrialized temperatures is where you want to go, but in light of the fact that we had a little ice age in the 18th century, are you indicating that we want to return to the little ice age period or are you indicating something between 1820 and 1900?

The premise of this question is not correct. I emphatically did not ever say or write that pre-1900 temperatures are a climatic condition to which I advocate humanity should endeavor to return. What is clear is that we scientists often measure changes in climate variables such as average temperature by describing how much they have changed since mid- or late 19th century. This is simply a convenient baseline, because that is the period when a more-or-less barely adequate global network of thermometers to define global average temperature first became available, and it is also the period when mankind began injecting large emissions of carbon dioxide into the atmosphere, from wood and fossil fuels. Today, global average surface temperatures are roughly 0.75 degrees Celsius, or 1.35 degrees Fahrenheit, higher than they were then. They continue to rise at about 0.2 degrees Celsius or 0.35 degrees Fahrenheit per decade. It is the rate of rise, and the likely consequences in terms of severe climate disruption during the current century if global carbon dioxide emissions continue unabated, that are the source of concern.

Response to Questions:

Subcommittee on Energy and Power
"Climate Science and EPA's Greenhouse Gas Regulations"
Hearing Date: 8 March 2011

John R. Christy
The University of Alabama in Huntsville

<u>The Honorable Ed Whitfield</u>

1. Dr. Somerville's testimony states that the IPCC has affirmed that: "The climatic roles of clouds, and of small liquid or solid particles ("aerosols") in the atmosphere, are among the subjects where intensive research is occurring and progress is being made, but only the results of future research can settle several interesting and important scientific questions."

Question 1.a. Is it true that these "interesting and important scientific questions" represent one of the critical debates in climate science?

Answer 1.a. The "climatic roles of clouds, and of small liquid or solid particles in the atmosphere" are indeed a source of serious debate in climate science. In fact the basic hypothesis that greenhouse gases will cause significant warming depends primarily on the role of clouds (essentially that cloud cover in models will shrink and allow the sun to warm the planet.) This positive feedback characteristic is present in models, but has not revealed itself in careful observations. The role of clouds is fundamental to projecting climate change, yet this critical aspect is poorly understood today. In one oblique test of the cloud hypothesis, Spencer and Braswell (*J. Geophys. Res.* 2010) found not positive feedbacks, but negative feedbacks by cloud changes. This suggests that greenhouse warming will be much less than models generally show. In addition, research that I and others have done demonstrate that over the past third of a century, the planet has warmed much less that models had projected with their high sensitivities to greenhouse gases. Understanding and quantifying this feedback is perhaps the most critical and illusive of debates in climate science today.

Question 1.b. Is it true that the resolution of this debate will have an important effect on our understanding of the magnitude of warming from carbon dioxide?

Answer 1.b. As noted above, without quantifying the impact of the cloud-climate feedback, there is a profound, first-order uncertainty in how greenhouse warming will be manifest.

Question 1.c. Is it true that these important scientific questions he mentions have large implications for policymakers?

Answer 1.c. Policymakers are essentially being told by many scientists and advocacy groups that human-caused global warming will be dramatic and dangerous. Yet, the claim depends on a hypothesis of significant uncertainty and evidence shows rapid warming is not occurring. In any case, measures adopted to reduce greenhouse gas emissions will have little impact whether the warming is dangerous or benign. U.S. policymakers should understand this simple fact, that greenhouse gas emissions are largely out of their control, will continue to rise, and that attempts to reduce emissions will have minuscule consequences on the climate. However, such measures will likely have serious consequences on energy costs and thus the economy. There may be other good reasons to try and force the economy away from carbon-based fuels, but controlling the climate is not one of them.

Question 1.d. Is this existence and importance of this debate being communicated clearly and prominently to policy makers?

Question 1.e. If not, please elaborate.

Answer 1.d and e. Communicating information about the lack of understanding of climate science in general, and of the uncertainties of feedbacks in particular, has become a war of sorts. Conflicting messages are possible because our science has no hard-core laboratory tests to settle disputes. Add to this the fact that because tremendous financial resources are at stake, we have numerous advocacy mechanisms engaged in pressing a view that brings advantage to a particular group. We do at least have observations, and those indicate that where greenhouse gases are supposed to be having their dominant impact, we see only minor responses to this point. Policymakers should be aware that our ignorance of the climate system is enormous, and basing policy decisions on various assertions being made today about climate science is a weak foundation on which to rest.

<u>**The Honorable Edward Markey**</u>

Question 1. In your written testimony, you compare observational temperature of the lower troposphere (TLT) data after statistical removal of El Nino and volcano effects to the average of the TL T trends from many climate models. The climate model average you are comparing to your processed observational trend includes some volcanic effects, which your observational data implies provides a net warming influence over 1979 to 2010. Why would you subtract the volcanic warming influence from the observations, but not from the model average? Doesn't this invalidate your comparison and conclusion that your observed trend is "only one third of the average rate the climate models project for the current era"?

Answer 1. The comparison of observations to models in my testimony was performed as an "apples to apples" comparison. Given the length of the testimony, the three days I had to prepare it from scratch, some details were, unfortunately, not included. I am grateful for the opportunity now to bring these to your attention. The key factor in the observations from 1979-2010 that must be removed to calculate the underlying trend is the volcanic influence (the influence of El Nino events was essentially zero.). Removing those extra-cold years in the early part of the period, tilts the trend to be less positive (i.e. +0.09 vs. +0.14 °C/decade.) Note that *Nature* published the original paper when I demonstrated that the volcanoes (at that time) were at the end of that time series (1979-1993) and thus had tilted the underlying trend to be more negative than it really was (-0.04 vs. +0.09 °C/decade.)

The global trend from the models in my testimony was determined over the period 1995 to 2020 to specifically avoid the volcanic period for the simple reason that some models included the volcanic aerosols and others did not. During the 1995-2020 period in the models, there was no acceleration of the greenhouse trend and no volcanic events, so this period would well-represent the observational period 1979-2010 (i.e. with considerable overlap and no volcanic impact in either models or adjusted observations.) So, rather than perform different adjustments for some models and none for other models, I selected a period common to all models and for which there were no volcanoes, thus a like-with-like comparison with adjusted observations could be made. (The paper describing this update will be submitted shortly.)

Question 2. In your written testimony, you suggest that temperature increases over land is most readily explained by land cover and land use change from human activities. Do you believe that surface development explains the observations of increasing global temperatures? If so, how does this explain increasing ocean temperatures as well?

Answer 2. The rising surface temperature measurements over land are affected by surface development, and this is where the largest trends are observed. [McKitrick (2010) demonstrated this warming pattern - warming where industrialization has occurred - is not a feature in modeled patterns of warming.] Thus, the influence on the global trend is substantial and therefore the global trend is impacted by the human development of the surface. However, I am not claiming that warming over land is due only to industrialization. The ocean warming trend is smaller, especially in the tropics over this period, so without the land-use impact on warming over land, the global trend would be less. The better metric to examine is the bulk atmospheric temperature where these issues of land-use change have little impact.

Question 3. In your written testimony, you cite the 2007 paper "A comparison of tropical temperature trends with model predictions" published in the Journal of Climatology that you coauthored with D.H. Douglass, B.D. Pearson and S.F. Singer. A subsequent 2008 paper published in the same journal by Santer et al. identified the existence of serious statistical errors in the Douglass et al. paper. Have you addressed the concerns raised by Santer et al. in the peer-reviewed literature or other scientific forums? If so, why have you failed to reference this in your testimony to Congress?

Answer 3. As noted in many places (see papers quoted below), Santer et al. 2008 (S08) had a number of major flaws. First, and most obvious, S08 did not base their results on the same experiment of Douglass et al. 2007 (D07). Simply put, the question asked by D07 was, "If models and observations have the same surface trends, do models and observations have the same upper air trends?" This was a way to compare apples with apples (i.e. having the same surface trend) because D07 was testing the *relationship* between surface and upper air trends. Another way to ask this is, "What is the upper air trend of models if they have the same surface trend as the real world?" The answer in D07 was that upper air trends in models and observations clearly don't agree when their surface trends do. Had S08 performed this test, they also would have found the same answer (as others have since – see below.)

However, S08 reworked the problem so that they did not address our question concerning the *relationship* between surface and upper air trends. S08 addressed this question, "Do models and observations have the same upper air trend?" As such, S08 did not restrict the question to the real-world observations of the surface. Another way to ask this question is, "Do models and observations have the same upper air trend no matter what the models' surface trends might be?" This is not a very interesting question in our view because is doesn't address what is happening in the real world. Thus, the claim of "statistical errors" in S08 deals with a question we did not address, and so their point is not applicable. [Without going into detail, our methodology utilized the individual model trends as the metric to test, not the time series of the models. We did not require temporal statistical errors on these model trends because we were dealing with a very specific precondition – that models and observations have the same surface trend.]

Secondly, Santer et al. relied on two poor-quality upper air datasets (RAOBCORE 1.3, 1.4) and two surface datasets that have been superceded (ERSST v2, v3) in their comparisons. Thus, not only was the question asked by S08 less useful for climate studies, the comparison they eventually performed utilized poor data. D07 specifically noted the problems with RAOBCORE 1.3 and 1.4 that were well-known and required repair. Indeed, as noted in Christy et al. 2010 below, the European Centre (who created the baseline dataset for RAOBCORE 1.3 and 1.4) had already begun to generate a new set of products that would eliminate the spurious upper tropospheric warming that infected the RAOBCORE datasets. Since that time, the Europeans have completed their new run and have shown that the extra warming reflected in RAOBCORE is no longer present.

Thirdly, another difference between S08 and D07 is the fact S08 stopped their comparison in 1999 rather than use the available data for succeeding years. Due to the fact the observations contained a large warming spike near their end because of the massive 1998 El Niño, this spike affected the observations but not the models. D07 noted this problem and sought to alleviate it by utilizing data through 2004 while McKitrick et al. 2010 went to 2009. Thus, S08 focused on a shorter, less representative time period for their different analysis.

Regarding the citation of peer-reviewed analysis on this issue, in the haste of preparing the written testimony, the three citations that were quoted in the testimony, which demonstrated S08 has been superceded, were left off of the reference list. I did not fail "to reference this in" my testimony because the peer-reviewed citations were clearly in the text, but then their sources were left off of the reference list. For this I apologize as I generated everything regarding this testimony myself over the weekend and slipped up on the reference list. Here are the three quotes again with the appropriate references.

> *Table 2 displays the new per decade linear trend calculations [of difference between global surface and troposphere using model amplification factor] ... over land and ocean. All trends are significant[ly different] at the 95% level. Klotzbach et al. 2010.*

> *[Our] result is inconsistent with model projections which show that significant amplification of the modeled surface trends occurs in the modeled tropospheric trends. Christy et al. 2010.*

> *Over the interval 1979-2009, model-projected temperature trends are two to four times larger than observed trends in both the lower and mid-troposphere and the differences are statistically significant at the 99% level. McKitrick et al 2010.*

Klotzbach, P.J., R.A.Pielke, Sr., R.A.Pielke, Jr., J.R. Christy, R.T. McNider. Correction to "An alternative explanation for differential temperature trends at the surface and in the lower troposphere." *J. Geophys. Res.* **2010**. Doi:10.1029/2009JD013655.

Christy, J.R., B. Herman, R. Pielke, Sr., P. Klotzbach, R.T. McNider, J.J. Hnilo, R.W. Spencer, T. Chase and D. Douglass, 2010: What do observational datasets say about modeled tropospheric temperature trends since 1979? *Remote Sens.* **2**, 2138-2169. Doi:10.3390/rs2092148.

McKitrick, R.R., S. McIntyre and C. Herman, 2010: Panel and multivariate methods for tests of trend equivalence in climate data sets. *Atmos. Sci. Lett.*, doi:10.1002/asl.290.

As can be seen, the conclusions in S08 have not been supported in the literature. At a minimum, S08 is clearly highly controversial. I have a much more detailed response on this issue in my public comment to the EPA (who unfortunately depended on S08). If that would be of interest to you, I would be happy to send it on.

There is a bit of a postscript here. RSS and RAOBCORE data have been reprocessed in the last 3 months. These new versions have been adjusted and now show trends *even lower* than were used in the papers above, further confirming the quotes displayed.

Question 4. After online publication of the Douglass et al. paper, one of the co-authors Dr. S. F. Singer held a press conference at the National Press Club at which he claimed that the paper proved that "Nature, not humans, rules the climate". Do you agree with Dr. Singer's statement and does it represent the principal finding of the paper? If you disagree, please explain why.

Answer 4. I am unaware of the content of the press conference by Dr. Singer, so cannot respond with confidence that I am addressing what he addressed. In general, one must realize that climate fluctuations due to natural, unforced variability (i.e. "nature") are very significant as a look at the history of climate will attest. Periods in the past 10,000 years have been colder and warmer than the present without human intervention. Climate models are very poor at replicating this natural, unforced variability, as noted in the Stephens article cited in my testimony. Regarding the impact of CO2, I think as a greenhouse gas it will cause *some* warming of the planet but new research is demonstrating (as noted in my testimony) that the climate system has significant negative feedbacks (unlike model theory) which strongly suggest the impact of the extra CO2 will not be dramatic (and efforts to control emissions will thus have minuscule results.) The best evidence available to me at present suggests a rate of temperature increase due to the enhanced greenhouse effect of 1 to 2 °C over a century, though some data suggest even less than this, including the current rate of warming.

<u>The Honorable Morgan Griffith</u>

Question 1. Do we know what the temperatures were during the period in history known as the Great Optimum, which lead to the rise of Mesopotamian and Egyptian cultures? That was a time in history of global warming, but how warm did it get?

Answer 1. The evidence is widespread and relatively robust that suggests temperatures in many locations were warmer in the period 4,000 to 10,000 years ago than today. Evidence from Greenland, Barents Sea, Europe, North America, China, South Africa, New Zealand, Tasmania and Antarctica demonstrate this (IPCC AR4 Fig. 6.9.) The timing of the temperature anomalies don't always coincide, but the long-term (centuries) average temperature was 0.5 to more than 2°C warmer than the present in these locations.

Question 2. How about for the period known as the Lesser Optimum? And how much did the temperature rise then? We know this period led to Vikings dominating Europe.

Answer 2. Temperatures in the "lesser optimum" which I assume occurred around 1,000 years ago is a subject of some controversy and includes the problems associated with the Hockey Stick. Greenland borehole temperatures indicate a period of about 500 years centered on 900 AD that was warmer than today, which suggests there were decades averaging more than 2°C warmer than the present.

Question 3. Has the IPCC studied why the ice caps on Mars are melting? Do we know whether this is a result of a shift in the orbit of Mars? Or is the Sun is putting out more radiant heat?

Answer 3. I'm unaware of whether the IPCC investigated the observed changes in ice caps on Mars. The factors which led to such changes are speculative, but certainly the role of varying solar radiation would be a top contender since the feedback processes on Mars would likely be limited.

Question 4. Why was I taught in school 40 years ago that greenhouse gases were going to lead to a new ice age?

Answer 4. Forty years ago, and I remember this well, many climate observers looked at the previous 30 years of Northern Hemisphere surface temperature data and thought that the slightly declining trend would continue and even speed up, perhaps leading to an ice age. The brutal winters in the NE U.S., Midwest and upper plains starting in 1976-7 and ending in 1978-9 bolstered that view. The cause for such changes was not explicitly known, though some attributed it to aerosols (not greenhouse gases.)

In my opinion, climate science is still in its infancy and we suffer from a "jump-to-conclusion" syndrome. In this situation whenever a climate anomaly occurs we jump to a conclusion about why it occurs and assume things will continue on in that direction. In truth, there is much we do not know about climate and weather (otherwise we would all be experts at prediction.) Climate science is a murky science and without laboratory experiments to settle disputes, we are, unfortunately, left with the opinions of scientists who have their own biases. Observations should be the foundation of our science, but that is not the case any more as the climate model establishment, with its 100-year predictions of disaster and tens of millions of dollars of funding, has become entrenched in our community. The observations, as noted in my testimony, do not foreshadow a rapidly warming planet. Our ignorance of the climate system is still enormous, despite the construction of climate models, and our policymakers need to know that.

Question 5. In regard to radiant heat and the sunspot effects, how could this affect global temperatures?

Answer 5. The variation in absolute energy from the sun is quite small, so in and of itself, this variability would be difficult to detect in a direct sense. However, there has been research performed that indicates the variation in solar output has a secondary impact which may affect cloud cover, which in turn can have a larger impact on the planet's temperature. The science in this area of climate is relatively new, so I have no real definitive statements to offer.

Question 6. What is the optimum temperature for man?

Answer 6. No one can say what is the optimum temperature for man. Certainly the great advances in agriculture and civilization occurred during the mid-holocene (climatic optimum) which was warmer than today between 10000 and 5000 years ago. Perhaps a key metric to ponder is that over the past 100 years the average American has chosen to live in warmer and warmer climates. Witness the growth of the southern tier of states relative to the states in colder climates.

Question 7. In regard to land use, can you amplify how that's affecting global warming and what we might be able to do about it? Is one of the concerns deforestation and peat bogs? Can you elaborate?

Answer 7. There is no question that humans have significantly changed the characteristics of the land surface. In general, by removing natural vegetation (and its cooling properties) and replacing this with hard surfaces (roads, buildings, etc.) or agriculture (vegetation that exists for a couple of months rather than all year) we introduce a warming influence in most places. In other regions, such as swamps which have been drained for agriculture, temperatures have changed in such a way that expands the range (hotter days but colder nights.)

Reversing the changing character of the landscape would require a massive undertaking in my opinion, since current changes are the result of the sum of human activities that seek advantages for our various enterprises. I have mentioned that the rapid warming of nighttime temperatures in the San Joaquin Valley of California can be reversed by removing all hints of human habitation and returning the region to a desert. As one could imagine, that is not going to happen because of the advantages our human population derive from the altered landscape (farms, homes, places of employment, recreation, transportation infrastructure, etc.)

There is one important point to make here. Habitat destruction in poor countries is a major cause of the reduction of population of many wild species. Such loss typically relates to deforestation in which poor societies scavenge for energy as represented by burning wood. Improving access to higher quality energy (i.e. electricity) in these countries would prevent much of that habitat destruction. An extra benefit of electricity is the improvement of air quality in the home where now, the U.N. estimates, about 2 million children die each year from respiratory diseases due to burning wood and dung in the homes.

Question 8. You asserted that corn and other crops are not particularly sensitive to temperature, and that the costs of EPA's regulation could burden farmers more than global warming itself. This is the position of the Farm Bureau, which supports HR 910. Could you elaborate on the relative risks of global warming versus global warming policies on the agriculture sector?

Answer 8. Corn and other crops are sensitive to temperature, but it is the simple fact that we successfully grow corn from North Dakota to Alabama that we know how to cope with a very wide variety of climates. Thus, whatever the climate will do in the future, it will not depart so far from the range over which we are able to adaptively manage our agriculture that we will be at serious risk of losing our food and fiber production. Some areas of the country have seen rising temperatures and in these areas, productivity has increased. Where temperatures have not risen, such as the SE, productivity has also risen.

Farmers deal with numerous hurdles, many financial, when making the decision to plant a crop. Adding to their expense by increasing the price of fuel and fertilizers through emissions legislation (for which it appears no measurable benefit may be derived) places an even greater burden on them and on those who buy their higher-cost products. These resulting higher costs for food will fall disproportionately on the poor among us. Thus, an emissions reduction mandate will act as a regressive tax.

The very slight climate changes that might occur from human emissions will already be within the range of climate conditions that vary from year to year. So, the farmer is generally ready to cope with climate changes, but as a business that works with a small margin, the farmer is not likely to cope as well with added costs from legislative mandates.

Responses to questions based on:

Congress of the United States
House of Representatives
Committee on Energy and Commerce
Subcommittee on Energy and Power
Hearing: March 8, 2011, "Climate Science and EPA's Greenhouse Gas Regulations"

Responses from: Christopher B Field

<u>The Honorable Bobby Rush</u>

1. **With 95% of the world's scientists saying that climate change is man-made and can be rolled back, do you think that it is wise policy for Congress and the federal government to risk our children's and grandchildren's futures because a few holdovers are not really certain that climate does exist and can be averted?**

The scientific evidence that climate is changing and that humans are a major cause is very strong. In the March 8 hearing, all witnesses agreed that carbon dioxide is a greenhouse gas and that changes in its concentration can chance climate. The differences among the witnesses concern the expected amount of warming and its impacts. Given the evidence and the current level of certainty, I think it is important for Congress and the Federal Government to seriously consider options for dealing effectively with climate change.

<u>The Honorable Bobby Rush</u>

2. **Dr. Christy indicated that crop loss may be contributed more to farmers not knowing what they're doing rather than to the impacts of climate change. How do you respond to this claim?**

The data on crop yields that I presented is based on the collective experience of almost all of the US farmers who have grown corn, soybeans, or cotton over between 1950 and 2005. Suggesting that they don't know wat they are doing is an insult to many of America's most skilled and dedicated indivudals. I feel very comfortable trusting the collective expertise of America's farmers.

<u>The Honorable Edward Markey</u>

1. **During the hearing, Dr. Pielke suggested that the statements made by scientific professional organizations like the American Geophysical Union (AGU) and the American Meteorological Society (AMS) are the work of a small group of scientists and are not representative of the opinion of the members of the societies. In your experience, do societies follow protocols to develop statements like these that are designed to endsure that the final products are representative of the broad membership? Are there ways to amend or update these statements as the scientific understanding of the issues advances?**

Yes, in my experience, the statements from professional societies do an excellent job of summarizing the state of the science and the collective opions of their memberships. In my experience, every one of the majorprofessional society statements is based on a thorough and comprehensive effort to evaluate all of the science and summarize the opinions of the scientific commuity represented by their members. I know of no reason that the positions of the professional societies cannot be changed as the scientific understanding advances.

<u>The Honorable Morgan Griffith</u>

1. **Do we know what the temperatures were during the period known as the Great Optimum, which led to the ise of the Mesopotamian and Egyptian cultures? That was a time in history of global warming, but how warm did it get?**

Based on the IPCC Fourth Assessment Report (WGI, Chapter 6), the period of 5000 to 6000 years ago was 0.5 to 2.0 C cooler than present in the Tropical North Indian Ocean (near Egypt and Mesopotamia).

<u>The Honorable Morgan Griffith</u>

2. How about the period known as the Lesser Optimum? And how much did the temperature rise then? We know this period led to the Vikings dominating Europe.

Based on the IPCC Fourth Assessment Report (WGI, Chapter 6), the global average temperature of the period of 900 to 1100 years ago was 0.4C to 0.9C cooler than present. The IPCC reviewed 12 temperature reconstruction studies. None reconstructed global average temperatures during this period as warm as current. The two reconstructions that were warmest during this period indicated that temperatures then were 0.4C to 0.6C cooler than present.

<u>The Honorable Morgan Griffith</u>

3. **Has the IPCC studied why the ice caps on Mars are melting? Do we know whether this is a result of a shift in the orbit of Mars? Or is the sun putting out more radiant heat?**

The IPCC is focused on the climate on Earth. The brief summary of recent studies of the climate on Mars is that cyclical changes in the shape of Mars' orbit result in a redistribution of ice. Recently, ice has been decreasing at the poles and moving to the middle latitudes. These changes are not changes in the total amount of ice on Mars, and they are not related to changes in the energy output from the sun.

<u>The Honorable Morgan Griffith</u>

4. **Why was I taught in school 40 years ago that greenhouse gases were going to lead to a new ice age?**

The science on the role of carbon dioxide and other greenhouse gases in warming the Earth has been very clear and not contested by any serious scientists for more than 100 years. In the 1970's, there was some concern about cooling from other pollutants, especially sulfur dioxide. Perhaps the teachers were confused about sulfur dioxide (which is a serious air pollutant but cools the climate) and carbon dioxide, which is an important greenhouse gas and heats the planet.

<u>The Honorable Morgan Griffith</u>

5. **In regard to radiant heat and the sunspot effects, how could this affect global temperatures?**

We have very accurate measurements of solar output over the last several decades. Over the last several years, solar output has been decreasing, as the sun has approached the low point in the 11 year snspot cycle. The IPCC Fourth Assessment report (WGI, Summary for Policymakers) concludes that changes in solar output since the beginning of the industrial revolution is about $0.12 W/m^2$. This is less than 10% of the change due to the increase in carbon dioxide concentration and is, therefore a minor contributor to warming over the last 100 years.

<u>The Honorable Morgan Griffith</u>

6. What is the optimum temperature for man?

It is unlikely that there is a single optimum temperature for man. For the people who live in cold regions, modest warming might make it impossible to pursue traditional lifestyles or to build the ice raods that are critical for oil and gas exploration. In warmer climates, the consequences of warming are more likely to appear as extra deaths from heat waves. For people in moderate climate, the largest impacts may concern changes in water availablity, crop yields, or extreme events. In all of these places, some people and activities will likely be helped by warming. For example, the opening of an ice-free Northwest passage may be a disaster for Native American hunting activities but a benefit for international shipping.

<u>The Honorable Morgan Griffith</u>

7. For Temperature thresholds, you indicated 90 degrees for cotton, 82 for corn, and 84 for soybean. Can you provide the corresponding numbers for barley, wheat, oats, millet, rice?

The data on temperature thresholds that I described (from Schlenker and Roberts, Proceedings of the National Academy of Sciences, 2009) are for the United States for corn, soybeans, and cotton. The data on barley, wheat, oats, millet, and rice have not been analyzed in a way that lets investigators ask whether or not they have similar thresholds. Based on a study of global-scale crop yields from 1961 to 2002, David Lobell and I concluded that, from 1981 to 2002, yields of wheat, corn, and barley were already impacted by warming. Rice yields do not appear to be impacted by the warming that has already occurred. We have not studied oats or millet.

<u>The Honorable Morgan Griffith</u>

8. If those numbers are unavailable for those other grains, is it because we have not studied them or is it that we have not yet reached their threshold?

In the 2007 study published in Environmental Research Letters, David Lobell and I looked at the world's 6 most important food crops – wheat, corn, soybeans, rice, barley, and sorghum. We did not study oats or barley. The global scale data are complete enough to identy impacts of warming, but they are not complete enough to identify thresholds. The threshold analysis has been completed only for corn soybeans, and cotton in the United States.

Answers to questions posed by The Honorable Morgan Griffith regarding the hearing "Climate Science and EPA's Greenhouse Gas Regulations"

By Roger A. Pielke Sr.

1. Do we know what the temperatures were during the period in history known as the Great Optimum which lead to the rise of Mesopotamian and Egyptian cultures? That was a time in history of global warming, but how warm did it get?

   It is regional climate, not a global average surface temperature that matters in terms of cultures. We live in regions and it is the local and regional weather and climate that we experience that matters. For the Mesopotamian and Egyptian cultures, unfortunately, we do not have quantitative measures (e.g. temperatures and rainfall statistics) to determine what the details of the climate were at this time period. We do know with respect to Roman culture, that in North Africa (such as in Tunisia and Egypt) there were woodlands on the hills (which are no longer there), large areas of wheat cultivation (which helped finance the Roman Republic and Empire), and even animals such as lions which are no longer found in this area. These examples of ancient cultures do show us that climate is always changing and that it is the regional climate that matters.

2. How about for the period known as the Lesser Optimum? And how much did the temperature rise then? We know this period led to Vikings dominating Europe.

   The same issues as #1 occur. We just do not have good enough data to diagnose what were the temperatures and precipitation during this time period. We do know, however, based on archeological records that Viking settlement of Greenland occurred during a regionally warm period, which was followed by regional cooling that resulted in the loss of that colony. This shows that regional climate variations are a natural part of the climate system. While, in my view, there is no doubt humans are altering the regional climate of many locations (irrespective of any global average surface temperature trend). However, the IPCC models have not shown any skill at predicting multi-decadal changes in the regional climate due to either human- and natural climate forcings and feedbacks.

3. Has the IPCC studies why ice caps on Mars are melting? Do we know whether this is a shift in the orbit of Mars? Or is the Sun putting out more radiant heat?

   Mars does have ice caps (both of liquid water and carbon dioxide) which change over time. This occurs both due to seasonal effects as well as the orbital path of Mars with respect to its distance from the Sun. The orbit itself has not shifted. In terms of output of solar energy, we have much more rigorous ways to monitor solar output (e. g. SORCE - "Solar and Anthropogenic Influences on Earth: The Current Solar Minimum and Predictions for Future Decades" http://lasp.colorado.edu/sorce/news/sns/2010/sns_jun_2010.pdf).

4. Why was I taught in school 40 years ago that greenhouse gases were going to lead to a new ice age?

We know that the addition of greenhouse gases is always a positive (warming) radiative climate forcing. There is no disagreement on this in the scientific community. With respect to the IPCC viewpoint, it is the addition of CO2 and other human inputs of greenhouse gases that cause initial warming that is amplified by the feedback of added greenhouse gas warming from water vapor as the oceans warm.

What the IPCC has inadequately communicated is that if the ocean surface does not warm (e.g. due to other water cycle feedbacks such as clouds and precipitation; due to radiative cooling from aerosols; or natural climate feedbacks such as from atmospheric/ocean circulation changes), there is no water vapor feedback. The CO2 radiative forcing by itself is relatively small. The water cycle is poorly modeled, however, as shown in Stephens, G. L., T. L'Ecuyer, R. Forbes, A. Gettlemen, J.-C. Golaz, A. Bodas-Salcedo, K. Suzuki, P. Gabriel, and J. Haynes (2010), Dreary state of precipitation in global models, J. Geophys. Res., 115, D24211, doi:10.1029/2010JD014532, so that, despite what the IPCC claims, they cannot yet properly predict how the water vapor responds to human and natural climate forcings.

5. In regard to radiant heat and sunspot effects, how could this affect temperatures?

The Sun's total output does change but only slightly over time since satellite records commenced. Most of the variations are in its shortest wavelengths (ultraviolet, X-ray). If the Sun's output was significantly reduced or increased, there would be an effect of the global average heat content. The best source of this information is the SORCE project that I listed above.

For recent papers on this subject, I recommend Lean, J. L., and D. H. Rind (2009): How Will Earth's Surface Temperature Change in Future Decades?, Geophys. Res. Lett., doi:10.1029/2009GL038932 and Scafetta N., R. C. Willson (2009), ACRIM-gap and TSI trend issue resolved using a surface magnetic flux TSI proxy model, Geophys. Res. Lett., 36, L05701, doi:10.1029/2008GL036307.

There is a set of guest posts on my weblog on this subject (e.g. see http://pielkeclimatesci.wordpress.com/2009/08/03/nicola-scafetta-comments-on-solar-trends-and-global-warming-by-benestad-and-schmidt/ and http://pielkeclimatesci.wordpress.com/2009/08/17/guest-weblog-solar-variability-and-its-effect-on-climate-change-by-nicola-scafetta/).

6. What is the optimum temperature for man?

There is no optimum temperature. First, human society has developed over a wide range of climates. Second, there is no single temperature that we experience; we typically have maximum temperature during the day and minimum temperatures at night. Winters are colder than summers. It is also important to emphasize that a global average surface temperature or its trend over time is irrelevant for the temperatures that society and the environment deal with. It is the regional and local climate that matters.

7. Is there an ideal average temperature that we need to return to, and if so what is it? What do we know from history about the fluctuations in temperature and their impact on mankind?

The answer to #6 addresses this. There is no ideal temperature. We also know that regional temperatures (and precipitation) vary within ranges between seasons, between years and decades, and over longer time periods. The multi-decadal climate models, such as reported by the IPCC, have not shown any skill at predicting these variations for yearly and longer time scales for the 20th century. We, therefore, should have no confidence in their skill for the 21st century including the extent that humans are altering the climate system. A recent paper of mine –

Pielke Sr., R.A., 2010: Comment on " A Unified Modeling Approach to Climate System Prediction", Bull. Amer. Meteor. Soc., 91, 1699–1701, DOI:10.1175/2010BAMS2975
http://pielkeclimatesci.files.wordpress.com/2011/03/r-360.pdf

discusses this issue.

As to how to move forward, I recommend a new approach as recommended in my weblog post

A Way Forward In Climate Science Based On A Bottom-Up Resource-Based Perspective. http://pielkeclimatesci.wordpress.com/2010/08/03/a-way-forward-in-climate-science-based-on-a-bottom-up-resourse-based-perspective/

and in a newly submitted paper

Pielke Sr., R.A., R. Wilby, D. Niyogi, F. Hossain, K. Dairuku, J. Adegoke, G. Kallos, T. Seastedt, and K. Suding, 2011: Dealing with complexity and extreme events using a bottom-up, resource-based vulnerability perspective. AGU Monograph on Complexity and Extreme Events in Geosciences, submitted.
http://pielkeclimatesci.files.wordpress.com/2011/03/r-365.pdf.

We recommend

"There are 5 broad areas that we can use to define the need for vulnerability assessments: water, food, energy, human health and ecosystem function. Each area has

societally critical resources. The vulnerability concept requires the determination of the major threats to these resources from climate, but also from other social and environmental issues. After these threats are identified for each resource, then the relative risk from natural- and human-caused climate change (estimated from the GCM projections, but also the historical, paleo-record and worst case sequences of events) can be compared with other risks in order to adopt the optimal mitigation/adaptation strategy."

This is a distinctly different approach than used by the IPCC (and CCSP) assessment process, and I would be glad to discuss further with you if you would like.

Subcommittee on Energy and Power
"Climate Science and EPA's Greenhouse Gas Regulations", held on March 8, 2011

Answers to Questions of the Honorable Bobby Rush and the Honorable Morgan Griffiths posed to Professor Knute Nadelhoffer following the hearing of March 8, 2011.

- Provided by Knute Nadelhoffer on April 8, 2011.

The Honorable Bobby Rush- Q1. **Please explain what the effects of climate change are on the economy and environment of the Great Lakes region?**

Predicting economic trends and economic responses to climatic and other factors does not lie within my area of expertise. However, I will offer informed assessments of possible economic impacts of human-generated greenhouse gas emission based upon my interactions and discussions with economists and policy experts, and upon my understanding of climate trends now occurring and projected through the current century in response to human derived greenhouse gas (GHG) emissions. For purposes of discussion here, these GHGs include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), atmospheric concentrations, all which have all increased dramatically above the relatively stable background levels of the 6 to 8,000 years preceding the turn of the last century as a result of human activities.

Measurements made across the region show changes in temperature and precipitation that are consistent with GHG-induced warming. For example, average annual temperatures have increased by 2.6 °F region-wide since the 1970s, with average winter temperatures now almost 4 °F higher than in the 1970s. This warming has been accompanied by many noticeable changes, including-

- Increases in growing season lengths by about one week during the 20th century.
- Changes in water cycle, including decreases in spring snow cover leading to earlier dates for spring melt, peak stream flow, and higher lake levels in spring and early summer.
- Delayed formation of winter ice on the Great Lakes and inland lakes, and shorter durations of winter lake ice, with some years being nearly ice-free.
- Shifts in seasonal rainfall, with more precipitation during spring and more severe summer droughts.
- Increased Great Lakes water temperatures of almost 0.2°F per decade since 1920 accompanied by an increase of more than 2 weeks in the duration of summer stratification.
- A doubling of heavy rainfall events (storms) since the early 1900s, increasing the risk of flooding across the region, particularly in Iowa, Missouri and Illinois.
- Fewer cold waves during the past two decades, accompanied by several major heat waves, particularly in 1995, 1999, and 2006.

These recent patterns of climate change are similar to changes observed at larger scales across the earth's surface, and taken as a whole, are highly consistent with scientific understanding of how increases in atmospheric GHG concentrations are driving temperature increases and changes in precipitation patterns.

If GHG emissions remain unchecked, the trends already observed (listed above) are likely to intensify, with average annual temperatures increasing by approximately 2.5 °F across the region my mid-century and from 5 to 10 °F by the end of the current century (Hayhoe and others 2010). Effects of these even more dramatic changes on agriculture, infrastructure (roads, storm water sewers, water supplies), economic activities (including shipping, manufacturing, tourism), and human health could be dramatic. For example, spring storms and summer droughts, both of which are likely to increase in frequency and intensity more than already observed if GHG emissions are not attenuated, will likely increase risks of crop failure for Midwestern staples (corn, soybeans, alfalfa, etc.) and the diverse fruits and vegetable crops of particular regions such as along the shores of Lake Michigan. These spring storms and intense heat events will continue to challenge and compromise our existing infrastructure, requiring more resources and revenues for improving sewers, water treatment and delivery systems, and road repair. More frequent and intensive heat waves, such as the 1995 Chicago heat event during which temperatures exceeded 90 °F for 7 days and high humidity, high night-time temperatures, and air pollution lead overwhelmed emergency responders, led to the closing of 23 hospital emergency rooms, and was responsible for as many as 700 heat-related deaths (Klinenberg 2002). If GHG emissions continue unabated, Midwestern cities such as Detroit and Chicago could experience heat waves similar to the 1995 Chicago heat wave every other year by mid-century and twice every summer by the end of this century (Freeze and others, 2009).

Together, the impacts of human GHG emissions on climate in the Great Lakes region and US Midwestern on agricultural production, infrastructure, and human health are likely to have negative impacts on the regional economy. Effects are direct in the case of agriculture, and indirect in the case of comprising infrastructure and human health, both of which are critical for driving economic recovery in the region.

Hayhoe K, VanDorn J, Croley T, Schlegal N, Wuebbles D. 2010. Regional Climate Change Projections for Chicago and the US Great Lakes. Journal of Great Lakes Research 36: 7-21.

Klinenberg E. Heat Wave: A Social Autopsy of Disaster. Chicago, Ill: University of Chicago Press; 2002.

The Honorable Bobby Rush Q2. **In your testimony you reference the fact that the Great Lakes provides hundreds of millions of people living in Illinois, Michigan, Wisconsin, and Indiana with drinking water. Should we fail to limit greenhouse gas emissions how will this affect the supply of drinking water to these millions of people?**

The ~35 million people living in these four states rely on either surface water (Great Lakes or rivers) or ground water to provide safe drinking water. Many factors not directly related to climate change can compromise drinking water quality (e.g., toxic chemical releases, malfunctioning water treatment facilities). However, warmer temperatures, spring flooding, and more intense summer droughts, all of which are increasing due to human-derived GHG emissions could also impact the amounts and quality of drinking water for these populations. For example, increased demands for irrigation water could compete with water needed for drinking and industry, especially in regions without access to surface waters. Also, intensive fertilization and over-application of nitrogen-based fertilizers used by farmers to compensate for heat and moisture stresses on crops could lead to increased inputs of nitrates to groundwater aquifers and surface water. In fact, these trends are already a concern, and this will likely increase as more spring storms and irrigation water deliver nitrates and other nutrients to surface and groundwater. Also, mercury emissions, which accompany CO_2 emissions from many coal-fired power plants will also continue to increase concentrations of methylated mercury compounds, especially in surface waters and the organisms inhabiting these waters, some of which are consumed by humans (e.g. fish from the Great Lakes). Excess nitrogen and phosphorus loading to our surface waters will increase and will likely continue to enhance toxic algal blooms which not only challenge water treatment facilities, but can also lead to health problems for swimmers and recreational users of lakes and rivers.

The Honorable Bobby Rush Q3. **What will be the effect on the Great Lakes region if we do not curb emissions of greenhouse gases?**

If we do not curb emission, by the end of this century we can expect (Freeze and others 2009) :

1) Hotter summers. For example)-
   - Every summer in Illinois would be hotter than 1983—the hottest summer during the historical baseline.
   - Chicago would experience more than 70 days per summer with highs over 90 °F and up to 30 days with highs over 100°F.
   - Chicago and Detroit will experience two heat waves per summer like the one that killed hundreds in Chicago in 1995, and one heat wave every other summer like the even deadlier European heat wave of 2003.
   - Air quality would deteriorate, as hotter weather causes more severe smog problems (assuming similar levels of tailpipe and smokestack emissions). This would have serious consequences for public health, including a greater incidence of asthma attacks and other respiratory conditions.
2) Dangerous storms and flooding.
   - Heavy rains would become more common throughout the year, leading to a greater incidence of flash flooding.
   - Winters and springs, when the flood risk is already high, would become more than 25 percent wetter.
3) New threats to agriculture
   - Crops and livestock would face substantially more heat stress, decreasing crop yields and livestock productivity.

- Warmer winters and a growing season up to six weeks longer would enable pests like the corn earworm to expand their range.
- Crop production would be inhibited by changing rain patterns such as wetter springs (which delay planting and increase flood risk) and almost 15 percent less rain during the increasingly hot summers.

Freeze, B, et al. 2009. Confronting climate change in the U.S. Midwest. Union of Concerned Scientists, www.ucsusa.org/mwclimate, 12 pp.

The Honorable Bobby Rush Q4. **Can you expound on your findings during your work in studying the Arctic and what impact climate change may have for population centers globally?**

The arctic is a "bell weather" region of the earth, in that changes so far are most severe in polar regions (the Arctic and Antarctic). As most of the ice-cover in the arctic exists as frozen sea-water, the eventual loss of summer ice in the arctic will lead to a dramatic change in the earth's energy balance. Summer sea ice is diminishing rapidly and will most likely not exist by mid-century under present emission rates. When summer ice disappears, the Arctic Ocean will shift from reflecting more than 80% of the summer sunlight as it has for centuries, to absorbing more than 80% of the solar energy hitting the surface in summer. This will warm the Arctic Ocean and also other oceans in the northern hemisphere as currents move warm water out of the arctic. This will contribute to sea-level rise due to thermal expansion of water and will alter weather patterns and regional climates in ways that are not well understood. Antarctic ice, which is mostly perched on the Antarctic land mass (continent) will continue to reflect sunlight, but accelerated movement of ice from land sources to the Southern Ocean will contribute to rising sea levels. Rising sea levels due to thermal expansion and to transport of Antarctic (and Greenland) ice to the oceans will threaten coastal human populations and increase damage in coastal areas resulting from hurricanes and other coastal storms. Importantly, dramatic changes in polar regions could lead to climate "surprises". In other words, effects of changes in ice cover could feed back to ocean circulation and atmospheric dynamics in ways that could lead to abrupt changes in our climate system that are presently not forecasted by global models.

The Honorable Bobby Rush Q5. **Dr. Christy indicated that crop loss may be contributed more to farmers not knowing what they're doing rather than to the impacts of climate change. How do you respond to this claim?**

Dr. Christy did not provide documentation or references to support this claim. I think he underestimates the abilities of farmers to adapt techniques and methods. Overall, I know from experiences growing up in a farming region of Illinois that uncertainties regarding weather and climate forecasting are factors that put farmers and farm economies at risk. This is why farming is dependent on crop insurance. Changes in climate described in my responses to Qs 1-3 will make predictions of yearly weather even more difficult for farmers. More frequent extreme events (floods, droughts, heat waves) will raise the risks for farmers, and will likely increase costs of insuring crops and decrease yields overall.

The Honorable Morgan Griffith, Q1. **Do we know what the temperatures were during the period in history known as the Great Optimum, which lead to the rise of Mesopotamian and Egyptian cultures? That was a time in history of global warming, but how warm did it get?**

There is no indication that the climatic phenomena referred to here were global in their extents. There is evidence that regional climatic changes had important effects on these and other ancient civilizations during the past 6 to 8,000 years. I defer to the climatologists on our panel to address this topic in greater detail.

The Honorable Morgan Griffith, Q2. **How about for the period known as the Lesser Optimum? And how much did the temperature rise then? We know this period led to Vikings dominating Europe.**

The *Lesser Optimum*, also known as the *Medieval Warm Period* (10^{th} through 13^{th} centuries) was a warm period in the North Atlantic region (eastern Canada through western Europe), but I know of no analysis suggesting this was a period of global warming. Rather, it was likely a regional temperature anomaly which may have been driven by century-scale variations in ocean currents and atmospheric circulation. This regional warming does appear to have led to increased food availability and easier navigation for people living on the Scandinavian peninsula. However, this regional event has little relevance to the dramatic changes we are facing at global scales as a result of human-generated greenhouse gases, other than serving as an example of how even relatively minor shifts in climate can alter human behavior and economic activities.

The Honorable Morgan Griffith, Q3. **Has the IPCC studied why the ice caps on Mars are melting? Do we know whether this is a result of a shift in the orbit of Mars? Or is the Sun is putting out more radiant heat?**

This is not my area of expertise, so I will defer to others for a more complete answer to this question. However, solar luminosity varies on the order of ± 0.15 watts per square meter on decadal time scales, and gradually at longer time scale. There is no evidence that changes in luminosity have contributed to the observed warming of the earth's surface during the past century. Polar ice fluctuations on Mars are more variable and are likely subject to different drivers than those influencing climate and ice dynamics on Earth. The lack of liquid water (particularly large oceans), a very thin atmosphere with a different chemistry than Earth's, and differing orbital eccentricities between Earth and Mars compromise the usefulness of using Martian polar ice dynamics to infer anything about climate forcings on Earth.

The Honorable Morgan Griffith, Q4. **Why was I taught in school 40 years ago that greenhouse gases were going to lead to a new ice age?**

No science texts from the 1970s (or any other decade in the 20th Century) that I have located describe or discuss evidence that greenhouse gases were leading to a new ice age. What science books do convey, is the fact that we are in the midst of an interglacial period which, during the past million or so years have last for approximately 20,000 years. Assuming that we avoid "geo-engineering" and that human-derived greenhouse gas emissions do not dramatically destabilize the climate, we might expect another period of continental glacial advance (an "ice age") in about 10 millennia. Several highly visible scientists, including Reid Bryson, Murray Mitchell, and George Kukla, did provide some data in the mid-1970s that we might be entering a cold period, but did not invoke CO_2 or other greenhouse gasses as drivers of this predicted change. This idea had a short moment in the sun when it was reported in Newsweek (April 28, 1975) and other popular press sources. However, this idea failed in the face of emerging evidence that the mean temperature of the earth was in fact (and still is) rising. There was never a compelling, evidence-based argument made in the 1970s that the earth was cooling. A consensus in support of the "cooling earth" hypothesis was never developed.

The Honorable Morgan Griffith, Q5. **In regard to radiant heat and the sunspot effects, how could this affect global temperatures?**

Solar sunspot activity follows an approximate 11-year cycle during which sunspots (dark structures) and bright structures wax and wane on the solar disc. The excess of radiant energy (referred to as "radiative forcing") during periods of maximum luminosity adds about 0.12 watts per square meter to the earth's surface (on average). This compares to a radiative forcing from human-released greenhouse gases (carbon dioxide, methane, nitrous oxide, and halocarbons) of about 2.5 watts per square meter. In other words, solar sunspot activity contributes a maximum of 1/20 as much energy as do excess greenhouse gas concentrations. As we continue to emit greenhouse gases (and to, regrettably, increase our emission rates) the fraction of radiative forcing due to sunspot activity will diminish even more as greenhouse gas concentrations increase in the atmosphere.

The Honorable Morgan Griffith, Q6. **What is the optimum temperature for man?**

Humans are adaptable, and have devised and adapted technologies to live across a range of climates and temperatures. The more important question here is how will the natural systems upon which humans and all others rely upon for food, building materials, fibers, medicines, and other life-supporting products and services be impacted and altered by changes in temperature and moisture extremes resulting from human-generated greenhouse gas emissions. This, of course, is a major challenge to our understanding which we must address if we are to provide resources needed to support the 7 billion people now living on earth.

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HENRY A. WAXMAN, CALIFORNIA
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ONE HUNDRED TWELFTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON ENERGY AND COMMERCE
2125 Rayburn House Office Building
Washington, DC 20515–6115

Majority (202) 225–2927
Minority (202) 225–3641

March 25, 2011

Dr. Donald Roberts
Professor Emeritus
Uniformed Services University
118 First Street
Clifton Forge, VA 24422

Dear Dr. Roberts:

Thank you for appearing before the Subcommittee on Energy and Power on Tuesday, March 8, 2011 to testify at the hearing entitled "Climate Science and EPA's Greenhouse Gas Regulations."

Pursuant to the Rules of the Committee on Energy and Commerce, the hearing record remains open for ten business days to permit Members to submit additional questions to witnesses, which are attached. The format of your responses to these questions should be as follows: (1) the name of the Member whose question you are addressing, (2) the complete text of the question you are addressing in bold, and then (3) your answer to that question in plain text.

To facilitate the printing of the hearing record, please respond to these questions by mail by the close of business on Friday, April 8, 2011. Your responses may be e-mailed to the Legislative Clerk, in Word or PDF format, at katie.novaria@mail.house.gov.

Thank you again for your time and effort preparing and delivering testimony before the Subcommittee.

Sincerely,

Ed Whitfield
Chairman
Subcommittee on Energy and Power

cc: Bobby Rush, Ranking Member,
Subcommittee on Energy and Power

Attachments

Subcommittee on Energy and Power
"Climate Science and EPA's Greenhouse Gas Regulations"
March 8, 2011

The Honorable Morgan Griffith

1. Do we know what the temperatures were during the period in history known as the Great Optimum, which lead to the rise of Mesopotamian and Egyptian cultures? That was a time in history of global warming, but how warm did it get?

2. How about for the period known as the Lesser Optimum? And how much did the temperature rise then? We know this period led to Vikings dominating Europe.

3. Has the IPCC studied why the ice caps on Mars are melting? Do we know whether this is a result of a shift in the orbit of Mars? Or is the Sun is putting out more radiant heat?

4. Why was I taught in school 40 years ago that greenhouse gases were going to lead to a new ice age?

5. In regard to radiant heat and the sunspot effects, how could this affect global temperatures?

6. What is the optimum temperature for man?

7. You stated that EPA's regulations would have a negligible impact on public health. Could you elaborate?

Answer to Questions of the Honorable Morgan Griffith

Answers to questions 1 through 6 are presented separately. Ken Haapala, Executive Vice President of Science and Environmental Policy Project, prepared answers to those questions. I present here answers to questions 6 and 7.

6. What is the optimum temperature for man?

Research suggests there really is no optimum temperature for man. A comfortable temperature is perhaps around 25° C. However, a temperature that results in the least number of deaths from all causes will vary with geographical area. The process of acclimatization changes the equation for what is or is not an optimum temperature. Research has shown that 25° is associated with fewer deaths in St. Louis, Missouri but 17°C is associated with fewer deaths in the Netherlands—again the differences seem to be a result of acclimatization. Globally, most people live in warmer regions at lower altitudes (about 80-90% below 500m) and greater numbers of people live in warm humid regions of the world. On the other side of this equation, cooler temperatures are associated with increased health problems. To some extent this can be attributed to people living in more confined spaces when temperatures are low. Cold is associated with health decrements due to such associations as increasing blood pressure to counteract cold temperatures, increased cardiac effort to keep the body warm, lower humidity in heated building and increased respiratory problems, etc. Thus, it seems logical to conclude, within reasonable limits, the warmer the climate the better. Last but not least, one dominant theme in human history is humans can adapt to changing environments and can create environments in both hot and cold environments for human survival.

7. You stated the EPA's regulations would have a negligible impact on public health. Could you elaborate?

The major gains that might result from cleaning the environment (air, water and food) have already been achieved. Yet a recent WHO document claims "**An estimated 24% of the global disease burden and 23% of all deaths can be attributed to environmental factors.**" The WHO statistics included malaria and many other ailments. If the authors of the report had restricted their analyses to just core issues relevant to EPA's jurisdiction, that is to say, public health decrements that can be attributed to contaminants in air, water and food, the results would have been truly trivial. For this reason I maintain EPA's regulations will have negligible impact on public health in the United States.

In the future we can expect greater and greater effort by EPA and other environmental organizations, e.g., UNEP, to expand authority into other public health endeavors. The reason is based on their consistent failure to link environmental pollutants to meaningful public health problems. Thus, it becomes a matter of survival for environmental organizations and bureaucracies largely concerned with regulatory controls over environmental contaminants. It becomes a bit embarrassing for them to continue spending vast sums of money to maintain the EPA bureaucracy when there is little or no evidence that their efforts are making a meaningful contribution to improved human health and welfare. The answer to this dilemma is to de-emphasize their primary areas of responsibility (pollutants and toxics) and grab authority over such topics as diarrheal diseases, respiratory infections, malaria, accidents, and other health issues—issues which rightfully belong to the U.S. Public Health Service, Department of Transportations, and the FDA. Basically, any public health issue that has even the slightest link to environmental conditions will be used to justify the EPA's future.

Answers to Questions from The Honorable Morgan Griffith
April 3, 2011

1. Do we know what the temperatures were during the period in history known as the Great Optimum, which lead to the rise of Mesopotamian and Egyptian cultures? That was a time in history of global warming, but how warm did it get?

A. We do not have sufficient information to accurately calculate historic global temperatures. However, we can obtain good indications of temperature changes over time from proxy data such as ice core borings taken in Greenland. These, backed by significant other proxy data, give us a good idea of the changes in temperatures in the Northern Hemisphere since the last Ice Age ended about 11,500 years ago. (Over 65% of the world's land surface area is in the Northern Hemisphere.)
B. The GISP2 Greenland ice cores reveal that for the past 11,500 years temperatures fluctuated rapidly by as much as four to seven degrees F, with most of the past 10,000 years warmer than today by as much as two to four degrees F. (Please note, that since the ice cores are taken at an elevation of about 10,000 feet, the annual measured temperatures, typically around *minus* 25 degrees F, are much lower than those measured at sea level for the same latitude.) The warmest period, the Holocene Climate Optimum (Great Optimum), was about 5,000 to 9,000 years ago (interrupted by an abrupt brief cold period about 8200 years ago).
C. During the Climate Optimum, the tree lines throughout North America and Eurasia were about 100 to 200 miles closer to the North Pole than today and, in mountains, trees grew at higher elevations than today. Both these indicate that temperatures were some 2 to 4 degrees F warmer than today.
D. During the later part of this period of warmth, some 2 to 4 degrees F warmer than today, the Mesopotamian, Egyptian, Indus, and Chinese cultures arose.

2. How about for the period known as the Lesser Optimum? And how much did the temperature rise then? We know this period led to Vikings dominating Europe?

A. The Holocene Climate Optimum was followed by periods of cooling and warming. The latest warm period is called the Medieval Warm Period or Little (Lesser) Climate Optimum (about 900 to 1300 AD) during which temperatures may be been about 2 degrees F warmer than today. Significant changes in agriculture occurred. It was during this time that Vikings settled Greenland and wine grapes were harvested in Europe further in climates too cold for such grapes today. This period was followed by the Little Ice Age during which temperatures fell by as much as 7 degrees F. The Little Ice Age was in two stages, the latter stage more severe than the earlier one.
B. Evidence of the Medieval Warm Period and the Little Ice Age are found in hundreds proxy records around the globe, including rock borings, sea sentiment borings, stalagmites in caves, etc. There have been a very few instances where such changes were not found.
C. It appears that the timing and the intensity of the Medieval Warm Period and Little Ice Age varies with geographical region.

3. Has the IPCC studied why the ice caps on Mars are melting? Do we know whether this is a result of a shift in the orbit of Mars? Or is the Sun putting out more radiant heat?

I'm not qualified to answer this question.

4. Why was I taught in school 40 years ago that greenhouse gases were going to lead to a new ice age?

I cannot explain why.

5. In regard to radiant heat and the sunspot effects, how could this affect global temperatures?

A. Changes in radiant energy from the sun would change global temperatures. According to the IPCC, the sun has not undergone sufficient changes in radiant energy to create the warming periods of the 20^{th} Century. However, other research indicates that changes in Solar Irradiance better explain changes in Arctic Surface Air Temperatures than increases in carbon dioxide.
B. Also, since the advent of satellite measurements in 1979, we now have comprehensive coverage of the globe. These data demonstrate the bulk of the recent atmospheric warming is in the middle to upper part of the Northern Hemisphere, with little or no warming in the Tropics or the Southern Hemisphere.
C. Changes in other forms of solar energy, solar wind and solar magnetism, are associated with changes in sunspot activity. For about 50 years changes in solar wind have been known to affect the high energy cosmic rays hitting the earth. An active sun, more sunspots, results in fewer high energy cosmic rays hitting the earth, a dormant sun, less sunspots, results in more high energy cosmic rays hitting the earth.
D. Evidence from stalagmites in caves and other physical evidence suggest that changes in frequency of high energy cosmic rays hitting the earth, partly controlled by solar activity, are closely associated with temperature changes.
E. Over ten years ago it was hypothesized that changes in cosmic rays hitting the earth's atmosphere causes changes in low-level cloud formation. Even small increases in low-level clouds cause a cooling effect by reflecting the sun's radiant energy to space. Thus, according to the hypothesis, the more cosmic rays hitting the atmosphere, the greater the low level cloud formation, which results in cooler temperatures.
F. This hypothesis was tested, simply, with interesting results. For the past year, the European Organization for Nuclear Research, CERN, has been intensively testing the hypothesis. The results of the CERN experimentation have not yet been reported.

6. What is the optimum temperature for man?

For thousands of years man has adapted to changes in temperature. There may not be a single optimum temperature for man, but, in general, warm periods have been beneficial to man and cold periods harmful. Throughout recorded history, cold periods have been marked by famine, disease, and death.

7. You stated that EPA's regulations would have a negligible impact on public health. Could you elaborate?

A. EPA regulations to reduce carbon dioxide emissions in the US will do little to reduce carbon dioxide emissions world-wide. China is now the world's largest emitter of carbon dioxide and is opening about one coal fired power plant per week. India is rapidly expanding its coal fired power plant capacity as well.

B. Generally, coal is the lowest cost fuel for generating electricity that can be shipped world-wide.
C. Coal exports from the US are increasing even as efforts are being made to stop construction of US coal fired power plants.
D. Foreign firms are exploring shipping coal from the Powder River Basin in Wyoming to China.
E. China does not impose the stringent controls on emissions of known toxic gases (carbon dioxide is not toxic) that the US imposes.
F. The proposed EPA regulations on carbon dioxide emissions in the US would have the same impact as a drastic increase in taxes on electricity, significantly driving up prices of US manufactured goods and significantly reducing the spendable income of the public.
G. Even if the IPCC models projecting future temperature changes were valid (they never have been validated), proposed EPA regulations will not significantly affect temperature increases because China and India would continue to emit ever increasing amounts of carbon dioxide.
H. The net result would likely be a reduction of emissions in the US, at great economic cost, and a significant increase in emissions worldwide – including air-borne toxins that are heavily regulated in the US.

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